

---

# Companion Lesson



# Plant Growth Investigations

## Overview

This hands-on activity builds on and reinforces students' understanding of organisms' sensory responses to stimuli. Students conduct investigations and gather evidence that shows how phototropism and geotropism affect plant growth. Students first investigate whether gravity influences plant growth by positioning corn seeds at various orientations. They set up investigations and make initial predictions about the results and then, after a period of 5 to 8 days, students observe the growth and discover that regardless of initial orientation, roots bend to grow downward and stems bend to grow upward. Students then plan an investigation of the effect that a light source's location has on plant growth. They make initial predictions and later discover that stems bend toward the light source. After being introduced to the terms *geotropism* and *phototropism*, students use a diagram to apply their understanding by predicting plant growth. The purpose of this lesson is twofold: students learn core science ideas about the ways that plants respond to stimuli, and they engage in the practice of planning and conducting investigations.

**Recommended Placement:** *Metabolism*, anytime after Lesson 3.3

**Suggested Time Frame:** three 45-minute class periods, each several days apart



- Crosscutting Concepts**
- Patterns
  - Cause and Effect

## Vocabulary

- geotropism
- phototropism

## Materials & Preparation

### Materials

#### For the Class

- Plant Growth Investigations copymaster
- 4 clamp lamps
- 6 60W lightbulbs
- 4 spray bottles with water
- 1 large bowl or dishpan\*
- water\*
- 2 large index cards\*
- 1 marker\*

#### For Each Group of Four Students

- 4 radish seeds
- 3 small paper cups
- soil to fill 2 paper cups
- 2 thin cardboard boxes
- 2 pieces of masking tape
- 1 pair of scissors\*

#### For Each Pair of Students

- 1 tray\*
- 4 soaked corn seeds
- 2 clear plastic lids

- 2 paper towels
- 12 pieces of masking tape
- 4 cotton balls
- 1 pen or marker\*

#### For Each Student

- Plant Growth Investigations: Parts 1–5 student sheets\*

\*teacher provided

## Preparation

**Note:** For a visual timeline of all the preparation, teaching, and waiting days that comprise this lesson, see the Teacher Reference section of this lesson.

### Before the First Teaching Day (Growth and Gravity Investigation)

1. **Print Plant Growth Investigations copymaster.** Locate the Plant Growth Investigations copymaster on the Richmond Resources webpage: [www.amplify.com/](http://www.amplify.com/)



### Preparation (continued)

richondscience. You may make one copy of all pages for each student or copy only Part 1 for the first teaching day.

**2. Soak corn seeds.** Soak 4 seeds for each pair of students. Place the seeds in a large bowl or dishpan and cover with water. After 48 hours, drain the water.

**3. Prepare trays of materials for first teaching day (growth and gravity).**

For each pair of students, place the following materials on a tray:

- 4 soaked corn seeds
- 2 clear plastic lids
- 12 pieces of masking tape
- 4 cotton balls
- 2 paper towels (dampened right before the lesson begins)
- pen or marker

**4. Locate and review rubrics.** Review the Rubrics for Assessing Students' Investigations of Geotropism and Phototropism in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they complete their investigations and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students' developing facility with science and engineering

practices and their understanding of disciplinary core ideas.

**5. Wet paper towels.** Immediately before the lesson, soak the two paper towels for each pair of students in water. Wring the paper towels enough so they are still very wet, but not dripping. Add wet paper towels to each pairs' tray.

**6. Immediately before the first teaching day, have on hand the following materials:**

- student sheets for Part 1
- trays of materials

### Before the Second Teaching Day (Growth and Light Investigation)

**1. Print Plant Growth Investigations copymaster, Parts 2 and 3.** If you haven't already, make one copy of Parts 2 and 3 of the Plant Growth Investigations copymaster for each student.

**2. Create and post vocabulary card on the classroom wall.** With a marker, write "geotropism" in large print on a large index card. Post this card on the classroom wall.

**3. Prepare cups.** Fill two paper cups with soil for each group of four. Fill a third cup with water to water the seeds.



**4. Prepare trays of materials for second teaching day (growth and light).** For each group of four students, place the following materials on a tray:

- 4 radish seeds
- 2 paper cups filled with soil
- 1 cup of water
- 2 cardboard boxes
- 1 pair of scissors
- 2 pieces of masking tape
- pen or marker

**5. Set up clamp lamps.** Place the clamp lamps in two locations in the classroom where students can set up experiments. If your classroom has windows that receive natural light, student can also set up their experiments near the windows.

**6. Immediately before the second teaching day, have on hand the following materials:**

- student sheets for Parts 2 and 3
- prepared clear lids with seeds from growth and gravity investigation (stored in the dark after first teaching day)
- trays of materials

- spray bottles filled with water

**Before the Third Teaching Day (Light Investigation)**

- 1. Print Plant Growth Investigations copymaster, Parts 4 and 5.** If you haven't already, make one copy of Parts 4 and 5 of the Plant Growth Investigations copymaster for each student.
- 2. Create and post vocabulary card on the classroom wall.** With a marker, write "phototropism" in large print on a large index card. Post this card on the classroom wall.
- 3. Plan which day to hold the third teaching day.** This should be 5 to 10 days after the second teaching day when plants have had time to respond to the light source. Pick up at Step 26 of the Instructional Guide.
- 4. Immediately before the third teaching day, have on hand the following materials:**
  - student sheets for Parts 4 and 5
  - students' light investigation materials



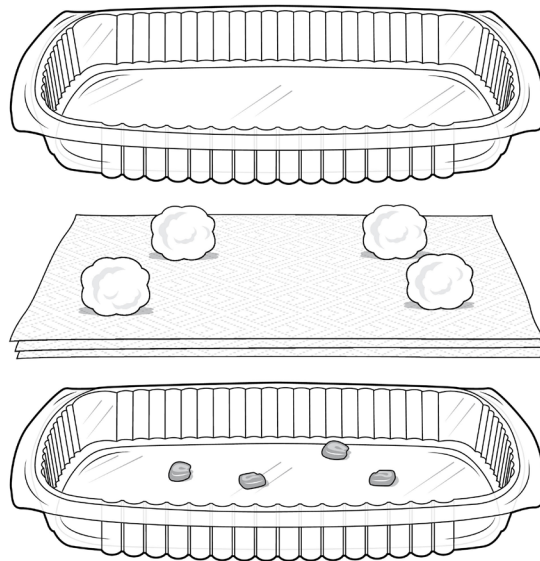
## Science Background

All organisms sense and respond to outside stimuli. Though this is less obvious in plants than in animals, response to stimuli is a key adaptation that helps plants survive. Phototropism is an organism's movement or growth in response to a light source. Phototropism is adaptive because it helps a plant grow toward places where more sunlight reaches the plant, allowing for more photosynthesis. The side of the plant that is less exposed to light will elongate, causing the plant to bend toward the light. Proteins called phototropins absorb light and cause a hormone called auxin to be transported to the side of the plant with less light. These hormones promote cell elongation on that side of the plant.

Geotropism is an organism's movement or growth in response to gravity. The response for plants is for stems to begin their growth upward, while roots begin their growth downward. Geotropism also occurs through the elongation of plant cells on one side of the plant. Very dense organelles called statoliths located in the tip of the root respond to the force of gravity and cause auxin to be transported to the side of the root that faces upward. Cells on the upward-facing side of the root elongate, causing the root to bend downward. The opposite occurs in shoots. Auxin is transported to the downward-facing side of shoots and cells on the downward facing side elongate, causing shoots to bend upward. This allows stems to attain a position above ground from seeds that sprout below the soil's surface, and this allows roots to grow underground where water and nutrient resources can be acquired. Unlike animals with nervous systems, these responses are not centralized, but occur via reactions at the local cellular level.

### Teacher Reference

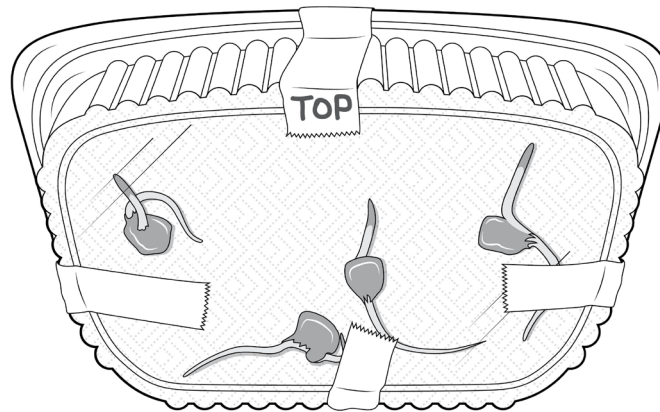
|  |   |   |  |
|--|---|---|--|
| <p><b>Prep Day</b><br/>Soak seeds for 48 hours.</p>  | <p><b>Prep Day</b><br/>Prepare trays of materials for gravity investigation.</p>  | <p><b>First Teaching Day (growth and gravity)</b></p> <ol style="list-style-type: none"> <li>1. Wet paper towels immediately before class.</li> <li>2. Students set up and predict gravity investigations.</li> </ol> | <p><b>Wait 5–8 Days</b><br/>Seeds for gravity investigations will be growing in the dark.</p>  |
| <p><b>Prep Day</b></p> <ol style="list-style-type: none"> <li>1. Prepare trays of materials for light investigation.</li> <li>2. Set up classroom area for light investigation.</li> </ol> | <p><b>Second Teaching Day (gravity and light)</b></p> <ol style="list-style-type: none"> <li>1. Students observe, record, and share results of gravity investigations.</li> <li>2. Students set up and predict light investigations.</li> </ol> | <p><b>Wait 5–10 Days</b><br/>Students need to briefly observe and water their light investigations every day.</p>   | <p><b>Third Teaching Day (light)</b></p> <ol style="list-style-type: none"> <li>1. Students record and share final results of light investigations.</li> <li>2. Students complete plant growth prediction activity.</li> </ol> |



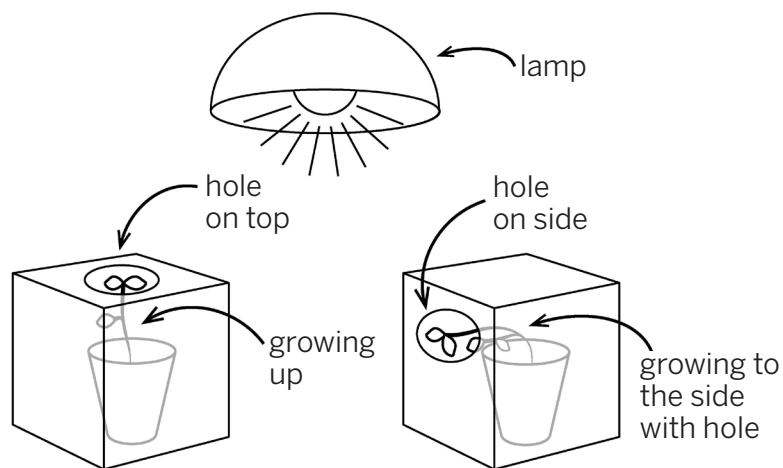
The gravity investigation setup.



### Teacher Reference (continued)



The gravity investigation setup after some growth.



One possible setup of the light investigation.





## Instructional Guide

### Explore and Activate Prior Knowledge


- 1. Connect to ideas about stimuli and information processing.** Remind students that “The Big Climb” article describes how Diego uses his senses to get information about his environment, and his body responds to that information. The human nervous system helps people sense and respond to the outside world. Conduct a short class discussion by asking students if they think plants can sense things in the outside world. Encourage them to use evidence to explain their thinking.
- 2. Discuss prior knowledge about root and stem growth.** Show students the soaked corn seeds and explain that the seeds will soon sprout the beginnings of a root and the beginnings of a stem (and some may have already begun to grow). Ask students in which direction they predict a young plant’s roots and stems will grow. [Roots will grow down into the ground. The stem will grow up. The stem will grow toward the light.]
- 3. Hold a class discussion about plant growth.** Lead an open-ended class discussion by prompting students with the following questions:
  - How do you think a plant can tell the direction to grow its roots and the direction to grow its stem?
  - What might plants be responding to when they grow in a particular direction?Invite students to share ideas, evidence, and further questions.
- 4. Focus the discussion on gravity and light.** Ask students whether they think a plant can tell which way is up. Also, ask whether they think a plant can tell where light is coming from. Accept all responses.

### Construct New Ideas

- 5. Discuss gathering evidence from an investigation.** Ask students to think about what would constitute evidence that a plant is sensing something in its environment. (We can’t ask the plant whether or not it can sense things.) Direct students to think about what they could observe about a plant’s roots or its stem. If students don’t bring it up, point out that a pattern/change to the direction that roots or stems grow would be evidence of the plant responding to something in its environment.
- 6. Introduce first question to investigate.** Explain that the class will first investigate and gather evidence about whether a plant can sense the direction of gravity. For this investigation, everyone in the class will conduct the investigation in the same way. Later, students will investigate light and direction of plant growth, and groups will design their own investigations.



### 7. Emphasize eliminating the variable of light.

 If a plant stem grows up, it could be difficult to tell whether it is growing away from the direction of gravity or toward a light source.

Invite student to share ideas for how to keep light from interfering in an investigation of plant growth and gravity. [Grow the seeds in the dark.] Reassure students that, although plants need light to sustain growth, they can grow for some time without light—this is how seeds are able to sprout and begin growing underground.

**8. Distribute the Plant Growth Investigations, Part 1 students sheets.** Review investigation setup instructions. Ask students to follow along as you go over the instructions for setting up the investigation.

**9. Emphasize making comparisons.** Point out that orienting each of the four seeds in a different direction will allow students to compare results for a variety of conditions. If the roots all start out in different directions but end up growing in one direction—down, that would be evidence that the plant is responding to gravity. If students were to set up all the seeds in the same way, and they all grew in the same direction, it would be hard to know whether the direction of growth was caused by the seeds' original position or something else.

**10. Distribute trays of materials and have pairs set up investigations.** Have pairs follow the instructions in Part 1 to set up their lids with four seeds inside. Refer to the illustration in the Teacher Reference section of this lesson.

**11. Students record predictions.** When students have their investigations set up, they should record their predictions by drawing and writing. As they do so, circulate and make sure the lids are taped together, the tops are labeled, and the lids have students' names clearly marked.

**12. Store lids with seeds in a dark location, then wait 5–8 days.** Collect and stack students' investigation setups. Store them on end with the edge labeled "TOP" facing upward in a completely dark location such as a closet, drawer, or cupboard. See the illustration in the Teacher Reference section of this lesson.

**13. Begin second teaching day.** Check to make sure that most seeds have grown root and stem tendrils before conducting the second teaching day. Return gravity investigation setups to students and distribute Plant Growth Investigations, Parts 2 and 3 student sheets. Have pairs discuss and record their observations in Part 2: Plant Growth and Gravity Investigation Results.

**14. Students observe other groups' investigations.** Have students leave their gravity investigation setups on their desks, and take a few minutes to quietly walk around the classroom and observe other pairs' results. Alternatively, have students pass their setups



around. It is not important for students to see every setup, but they should observe quite a few since the results will vary.

**15. Discuss evidence as a class.**

- Invite students to share observations and patterns they noticed. [Even though different seeds' stem and root tendrils initially grew in different directions, eventually each seed had one tendril (the stem) turn upward and the other (the root) turn downward.]
- Next, invite students to discuss what the evidence suggests about a plant's ability to sense the direction of gravity. [The plant probably has some way to sense which way is up and which way is down, even when there is no light.]
- Have students imagine a sprouting seed buried in the soil. Ask why it might be important for the new stem and root to be able to sense the direction of gravity. [Light is above the soil, so the stem needs to grow up to get to the light. Water is deeper in the soil, so the root needs to grow down to get to the water.]

**16. Introduce the term *geotropism*.** Explain that as students have discovered, plants can sense the direction that gravity is pulling (down, toward Earth). In response, their roots begin growing downward, in the direction of gravity, and their stems begin growing upward, away from the direction of gravity.

 Geotropism is an organism's movement or growth in response to gravity.

Point out that this vocabulary word is posted on the classroom wall and the definition can be found in the glossary at the back of their Student Editions.

**17. Introduce second question to investigate.** Explain that each group will now plan and conduct an investigation to find out if plants can sense the direction of a light source in a way that affects the plant's direction of growth.

**18. Review importance of light to plants.** Ask students to review why light is important to plants. [Plants use energy from sunlight to make their own food from water and gases in the air.] Explain that a plant's leaves need sunlight in order to make food during the process of photosynthesis.

**19. Introduce materials.** Hold up the paper cups, soil, and radish seeds. Explain that students will use these seeds for their experiment. Hold up a cardboard box and scissors and explain that students can use these boxes—cut and changed as they wish—to help control the direction in which light reaches the plants. Point out the clamp lamps and/or windows with natural light that students can use as light sources.

**20. Discuss the difficulty of testing the effect of light on roots.** Point out that it is difficult for students to test if the roots respond to light so it is okay if they only test the effect of light on stems.



- 21. Discuss making comparisons and having the same setup.** Remind students of the importance of making comparisons in an investigation. For example, in the growth and gravity investigation, the class compared the growth from seeds that at the beginning were pointing in different directions. Remind students of the importance of making sure the setups that they will compare are the same in all ways except for the difference that students will investigate. For example, in the growth and gravity investigation, the class made sure all the seeds received no light.
- 22. Groups discuss investigation plans.** Have each group discuss how they will set up their investigations. Circulate and check in with groups as they discuss.
- 23. Students record investigation plans and predictions.** Direct students to Part 3: Plant Growth and Light Investigation Setup and have them record their investigation plans.
- 24. Distribute trays of materials and have groups set up investigations.** As groups finish recording, they should set up their investigations. There are some tips you may want to give students:
- Seeds should be planted a few centimeters apart at a depth of about 1 centimeter. Seeds should be covered with loose soil.
  - Enough water should be added to their planted seeds to wet the top centimeter or so of the soil, but students should be careful to not add too much water.
  - Setups should be placed either near the clamp lamps or a window with natural light.
- 25. Have students monitor investigations every day for 5–10 days.** If possible, provide a few minutes for students to check on the progress of their investigations every time the class meets for the next few days. For best results, students should keep the seeds and seedlings moist by spraying them with water everyday.
- 26. Groups record and discuss observations.** After 5–10 days, have pairs return to their investigations and discuss the results. Distribute the Plant Growth Investigations, Parts 4 and 5 student sheets and have each student record their observations in Part 4: Plant Growth and Light Investigation Results.
- 27. Students observe other groups' investigations.** Have students look at other groups' investigations and note any similarities or differences in results.
- 28. Discuss evidence as a class.**
- Invite students to share their observations and patterns that they noticed. [Plant stems grow toward the direction of the light source.]
  - Next, invite students to discuss what the evidence suggests about a plant's ability to sense the direction of light. [The plant probably has some way to sense the direction of a light source, and it grows toward it.]



- Ask why it might be important for a stem to be able to sense the direction of light. [A plant might sprout where there is not a lot of light and they will need to grow toward light to get enough for photosynthesis.]

**29. Introduce the term *phototropism*.** Explain that as students have discovered, plants can sense the location of light sources and in response, their stems grow toward the light.

 Phototropism is an organism's movement or growth in response to light.

Point out that this vocabulary word is also posted on the classroom wall and the definition can be found in the glossary at the back of their Student Editions.

### Apply New Ideas

**30. Students complete diagrams and write brief explanations.** Direct students to Part 5: Plant Growth Prediction where they will complete the diagrams and write their explanations.



## Rubrics for Assessing Students' Investigations of Geotropism and Phototropism

The rubrics below may be used with students' investigations of plant root growth and plant stem growth to formatively assess students' developing facility with science and engineering practices and understanding of disciplinary core ideas.

### Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations

Note that this rubric applies to students' investigation plans in Part 3: Plant Growth and Light Investigation Setup of the Plant Growth Investigations student sheets. Rubric 1 is designed to monitor and support students as they develop dexterity with the science and engineering practice of Planning and Conducting Investigations. For each criterion, levels are described to monitor students' progress by indicating the degree to which students can independently demonstrate fluency with the science practice. This rubric may be used formatively to support students' facility with the practice of Planning and Conducting Investigations. It features targeted questions that a teacher might use to assess students' investigation plans, and it provides specific feedback for revisions and for future encounters with the practice.

| Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations  |   |       |
|--|---|-------|
| Criteria   | Description and possible feedback   | Level |
| <p><b>Produces data that can serve as the basis for evidence.</b></p> <p>Could the data generated by the investigation be used as evidence to support an answer to the question?</p> | <p>Students don't specify what data will be collected.</p> <p>Possible feedback: <i>What information will you be able to record as you conduct your investigation?</i></p>  | 0     |
|  | <p>Students specify the data that will be collected, but the data indicated could not serve as evidence to answer the question.</p> <p>Example: We will observe and record the length of the stems.</p> <p>Possible feedback: <i>How will your data help you know if light affects the direction of a plant's growth?</i></p> | 1     |

(Table continues on the next page.)



**Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations** (continued)

| Criteria  | Description and possible feedback   | Level |
|---|---|-------|
| (continued from previous page)  | <p>Students specify the data that will be collected, and the data indicated could serve as evidence to answer the question.</p> <p>Example: We will observe and record the direction the plant grows.</p>   | 2     |
| <p><b>Plans for fair tests by controlling variables.</b></p> <p>Does the investigation change one variable at a time, holding other variables constant?</p> | <p>Students change more than one variable at a time or don't describe which variables they will keep the same.</p> <p>Example: Students change the orientation of the light relative to the plant and also change the amount of water that they give the plants.</p> <p>Possible feedback: <i>What besides the location of light could affect your results? How can you make sure that won't affect your investigation?</i></p> | 0     |
|   | <p>Students change one variable at a time, holding other variables constant.</p> <p>Example: Students only change the orientation of the light relative to the plant between trials.</p>  | 1     |



## Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to students' predictions in Part 5: Plant Growth Prediction of the Plant Growth Investigations student sheets. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative, and space is provided to note if students are demonstrating understanding or struggling with each idea. If students are having difficulty, you might consider returning to the gravity and light investigations and lead a student discussion using the evidence they collected in order to help all students build the idea that plants can respond to stimuli, such as gravity and light.

### Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

| Criteria   | Description   | Is there evidence of student understanding? |
|--|---|---|
| <p><b>Consistent with accepted science ideas.</b></p> <p>Are students' predictions consistent with accepted science ideas?</p> | <p>Students demonstrate understanding of the idea that plants can respond to gravity (geotropism).</p> <p>Example: The root and stem of a plant can sense gravity. When there is no light, the stem will grow up, away from the direction of the pull of gravity. The roots will grow down toward the direction of the pull of gravity.</p> |   |
|  | <p>Students demonstrate understanding of the idea that plants can respond to light (phototropism).</p> <p>Example: I think the stem will grow that way because it can sense the light and grow toward it..</p>  |   |





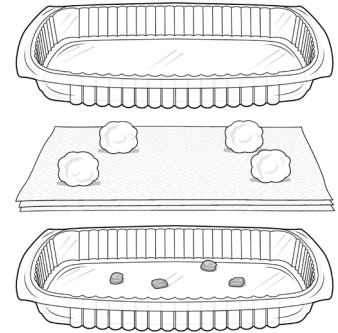
## Plant Growth Investigations, Part 1

### Part 1: Plant Growth and Gravity Investigation Setup

**Question:** Does gravity affect the direction of a plant's growth?

**Setup:**

1. Place four corn seeds in a plastic lid. Face the pointy part of each seed in a different direction. Space the seeds apart from one another.
2. Lay two wet paper towels over the seeds. (This will give the seeds the water they need to grow.)
3. Place four cotton balls spaced apart on the paper towels. (This will keep the two lids from squeezing the seeds too tightly.)
4. Fit the second lid into the first lid and tape the edges. Write "TOP" on the tape on one long end of the lids.
5. Write your names on a piece of tape and place it somewhere visible on the lids.



**Plan:**

What will you change about the seeds in your setup?

*The direction a seed points. Each seed will start off pointing in a different direction.*

What will you observe and record?

*The direction the stem and the roots grow for each seed.*

What will you keep the same in every setup?

*All seeds will be in the dark with the same amount of water from the paper towels.*



---

## Plant Growth Investigations, Part 1 (continued)

**Predict:**

1. Draw the four seeds, showing which direction the pointy part of each seed is facing.
2. For each seed, draw and label a root and a stem, showing which direction you think each will grow.

*Drawings will vary.*

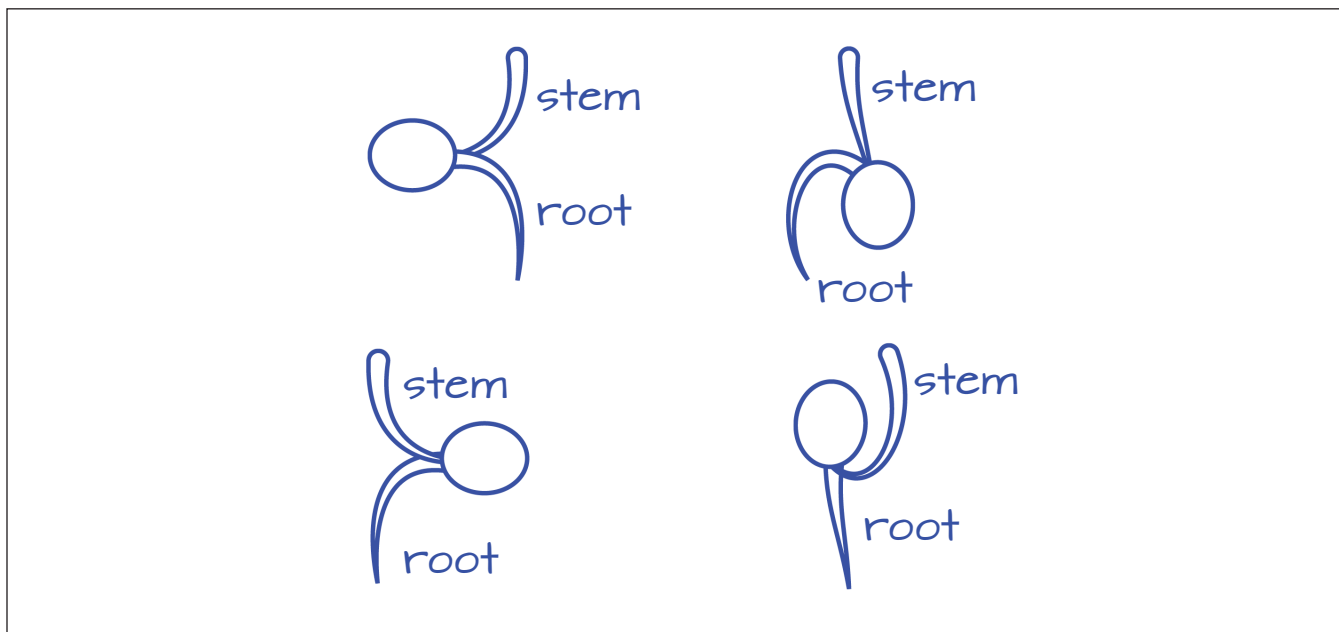


## Plant Growth Investigations, Part 2

### Part 2: Plant Growth and Gravity Investigation Results

#### Record Observations:

After some growth, draw the four seeds. Show which direction the pointy part of each seed is facing, and the growth of the stem and root. Label which you think is the stem and which is the root for each seed.



Describe what you notice about the direction of growth of stems and roots.

The ones I think are stems curve upward even if they start out downward or sideways. The ones I think are roots curve downward even if they start out upward or sideways.

#### Analyze:

Explain what you think this shows about the question *Does gravity affect the direction of a plant's growth?*

I think this shows that plants respond to gravity by making their roots grow down and their stems grow up.



---

## Plant Growth Investigations, Part 3

### Part 3: Plant Growth and Light Investigation Setup

**Question:** Does the location of light affect the direction of a plant's growth?

**Plan:**

Investigation plans will vary. Example:

What will you change between each setup?

We will place one seedling near the lamp in a box with a hole for light to come in at the top. We will place the other seedling near the lamp in a box with a hole for light to come in on the side.

What will you observe and record?

We will observe the direction the plant grows. Will they both grow up, or will they each grow toward the hole in the box?

What will you keep the same in every setup?

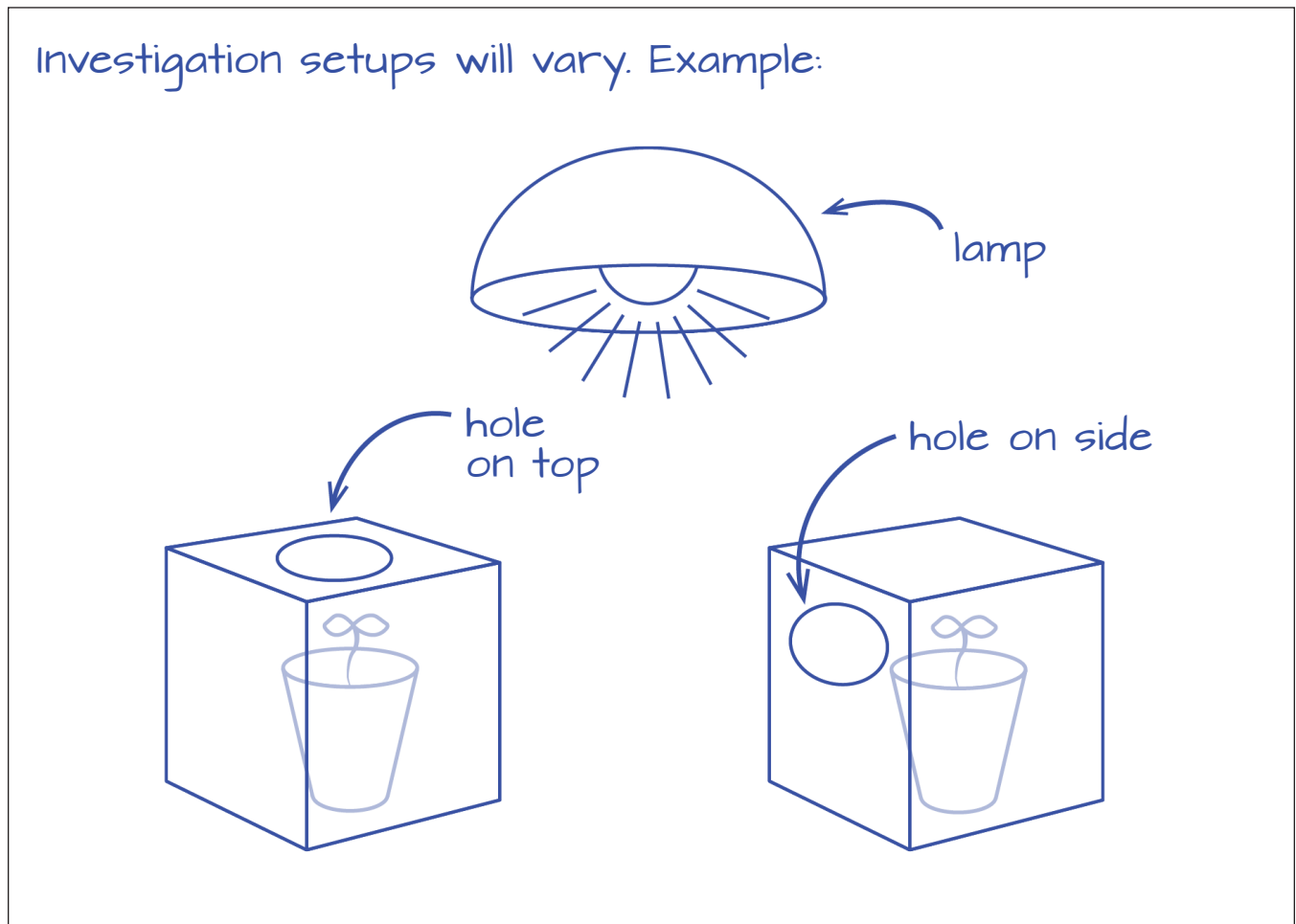
Both will be the same distance from the lamp. Both will get the same water.



## Plant Growth Investigations, Part 3 (continued)

### Setup:

Draw and label a diagram of your investigation plan.



### Predict:

Describe what you think will happen and why.

Example: I think the plants will grow toward the hole in the box. Plants need light to survive, so I think they must have some way of responding to where the light is coming from.



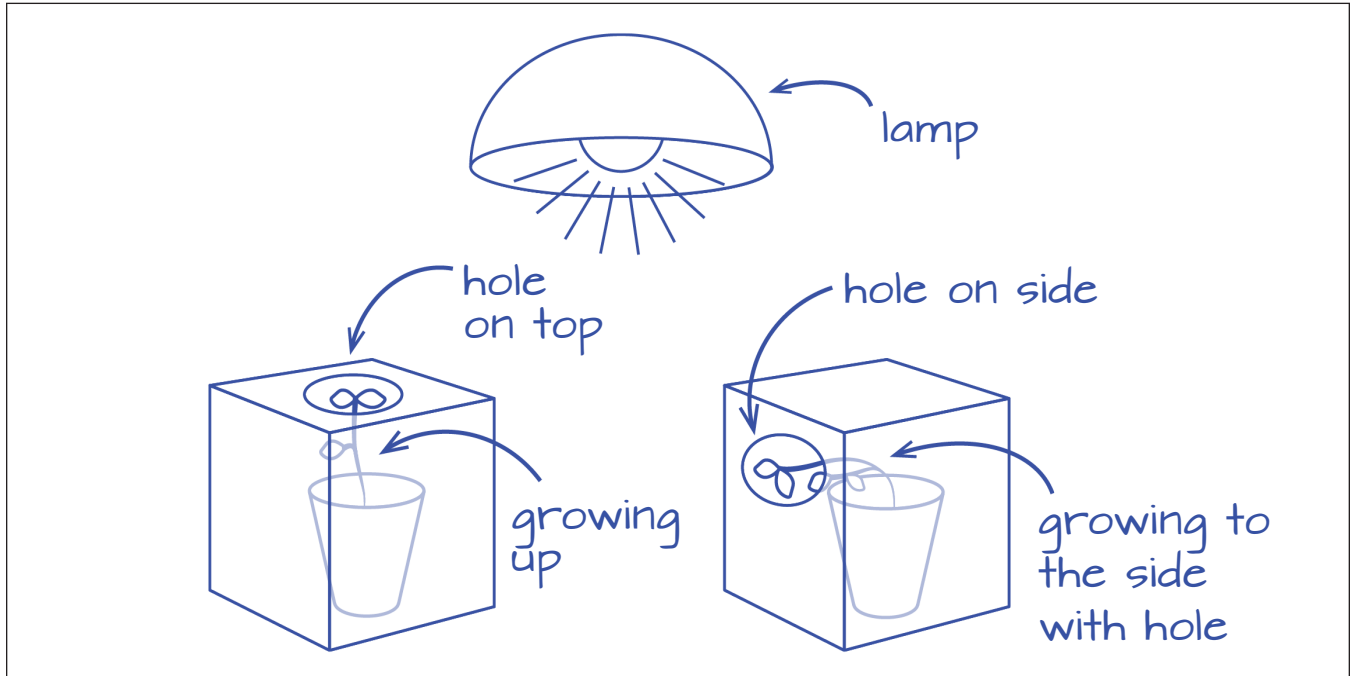
## Plant Growth Investigations, Part 4

### Part 4: Plant Growth and Light Investigation Results

#### Record Observations:

Results will vary. Example:

Draw and label observations after a few days of growth.



Describe what you observed about the direction of growth.

Each plant grew toward the hole in the box where light comes in. The plant with the hole on top of the box grew almost straight up. The plant with the hole on the side of the box grew to that side.

#### Analyze:

Explain what you think this shows about the question *Does the location of light affect the direction of a plant's growth?*

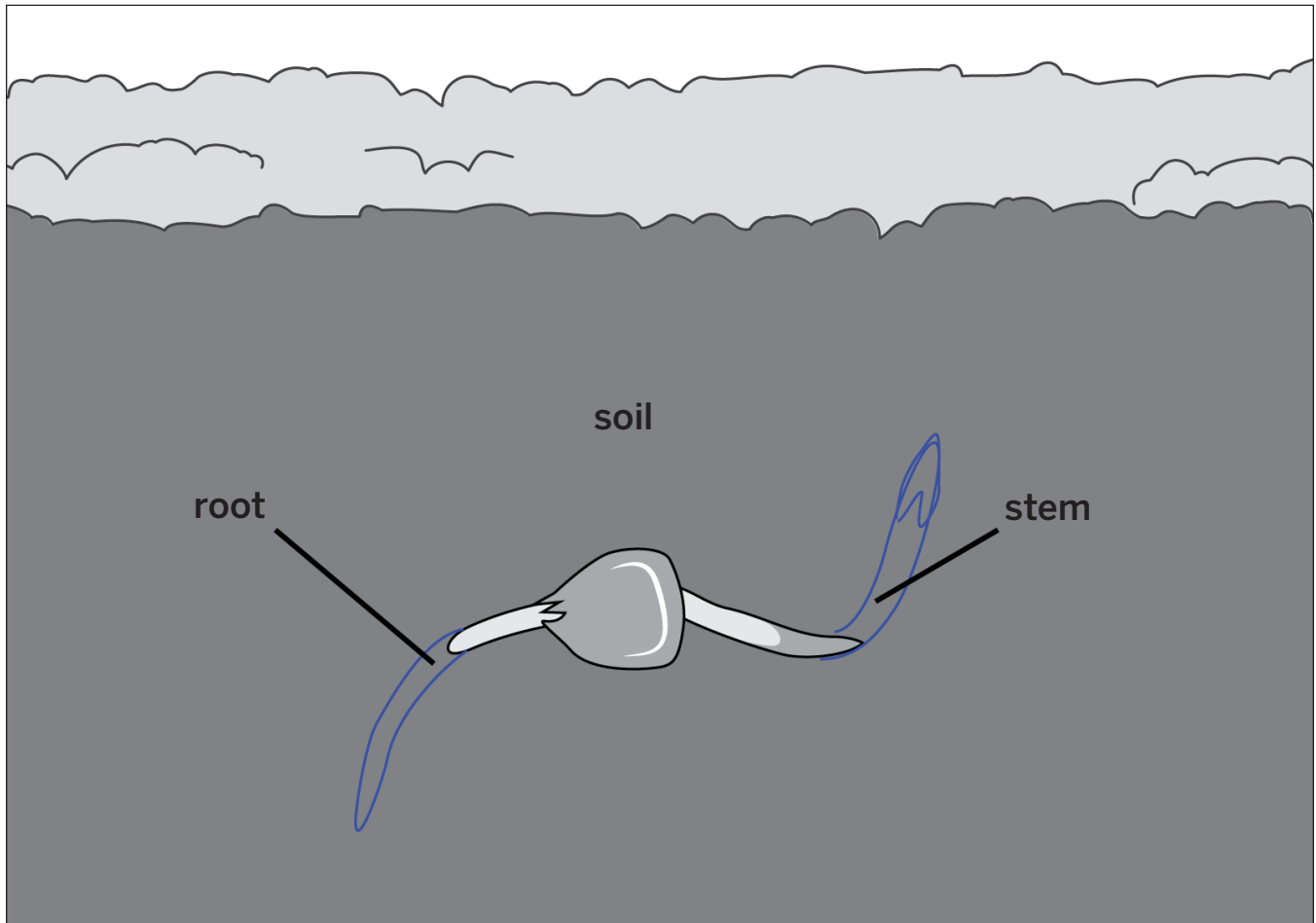
I think this shows that plants respond to light by making their stems and leaves grow toward where the light is coming from.



## Plant Growth Investigations, Part 5

### Part 5: Plant Growth Prediction

1. The diagram below shows a seed that is sprouting underneath the soil where there is no light. On the diagram, draw what you think will happen after several days of growth.



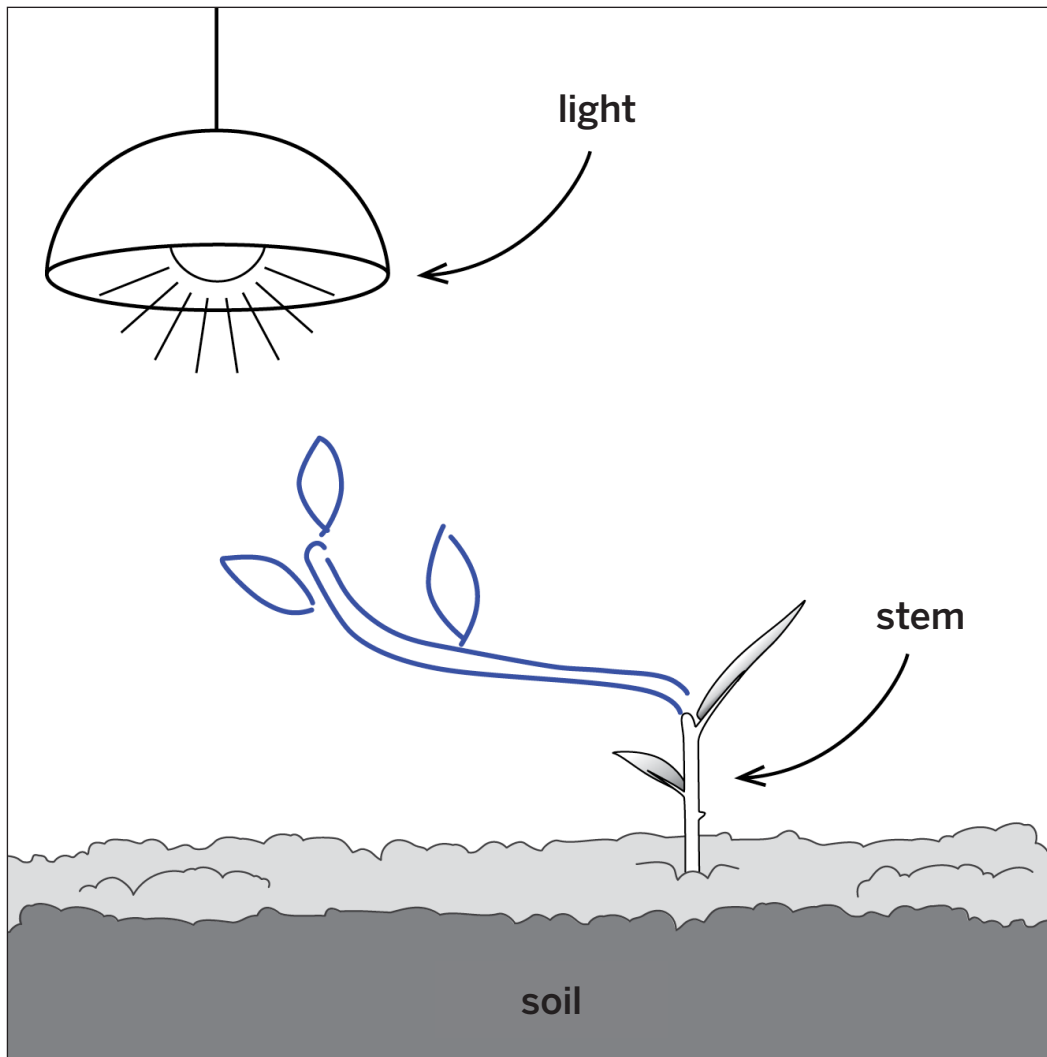
2. Explain why the root and stem will grow in the way that you drew it.

The root and stem of a plant can sense gravity. When there is no light, the stem will grow up, away from the direction of the pull of gravity. The roots will grow down toward the direction of the pull of gravity.



### Plant Growth Investigations, Part 5 (continued)

3. The diagram below shows a plant that just sprouted from the soil. On the diagram, draw what you think will happen after several days of growth.



4. Explain why the stem will grow in the way that you drew it.

I think the stem will grow that way because it can sense the light and grow toward it.