3.3 Up and Running

Action Synopsis

Students set up experiments to test the effects of compost tea on plant growth, learn about plant development, then monitor their experiments for 3–5 weeks.

Session 1	40 minutes
1. Demonstrate experiment techniques.	*demonstrating methods*
2. Work in groups to set up experiments.	*investigating*
3. Record experiment activities in journals.	*documenting*

Session 2	40 minutes
1. Check to see if seeds have germinated.	*observing*
2. Discuss ideas about what happens to seeds after they're planted.	*examining prior ideas*
3. Observe, draw, and discuss dry and soaked bean seeds.	*observing & recording*
4. Look at a drawing of the inside of a bean seed and name the parts of the seed, then discuss a drawing of plant development.	*introducing new information*
5. Answer questions about where a developing plant gets nutrients and energy.	*applying knowledge*

Continued

Ongoing Monitoring	**10–20 minutes, 2–3 times a week, for about 3 weeks**
1. Thin plants to one seedling per cup.	*investigating*
2. Make compost tea.	*investigating*
3. Water, treat, and measure plants, and record observations.	*observing & recording*
4. Share ideas and findings in periodic class meetings.	*processing findings*
5. Share note-keeping strategies, and develop data charts.	*documenting*
6. Relate the experiment to the concept of nutrient cycling.	*reflecting*

Desired Outcomes

Throughout the lesson, check that students:

✓ Can set up an experiment according to plans.

✓ Know the parts of a seed and how seeds develop into a mature plant.

✓ Understand where plants get nutrients and energy as they grow.

✓ Can accurately make and keep records of observations and measurements.

✓ Are willing to exchange and reflect on information with peers.

What You'll Need

Session 1

For the class:

- ❑ newsprint poster of experiment design plan (see page 273)
- ❑ large bucket or dishpan
- ❑ several measuring cups or 8-oz. plastic cups
- ❑ cleanup supplies:
  - broom
  - whisk broom
  - dustpan
  - paper towels
  - sponges
  - bucket of water

For each group of 3–4 students:

- ❑ set of experiment materials (see "Getting Ready"):
  - 24 6-oz. clear plastic cups

Continued

- pushpin
- approximately 9 cups of vermiculite
- plastic bag, 1-gallon size (see "Getting Ready")
- 24 radish seeds
- mini paper cup
- 12 pot labels (see "Getting Ready")
- permanent marker

Session 2

For the class:
- ❑ overhead transparency of "Inside of a Seed" (page 293)
- ❑ overhead transparency of "Growing from Seed to Young Plant" (page 294)

For each student:
- ❑ 2 large beans—one dry, one soaked (see "Getting Ready")
- ❑ hand lens
- ❑ copy of "Growing from Seed to Young Plant" (page 294)

Ongoing Monitoring

For the class:
- ❑ compost tea materials:
  - compost (see "Getting Ready," page 259)
  - dishpan or bucket
  - measuring cup
  - a sheet of cheesecloth
  - rubber band
  - water dispenser (optional—see page 288)
- ❑ containers and potting soil for planting thinned seedlings (optional—see "Getting Ready")

For each group of 3–4 students:
- ❑ watering equipment:
  - distilled water (optional—see "Getting Ready")
  - 2 plastic dropping pipettes
  - 2 medium-size plastic cups (8–9 oz.)
- ❑ several rulers, preferably small 15 cm size

For each student:
- ❑ copy of "Compost Tea Experiment Data Chart" (optional—page 296)

Vocabulary

COTYLEDONS - Seed leaves; the leaves of the embryo in a seed.

EMBRYO - The early stage of development of an organism.

GERMINATE - To sprout; to begin to grow.

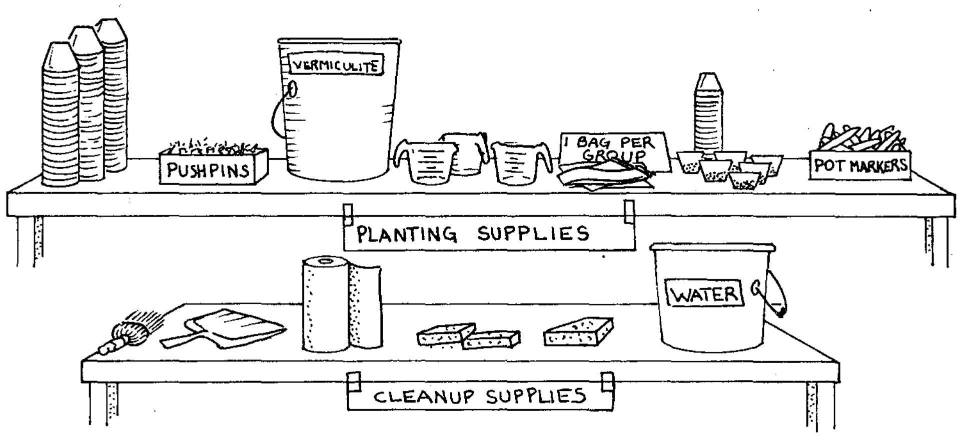
SEED COAT - Tough outer layer of a seed that protects the embryo.

SEEDLING - A plant in its first stages of growth.

Getting Ready

Session 1

- ♦ The quantity of materials listed in "What You'll Need" is enough for each group to set up 12 nested planting units—6 treatment and 6 control plants. This number could vary depending on your students' experiment design.
- ♦ Students need the plastic bag to carry from the distribution area to their desks. They could use a basin or cut-off gallon milk jug instead.
- ♦ Students can label their planting units by writing with a permanent marker on plastic pot labels, wooden craft sticks, or masking tape.
- ♦ Pre-moisten the vermiculite. Empty two 8-quart bags into a bucket or dishpan (or do it in two batches), shielding your nose and mouth from floating vermiculite dust particles. Hold the container under a faucet and add water (or use distilled water), mixing with a large spoon or your hands until all of the vermiculite is saturated, but not too wet.
- ♦ If you want seeds to germinate quickly after students plant them, cover them with water to soak overnight. The next day, drain the water and count 24 seeds into one mini paper cup for each group. Radish seeds are large enough so that students can handle them easily. If you are using smaller seeds, consider providing toothpicks that students can wet to pick the seeds from the cup in order to plant them.
- ♦ Set out experiment and cleanup materials on a table so that distribution can work like a buffet.



Session 2

- ♦ Soak one bean seed for each student overnight in water.

Ongoing Monitoring

- ♦ If students opt to save the seedlings they thin from their experiment planting units, they'll need containers such as paper cups, milk cartons, or margarine tubs to plant them in.
- ♦ If your water is high in nitrogen (greater than 5–10 parts per million), consider using distilled water for the experiments. Students' experiments will work best if the water they give control plants is low in nutrients. Some regions have a lot of nitrogen in their water

supply, particularly agricultural and urban areas. You can check with your local soil and water agency to see if your water is likely to be high in nitrogen. You could also test your water using nitrogen test strips or a water test kit, available from science supply catalogs (or perhaps from a local high school teacher). You can purchase distilled water at pharmacies, or buy an inexpensive water deionizer from a science supply catalog.

Action Narrative

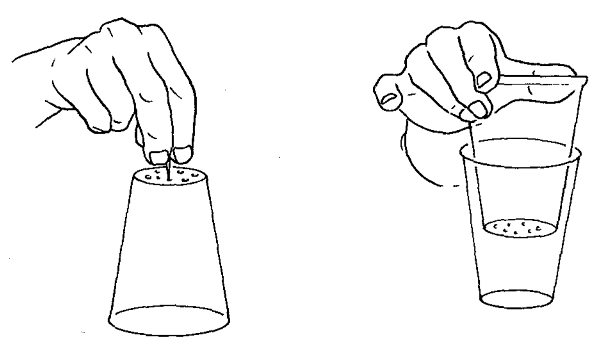
Session 1

I've posted the experiment design we made together so you can refer to it as you set up your experiments.

This teaching narrative assumes that each group will set up a replicate of a whole class experiment. The step-by-step planting instructions that follow will help assure that seeds will germinate and grow, and that all replicates will be set up identically. If your students have had prior experience growing plants, you can let them work out proper planting techniques on their own, rather than guiding them through the following methods.

Before you get started, I want to show you a few techniques to use. First, you need to make drainage holes in the cup that you'll plant seeds in. Then set that cup into another cup for water to drain into.

Turn one cup upside down and punch several holes in the bottom with a pushpin.



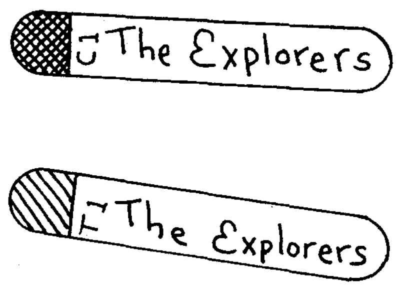
Next, fill the cups with vermiculite, then plant two seeds in each. If both seeds grow, you can remove one later.

Use a ruler to measure and mark a fill-line a few centimeters below the top of the cup. Or use a measuring cup to measure the vermiculite. If students are using solid compost as their experimental variable, then set up the cup as shown on page 272. It is important to tamp down the vermiculite in each cup the same amount—a gentle tap on the surface will do.

Next demonstrate seed planting. Most kinds of seeds should be planted only as deep as they are large, but check your seed packet for specific directions. Plant the two seeds near the center of the cup so that whichever one survives will have maximum room to grow.

Label each cup. What should go on the labels?

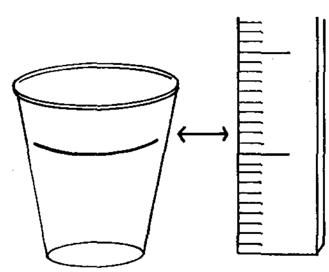
Show students the pot markers or masking tape they'll use as labels. One way to label the cups is to call the six Treatment cups T1–T6, and the six Control cups C1–C6. If students are using wooden craft sticks, they might want to color the tops of the sticks in treatment and control cups two different colors. Each group's name or initials should go on the labels, too.



Send one person from your group to get materials, then work together to set up your experiment.

Have the delivery person from each group scoop about 9 cups of vermiculite into the gallon-size plastic bags or other containers to bring back to their desks. This way group members can work together to fill their 12 planting cups.

As students set up their planting cups, check to see if they have figured out a way to get the same amount of vermiculite in each cup. Two ways to accomplish this are to measure the vermiculite with a measuring cup, or to use a ruler and marker to measure and mark a fill-line on each cup.



Make sure students don't plant seeds too deeply or else the seedlings will take a long time to emerge, or the seeds might not sprout at all.

This is a good time to monitor group interactions. All group members will want to be involved with the materials, so conflicts might arise if some students dominate the action. Suggest to groups that are experiencing conflicts that they stop what they are doing to focus on their group process for a minute. Let them know that they need to work out their own problems fairly, rather than relying on you to intervene. Remind them that learning to work together productively, respecting their different strengths and opinions, and helping each other develop new abilities are important aspects of their science experience.

Check to see how moist your vermiculite is. Since I pre-moistened it, you probably won't have to add water to the cups today.

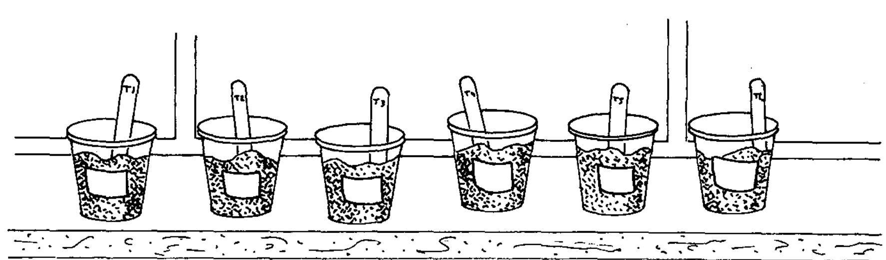
The cups most likely won't need water until the seeds germinate in about 2–3 days. The compost tea treatment shouldn't start until the cotyledons unfurl, since fungus from the compost can kill the tender seedlings while they're germinating.

If you have extra seeds, students might find it interesting to put a few in moist paper towels surrounded by plastic wrap, or in a plastic sandwich bag with a drop of water, so that they can observe them sprout.

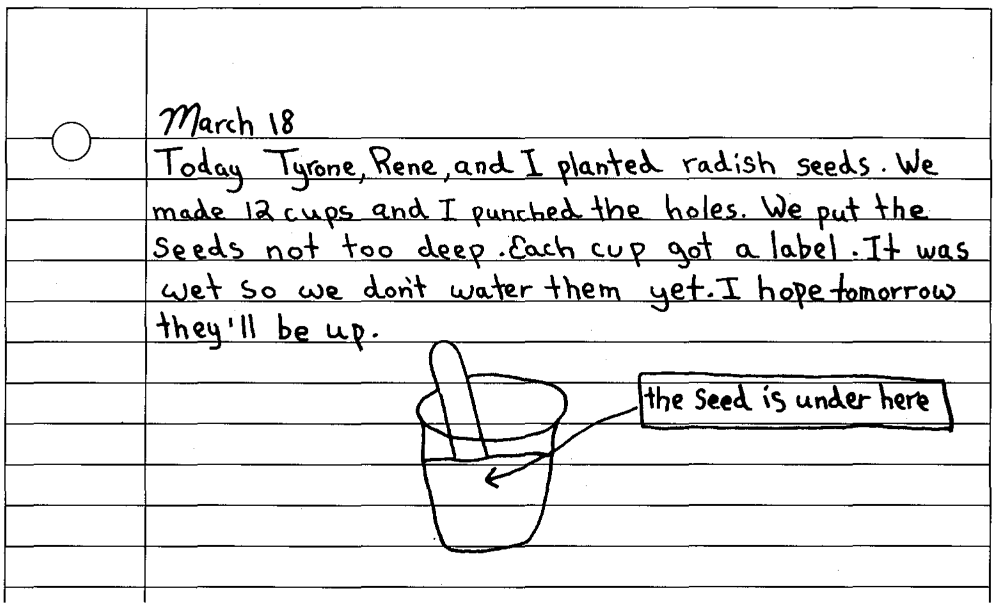
Bring your cups to the windowsill, and clean your work area.

Cleanup is an important part of all science experiments. Help students get in the habit of taking responsibility for cleaning up efficiently. Have them shake out the plastic bags and/or wipe the containers they used for vermiculite into the trash can, then turn the bags inside out to dry so that you can reuse them.

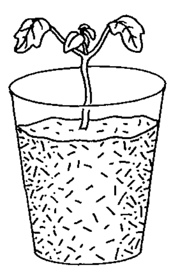
Record what you did today in your journals.



Once cleanup activities have settled down, create a quiet atmosphere so that students can concentrate on writing in their journals.


March 18
Today Tyrone, Rene, and I planted radish seeds. We made 12 cups and I punched the holes. We put the Seeds not too deep. Each cup got a label. It was wet so we don't water them yet. I hope tomorrow they'll be up.

Creating Optimal Growing Conditions



Classroom conditions aren't always friendly for growing plants. To maximize plant survival, go over the following tips with students, so they can take responsibility for looking after their plants' health.

Protect from excessive heat and drying. If you are keeping plants near an active radiator, insulate the surface the plants sit on with material such as styrofoam, or a foam pad. Also put a pan of water on the radiator to add moisture to the air. If your windowsill area heats up because of intense sunlight, keep a window open to allow air to circulate. Draw the shades if plants show signs of wilting or leaf burn. Over weekends, and especially for longer school breaks, put plastic bags or sheets of plastic wrap loosely over the plants to conserve moisture. Students could also put a small amount of water in the outer cup of their planting units before weekends or vacations.

Provide plenty of light. The more light the plants get, the faster they'll grow and respond to nutrients. A south-facing window that provides 4–5 hours of sunlight a day is best, with east- or west-facing windows being second best. If you only have access to north-facing windows, consider using supplemental plant lights 6–8 hours a day. Plant lights are the best option overall, if at all feasible.

Don't overwater. Students have a tendency to love their plants to death by overwatering them. Before the seeds germinate, they can be easily washed out with a glut of water. Using dropping pipettes helps prevent overwatering. Vermiculite should be kept moist, but not soggy. Students can see through the cup to tell when the vermiculite is saturated. They can also watch for drainage into the outer cup, and stop adding water as soon as they see it dripping out the bottom of the inner cup. They should pour out excess water from the outer cup, except just before weekends.

Cover roots. When roots start to grow to the edge of the cup, cover the cup with black paper to keep the roots in darkness.

Handle gently. Plants often get mauled as students measure them. The experiment provides an opportunity to encourage students to develop their fine motor coordination. Let them know that scientists often have to learn to handle fragile or tiny things as they do experiments. Explain that they shouldn't ever squeeze the stem which might damage the tissues that transport water and sugars to all parts of the plant. Handling plants can affect their growth, so the plants should be handled minimally, and the same amount.

Session 2

Check on the cups of seeds you planted to see if anything looks different.

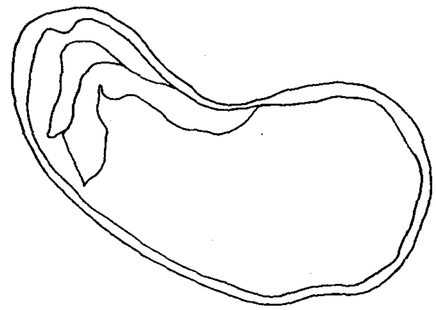
It takes a few days for seeds to germinate and emerge above the vermiculite, so students may or may not see any changes.

Let's think about what might be happening to the seeds in the cups, even if we can't see anything growing yet. Any ideas?

As students share their ideas, note how much prior knowledge they have about how plants grow from seeds. If you put some seeds to sprout in paper towels or plastic bags, have students check on them and speculate about whether or not these seeds reflect what is happening to the seeds beneath the vermiculite.

To learn more about what happens as seeds grow, everyone will get two bean seeds—a dry one and one that soaked up water overnight. Observe them both with a hand lens, then take the outside layer—the SEED COAT— off the soaked bean. Then you can gently pull the two halves of the bean seed apart and see what is inside. Draw what you see.

Hand out the bean seeds and lenses. Give students time to make and draw their observations. You could use one of their drawings later in lieu of the prepared overhead transparency of the inside of a seed, if you have a plain paper projector or if the student is willing to trace the drawing onto a transparency.



After they have finished, ask questions such as:

What was the difference between the dry seed and the soaked seed?
Encourage students to use detailed and descriptive language to explain how the seeds look, feel, and smell.

Did the seeds you planted look more like the dry or the soaked seed? How do you think they look now that they've been planted for a day?
Students' responses will depend on whether or not you pre-soaked the seeds for their experiment. Since they were planted, the seeds have probably absorbed more water from the wet vermiculite, and have begun to expand.

Does anyone know what it is called when a seed begins to grow?
Students might use the term "sprout," which is another term for GERMINATE.

Here is a drawing of the inside of a bean seed. See if it looks like what you drew.

Show the "Inside of a Seed" overhead transparency, covering the vocabulary words with a sheet of paper.

Does anyone know what the parts of the seed the arrows point to are called?

Once students share their ideas, remove the paper that covers the terms and discuss them. The EMBRYO is the baby plant. One end will be the growing tip or shoot from which the leaves grow, and the other will be the root. COTYLEDONS are the seed leaves. They contain nutrients and energy that the embryo needs to start growing.

Now let's look at how this seed will change as it grows.

Show the "Growing from Seed to Young Plant" transparency, covering the bottom questions section with a sheet of paper. Explain the growth stages as follows:

A: The seed begins to absorb water. The cotyledons start to draw nutrients and food energy from the embryo.

B: The embryo sprouts roots and a shoot that begins to push above the soil.

C: The cotyledons burst out of the seed coat. The plant begins to use up the stored nutrients and energy to grow. Meanwhile, the plant is beginning to take in nutrients from the soil, and is beginning to make its own food energy through photosynthesis. This tiny plant is called a SEEDLING.

D: The first true leaves start to grow. The plant now takes in even more nutrients from the soil, and makes all of its own food energy. The cotyledons will turn yellow and die as the other leaves take over their job.

Here is a copy of the overhead, with questions for you to answer on the bottom.

Hand out a copy of "Growing from Seed to Young Plant" to each student. If there is time, they can work on it in class independently or in pairs. Or they can complete it for homework. See the "Growing from Seed to Young Plant—Teacher's Page" for examples of well-reasoned student responses. Discuss the completed sheets as a class. The basic idea students should understand is that plants need to take in nutrients through their roots once they use up the nutrients stored in their cotyledons.

You might want to review photosynthesis, and the terms nutrients *and* energy *with the class. Students should understand that plants make their own food to use for energy, and that they also need nutrients from soil and water to stay healthy and grow. See Lessons 1.6 "Making Food Chains" and 1.7 "Food for Thought" for ideas on introducing these concepts.*

Ongoing Monitoring

Students will need ten to fifteen minutes two or three times a week for at least three weeks to water, treat, and measure their plants, and to record observations. You can also continue with Lessons 3.4 and 3.5 during this time period.

Thinning Seedlings

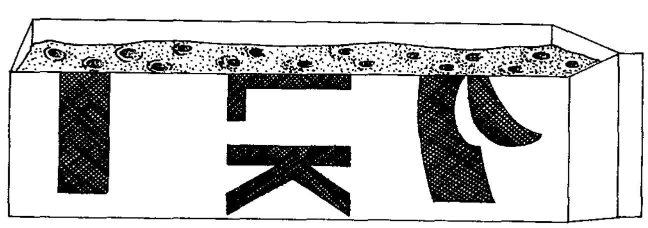
After plants have been growing about a week it is time to thin them to one seedling per cup.

Now that your seedlings have started to grow above the vermiculite, it's time to remove one of them from each cup so that the one left will have more room to grow.

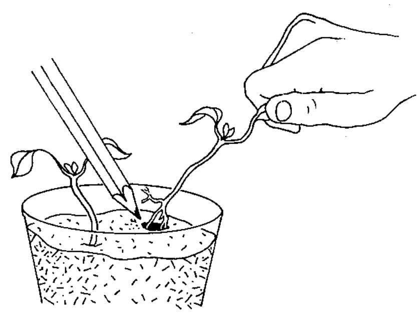
Students should decide which seedling to keep in each cup for their experiment.
They should keep the seedlings that are the healthiest and of similar size, so that all of their replicates are as similar as possible.

An easy way to thin seedlings is to cut them off with scissors at soil level. But students will probably not like the idea of killing the extras. An alternative is to remove an intact seedling from each cup. This risks damaging the roots of the remaining plant, so discuss the options with your class. If the plants are edible, such as radish, the students could eat the seedlings, which means they could cut them off at the soil surface.

If students decide to transplant, have them prepare cups of potting soil or a whole class planting tray for the seedling transplants. They can use pencils to make planting holes in the new containers.



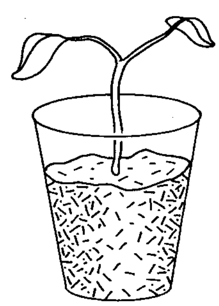
Have students carefully remove their unwanted seedlings by holding onto a leaf and pulling gently as they loosen the roots from the soil with a pencil, being careful not to disturb the other seedling in the cup. Students should also be sure not to squeeze the stem, which would damage the plant's ability to transport water and sugars.



Finally, have students transplant their seedlings into the holes they prepared, making sure the holes are deep enough for roots to point straight down, and gently press the soil around the roots.

Watering and Beginning the Compost Tea Treatment

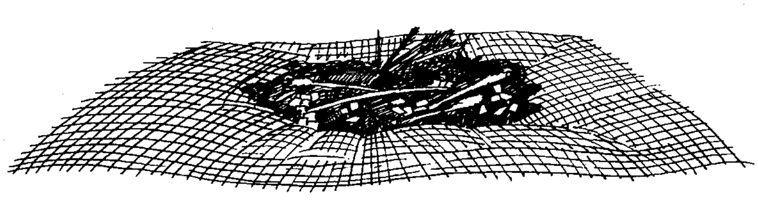
Gather the compost tea materials (compost, a measuring cup, cheesecloth, a rubber band, a bucket, and deionized or tap water) after the cotyledons have unfurled.



We've been waiting for the cotyledons to unfurl before giving the plants compost tea, because there might be molds in the compost that can make tiny plants rot. Now that the plants are taller and stronger, it is less likely that would happen. So we're ready to make a batch of compost tea for you to use on your treatment plants.

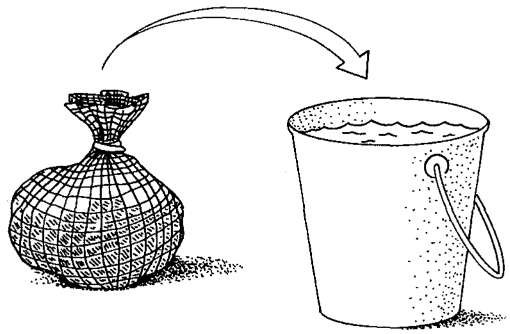
Have students help you make the compost tea as follows:

1. Measure a gallon of water into a bucket or dishpan.
2. Open a square of cheesecloth. Put 4 cups of compost into the center of the square.

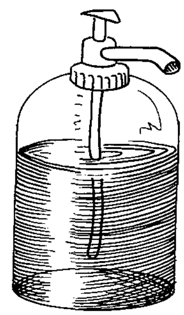


3. Gather the cloth into a bundle and fasten it with a rubber band.

4. Put the bundle of compost into the water, swirling it a few times to saturate it.



5. Let the compost soak in the water overnight. Remove and discard it the next day. The tea should be a light caramel color. If it is as dark as a strong tea beverage, dilute it with water. You can keep the compost tea in the bucket where students can scoop it out with cups as needed, or use a funnel to pour it into a water dispenser.



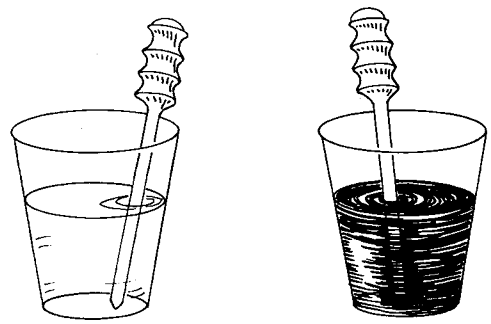
6. Repeat the procedure to make smaller batches of compost tea as needed, using a ratio of 1 cup of compost to 4 cups of water.

Caution! Be sure students always wash their hands after handling compost and compost tea to remove bacteria and fungal spores.

Students should record information about their treatment and control plants before beginning the compost tea treatment, so that they know how the plants are similar or different from the outset.

Students can decide whether to give their treatment plants only compost tea, or alternate tea treatments with plain water. If the tea is not too concentrated, there is no reason why they can't give it to the plants during every regular watering.

An easy way to manage watering the plants with a measured amount of liquid is for each group to have two cups to use as water reservoirs—one for plain water and one for compost tea—and two graduated dropping pipettes—one for plain water and one for compost tea.



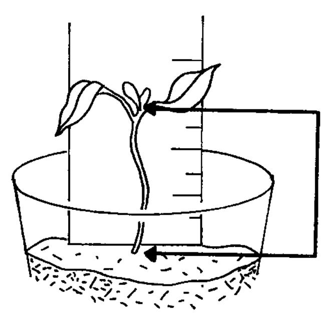
What's In Compost Tea?

In addition to nutrients released from dead plants by decomposers, compost tea contains microscopic bacteria and fungi. There also will be plant-derived molecules such as tanins (used for tanning leather), which are much like the substances that flavor and color tea beverages.

To see if there are different atoms and molecules in plain water (tap and deionized) versus compost tea, students can dip blue litmus paper into each. The paper will turn red in the presence of nutrient molecules that make a solution acidic.

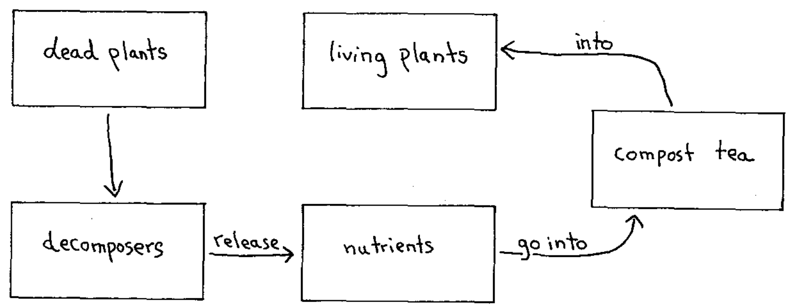
Class Meetings

Hold class meetings periodically for students to share observations and ideas. They can also demonstrate measuring techniques to one another to double-check that they are all measuring in the same ways.



Class meetings can also be forums for sharing "news bulletins," such as when a group discovers a new indicator of plant health (e.g., the size of leaves) to observe and measure.

Focus some of the meetings on discussions of nutrient cycling. One way to do this is to have groups of students map out and then display the pathway they think nutrients are taking in their experiment. They can arrange a set of cards on paper, similar to concept mapping.



Challenge students to support the theory they've illustrated with evidence that is emerging from their experiments. If experimental results are not supporting the theory, ask them to speculate about, and perhaps illustrate, what else could be happening.

Keeping Records

Early on you might want to focus a class meeting on note-keeping strategies.

Let's share the different ways people are keeping records.

The compost tea experiment provides a rich opportunity for students to keep a variety of notes and drawings. Giving students a chance to share their notes helps them take pride in, and see the value of their records. It also shows them that there are many ways to record observations.

Date:	What I did:	What I noticed:	What I wonder about:
April 11	Started giving compost tea to treatment plants	The treatment and control plants look the same to start with	When will they start to look different?

In addition to encouraging creative notetaking, introduce data tables as a convenient format that scientists use to organize their data. Some students might have devised their own data charts that you can use as examples, or give each student a copy of the "Compost Tea Experiment Data Chart."

What to Expect

Students should begin to see subtle differences between treatment and control plants within two weeks, with differences continuing to get more obvious as time passes. The more light the plants get, the more quickly they'll grow, and the sooner untreated plants will show signs of nutrient deficiency. The most notable difference between treatment and control plants will likely be the width and length of leaves, with the control plants having smaller leaves. The control plants might also be paler, or even yellowish. All cotyledons turn yellow as they grow older, so it is better to compare color of true leaves. Also, you can compare when cotyledons fade and wither. If you are using radishes, students might notice a difference in the size of the radish developing at the base of the stems.

Trouble shooting. Too much of a good thing can be toxic! Especially under very low light conditions, plants might not be using the nutrients in the compost tea very rapidly. Thus, the nutrients could accumulate and act as toxins rather than as fertilizer. This could also happen if the compost tea is too strong. The toxic effect will show up as mottling on the surface of leaves. Other reasons that treatment plants might not grow well are mentioned on pages 283–284.

If the treatment plants begin to look worse than the control plants, students could speculate about why, but decide not to change their experiment. Or they could try a variation on the basic experiment using half of their treatment and control plants, diluting the compost tea to half-strength, or giving the plants more light.

Ongoing Assessment

Student Reflections

Have students send a C-Mail message or record thoughts in their journals. Optional writing prompts include:

What is good and what is bad about working in a team to do an experiment?

Ways our team could work better together are...

Things I've noticed about myself as a scientist are...

Teacher Reflections

❑ Are students working together productively and settling their own disputes?

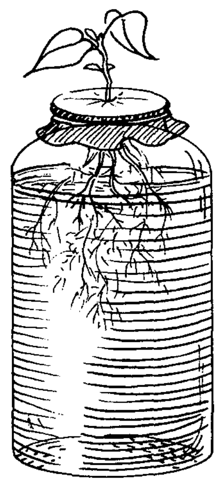
❑ How clear are their ideas about where plants get nutrients and energy?

❑ Are they developing notetaking skills and a commitment to accuracy?

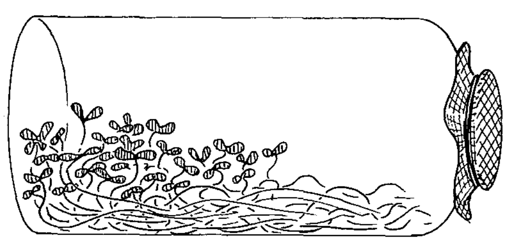
❑ Are they trying to make sense of their observations?

Extensions

Hydroponics. Have students find out how plants are grown without soil. If possible, visit a commercial grower that uses hydroponics. Try to grow plants, from houseplant cuttings to lettuce and beans, without soil.



Sprouts to Eat. Students can sprout alfalfa and radish seeds, then add them to their lunches! Make sure to use seeds that have not been treated with a fungicide (often a brightly colored powder coating the seeds). They should soak the seeds in water overnight, then drain them. They'll need to rinse them every day, and keep the sprouts' jar in a dark place.

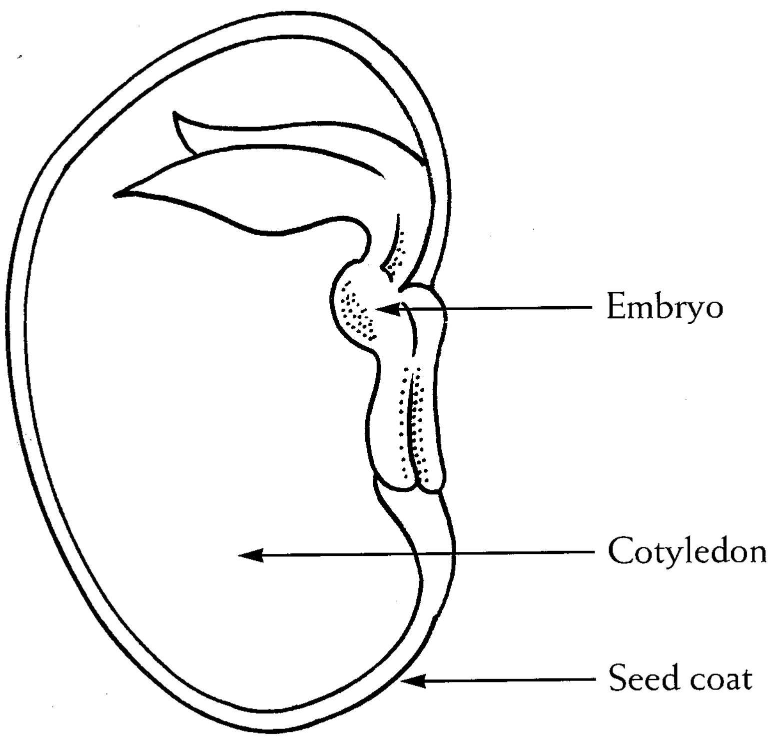


Home-based Experiments. Send home a list of plant experiment suggestions that students can do with their families, and then report their results back to the class. Some ideas are: a) test other homemade solutions (e.g., eggshells or manure soaked in water) to see if they help plants grow better than plain water; b) compare the growth of plants given different amounts of fertilizer; c) collect soils from different locations outdoors and compare how well plants grow in each.

Big Books. Suggest that students write, illustrate, and bind "big books" on plant growth for kindergarten or primary-grade students.

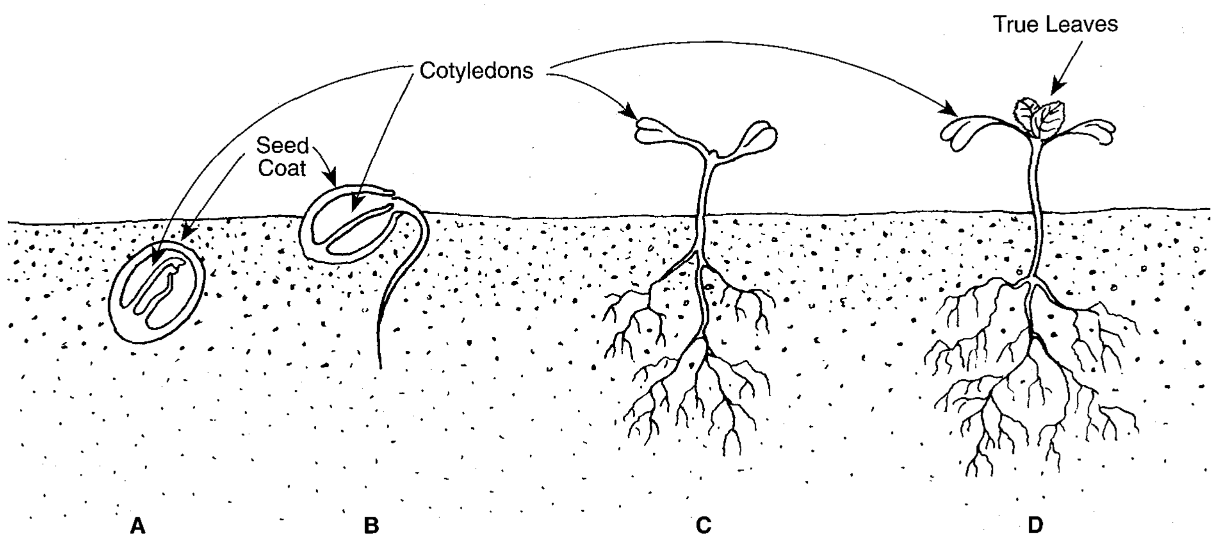
Farm Comparisons. Have students check the library or contact agricultural offices to find out the differences between farms that use compost and manure as fertilizers, and those that use only chemical fertilizers. Ask students to list the pros and cons of each approach (i.e., costs, environmental impact, quality and quantity of food produced). If possible, visit a local farm or an agricultural experiment station.

INSIDE OF A SEED



NAME(S)______________________________ DATE__________

GROWING FROM SEED TO YOUNG PLANT



1. In picture B, where is the tiny plant getting most of its nutrients and food energy?

____

2. Where is the plant in picture D getting its nutrients?

____

Where is it getting its food energy?

____

3. If you sprouted a seed on a paper towel, what do you predict would happen to the seed after 3 weeks? Why?

____

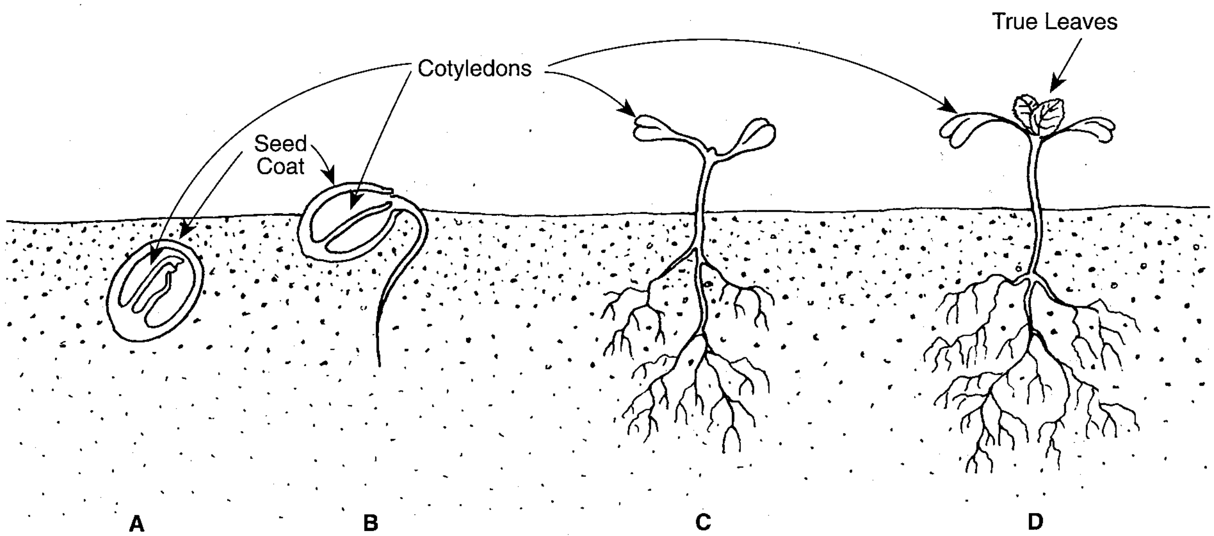
____

4. If you wanted the seed you sprouted in the paper towel to grow into a healthy plant, what would you have to do with it? Why?

____

____

Growing from Seed to Young Plant — Teacher's Page



1 In picture B, where is the tiny plant getting most of its nutrients and food energy?
Since the plant does not yet have well-developed roots or leaves, it still gets its nutrients and energy from the cotyledons.

2 Where is the plant in picture D getting its nutrients?
The plant now has roots, so it is getting nutrients from the soil.

Where is it getting its food energy?
The plant is using its true leaves to make food through photosynthesis.

3 If you sprouted a seed on a paper towel, what do you predict would happen to the seed after 3 weeks? Why?
It would probably die because it would have used up the food stored in its cotyledons without getting sunlight and nutrients.

4 If you wanted the seed you sprouted in the paper towel to grow into a healthy plant, what would you have to do with it? Why?
You would have to plant the seedling in soil (or in a fertilizer solution, such as in hydroponic gardening) so it could get nutrients, and then put it in light so that it could make its own food.

Name(s)____

Compost Tea Experiment Data Chart

Plant Height (in centimeters)

Date	Treatment							Control						
	T1	T2	T3	T4	T5	T6	Average Height	C1	C2	C3	C4	C5	C6	Average Height