3.4 Exploring Plant and Soil Connections

Action Synopsis

Students prepare for and do an outdoor investigation of soil in areas where plants and other landscape features differ, then use their findings to think about plant and soil connections.

Session 1	1 hour	
1. Imagine being a plant outdoors.	*examining prior ideas*	
2. Discuss how plants get nutrients, and what conditions could affect where plants grow.	*generating ideas & questions*	
3. Hear and discuss a story about Dr. Charlie Canham, a scientist who studies plant communities.	*linking to real world*	
4. Go over questions and procedures for outdoor soil investigation.	*familiarizing*	

Session 2	1 hour	OUTDOORS
1. Review outdoor study rules and get oriented to the study site.	*familiarizing*	
2. Work in groups to find two sites, write a research question, collect soil samples, and record observations.	*investigating*	

Continued

Session 3 — **40 minutes**

1. Compile outdoor study findings in groups. — *processing findings*
2. Share research questions and findings as a class. — *processing findings*
3. Have a final discussion about plant and soil connections. — *reflecting*

Desired Outcomes

Throughout the lesson, check that students:

✓ Can envision roots growing in soil and taking in nutrients.

✓ Are aware of some ways that ecologists study plant communities and help people manage land.

✓ Can use visible differences in sites to predict differences in soil.

✓ Know how to look for patterns in their data in order to make generalizations.

✓ Can explain how soil could affect plant communities, and how living and dead plants could affect soil.

✓ Are familiar with a variety of factors that together determine what plants grow where.

What You'll Need

Session 1

For the class:

- ❑ overhead transparency of "Shrub Invaders" (page 311)
- ❑ overhead transparency of "Root Races" (page 312)

For each student:

- ❑ copy of "Plant & Soil Connections Data Sheet" (page 313)

Session 2

For each group of 3–4 students:

- ❑ tray (e.g., cookie sheet, foil pan, dishpan) lined with white paper
- ❑ trowel or large metal spoon
- ❑ piece of rigid plastic 2" pipe, about 50 cm long (optional)
- ❑ several hand lenses
- ❑ rulers

Vocabulary

COMPETITION - The interaction of two or more organisms seeking a limited resource that they both need.

FIBROUS ROOTS - Fine roots that branch in all directions with no central main root.

PLANT COMMUNITY - The group of different kinds of plants growing in the same area.

SHRUB - A low-growing woody plant that usually has many stems.

TAPROOT - A central root that grows downward and has smaller roots extending outward from it.

Getting Ready

Session 1

♦ Decide on groups of 3–4 students.

Session 2

♦ Scope out a study site by looking for an area that has several distinctive areas within it (e.g., with and without plants; grassy and forested areas; low/moist and high/ dry places). If you cannot find a suitable location for an outdoor excursion, you can modify the lesson by asking students to take a soil sample at home, and record observations on their data sheet. They can bring their soil samples to class, and share their observations within groups.

♦ Read the Extensions (pages 306–307) before going outdoors in case you would like to do any of them, or collect soil samples for them, during the field trip.

Action Narrative

Session 1

In your experiment, you're comparing how well plants grow with and without nutrients from decomposed plants. While the experiment is running, we're going to take some time to explore how decomposing plants affect soil and living plants outdoors—in an ecosystem.

To start thinking about plants growing outdoors, close your eyes.

It often helps to dim the lights while guiding students to use their imaginations.

Imagine that you're a plant growing outside. Picture what type of plant you are. Now imagine that your feet are your roots, your legs are your trunk or stem, and the rest of your body is the branches and leaves, or pads if you're a cactus.

Focus on the underground world around your roots. What is the soil like? Is it rocky, sandy, or smooth? Moist or dry? What are your roots like? Are they FIBROUS ROOTS, with a lot of thin hair-like strands? Or do you have woody tree roots, or a long TAPROOT like a carrot? What's coming in through your roots? How does that feel? Are any soil critters moving around your roots? Are any nibbling on them? Maybe there are strands of fungal hyphae growing near your roots. Are there any decomposing plants on top of, or in the soil around your roots?

Now look around in your mind's eye at where you're growing. Is it sunny or shady? Are there other plants near you, crowding or shading you? Or do you have a lot of space around you? What kinds of plants live nearby? Are they the same as you or different?

When you're ready, open your eyes and we'll share some of the images you had.

Call students' attention to the variety of plant and soil types, environmental conditions, and surrounding vegetation they imagined. Have them consider which of the images are most like plants and conditions common in your local region, and which are not.

Continue the discussion with questions such as:

What did you imagine coming in through your roots?

See whether or not students have a picture of nutrients dissolved in water entering a plant through its roots. Whereas animals can break food down into simple nutrient particles in their guts, plants must take in nutrients from materials that have been pre-digested by decomposers. Make sure that students understand that even when plants aren't given liquid fertilizer or compost tea, they still take up soil nutrients dissolved in water. The nutrients that decomposers release from dead plants, and that come from weathered rocks, go into solution when they come into contact with water that enters the soil as rain or snowmelt.

A group of different kinds of plants that live in the same area is called a PLANT COMMUNITY. Did you imagine different kinds of plants around you? What did your plant community look like?

If you have a plant community outside your classroom window, have students describe it after they've discussed their imaginary communities. Otherwise, talk about other familiar areas where there is a natural area of plants, such as a nearby park.

Why do you think certain plants grow in some places, but not in others?

Encourage and expect a wide variety of preliminary ideas from students, which will grow and change when they do their outdoor exploration. Climatic conditions determine many of the patterns of plant distribution around the globe. Within a local environment, sunlight, temperature, wind, moisture, landscape features, and soil type and fertility are some of the physical factors that influence plant distribution. Biological factors, such as seed sources, presence of animals that transport seeds or eat seeds and seedlings, and interactions among plants themselves (e.g., shading each other, competing for water) also determine what plants live in a given spot.

Would you expect more or different kinds of plants to grow where there are a lot of dead plants decomposing on the ground than where there is no leaf litter? Why or why not?

Students will continue to explore this question when they go outdoors during the next session. Encourage them to articulate their prior ideas, but they don't need to settle on any definitive answers yet. In general, soil that is rich in decomposing plant material has more nutrients and retains more moisture, and thus is more favorable for plant growth. Plant communities in nutrient-poor, dry soils will contain plants that are adapted to these conditions, many of which will be different species than those that grow in rich soils. Amount of plant growth is influenced by factors in addition to soil, especially sunlight.

Before we make plans for doing an outdoor investigation of what the soil is like in different areas, I want to read you a story about the work of a scientist named Dr. Charlie Canham and his research team. They are interested in where different plants grow for an unusual reason—they want to help prevent tall trees from growing in certain areas.

Read aloud the story on pages 308–310.

Make sure students have understood the story by asking questions such as:

What are Dr. Canham and his colleagues studying and why?

They are studying how shrubs' use of critical resources such as sunlight, water, and nutrients might prevent tree seedlings from growing. They are studying this question to try to help electric utility companies figure out ways to prevent trees from growing beneath their power lines.

What did they find out from doing the experiment in which they planted tree seedlings in the middle of shrubs?

Dr. Canham and his team discovered that in poor soil, the tree seedlings benefited most from not having to compete with shrubs for water and nutrients. In rich soil, the trees benefited most from not having to compete with shrubs for sunlight.

What did Dr. Canham discover from doing the "Root Races" experiment?

He found out that plants that normally grow in soil that is poor in nutrients can grow towards patches of soil that are high in nutrients more quickly than the roots of plants that usually grow in soil that is high in nutrients.

Now let's make plans for our own outdoor study. For his outdoor experiment, Dr. Canham looked for areas where the soil had different amounts of nutrients and moisture. He found that this had a big effect on the plants growing in each area. We're going to do something similar to explore whether or not the soil is different in areas that look different above ground.

How do living and dead plants, and other conditions above ground, affect soil?

When we go outside, each group's challenge is to find two places where you think the soil might be different. What are some clues to look for above ground?

Some ideas students might mention include comparing locations: with and without plants; where different kinds of plants grow; where there is a leaf litter layer and where the ground is bare; under and between hummocks of grass; under shrubs or cactus and in the open; where the ground is rocky and where there are no rocks; or where the ground is trampled and undisturbed.

Help students understand that the purpose of their study is to see if they can detect any connection between the amount or types of living or dead plant material above ground, and the consistency, moisture, or nutrient richness of the soil below ground.

Here is a data sheet for recording your observations. Look it over in your groups, then be ready to summarize your tasks in your own words.

Assign students to groups and give each person a "Plant & Soil Connections Data Sheet." After they read and discuss the data sheet in their groups, have them summarize their challenge aloud. They might need help understanding what they should write as a question for item #2. If so, explain that once they are outside they can form a question about differences between two sites such as *Is the soil in a place covered with pine trees different from the soil in a place covered with grass?*

Session 2

What are some behaviors to keep in mind while doing field work?

Review field trip rules and safety reminders (see page 69).

Remember that we should try not to destroy the roots of plants when digging soil samples.

Have each group get its trowel, plastic pipe, tray, hand lenses, and data sheets to take outside.

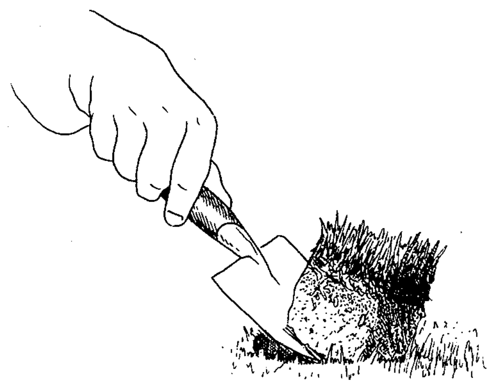
When you arrive at the study site, gather students in a central meeting location. Point out prominent landmarks that mark the study site boundaries.

Look around with your group for two sites within the boundaries where you think the soil could differ. Decide on a specific question you want to answer, and write it on your data sheet. Then go to the first site, and complete Part 1 of your data sheet.

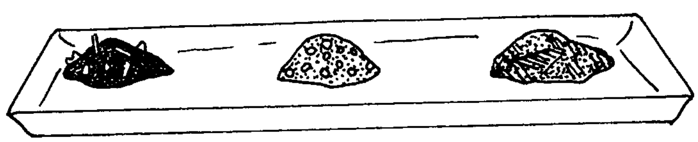
Each group's sites don't need to be far apart. For instance, the upper layer of soil directly beneath and one meter beyond a shrub could be different. Help students make and record detailed observations of above-ground characteristics, such as the depth of leaf litter and the types of prominent plants.

Next, dig a soil sample and put it on your tray to examine it. Record your observations of the soil in Part 2 of the data sheet. Follow the same procedures at your other site.

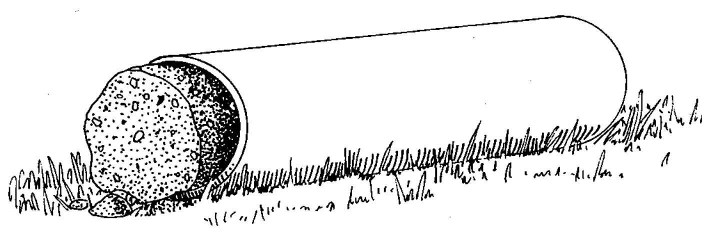
You might want to demonstrate a few methods of collecting soil samples. If the soil is moist or held together by a network of fine roots, students can cut out a square of soil to observe.



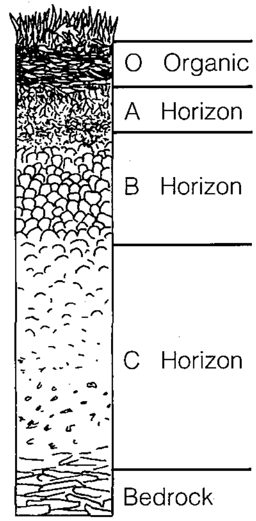
If the soil is dry, students can remove soil one scoop at a time, and display the scoops side-by-side on their tray to observe any differences in the samples from upper to lower layers of the soil.



Another method for collecting soil samples is to push a piece of 2" plastic pipe into the ground as far as it will go, then remove it. Students will have a soil core inside the pipe which they can push out carefully with a stick.



Soil Profiles



Soils have different layers, called horizons, between the uppermost decomposing organic matter at the surface of the soil, and mineral or bedrock at its base. These layers differ in texture and color because of the size and type of particles in them. Soil horizons form in part through the action of water that leaches and deposits different minerals and organic particles in different layers. Plowing, rototilling, or bulldozing and grading can eliminate or alter soil horizons.

All soils have some sort of profile, although how thick and distinct the horizons are varies greatly from place to place. Students won't see an entire soil profile just by digging 10 centimeters or so into the soil, but they might notice that the color and/or texture of the soil changes the deeper they dig. Differences in the appearance or thickness of soil horizons might be one of their major findings when comparing soils in their two sites.

Help to focus students' observations on characteristics of their soil samples, such as texture, color, layers, organisms, fungal hyphae, and burrows. They could also measure the width of each distinct layer, and rate the moisture level of the soil.

Make sure students return their soil samples to the holes they dug, unless you want soil for the "Growth of Plants in Different Soils Test" (see page 307).

Session 3

Spend some time in your groups pulling together the information you collected outdoors. Be ready to share your research question and findings with the whole class.

Have students work in their groups to share and complete the notes they recorded on their data sheets, and decide which data sheet(s) to hand in at the end of class to represent their group's findings.

Let's share your questions and the answers you discovered.

You might want to record each group's question on a class list.

Is the soil under a rock different from the soil under a shrub?

Is the soil under the swing set different from the soil under the lawn?

Is the soil in a place with a lot of dead leaves different from the soil where the ground is bare?

Once each group has shared its findings, the class can try to find patterns in their observations, to see if they can make any generalizations. Help students realize that this is how scientists build knowledge. Encourage them to support their ideas with evidence.

Depending on the sites students investigated, they may or may not have noticed correlations between the character of the soil and the living or dead plants on it. This is truly an opportunity for your class to draw its own conclusions about the soil conditions different plants seem to grow in locally, and in turn how living and dead plants and other conditions above ground might be influencing the soil. However, students should realize that since they didn't do a controlled experiment, more than the one factor each group focused on (e.g., sites with and without leaf litter) varied between the two sites. This makes it difficult to attribute any differences in soil they observed to a single factor.

Conclude with questions such as:

How do you think dead plants affect soil and the living plants that grow in it?
In general, dead plants enrich soil with nutrients. The organic matter also helps the soil retain moisture. In these ways, leaf litter enhances a soil's ability to provide two important resources for plants.

How would the ability to live in soil that is low in nutrients and moisture be beneficial to a plant?
There are many places where these conditions occur, so plants that can tolerate them can flourish there.

In addition to soil, what else could affect where plants grow?
It is important for students to realize that where plants grow is not just due to soil, but also to climate and other physical and biological factors. (See page 300 for variables that influence where plants grow.)

What new questions or ideas for investigations do you have as a result of your observations?
As students share their ideas, help them realize that scientists usually have many more questions after doing an investigation than they had to begin with.

Ongoing Assessment

Student Reflections

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

If I was a plant, I'd want to live ____________________ *because...*

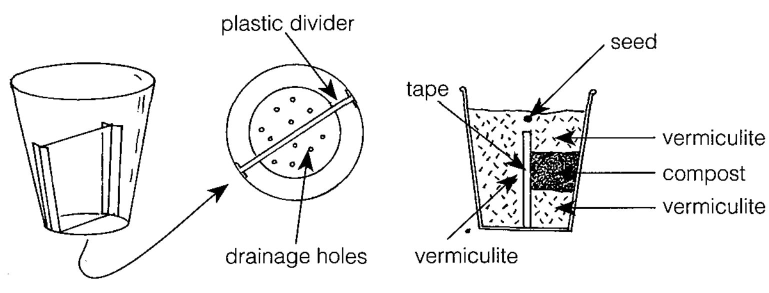
To make perfect conditions for growing garden plants, I would...

Teacher Reflections

- ❑ In what ways did students' prior ideas about soil and plant connections change and grow?
- ❑ Do their data sheets reveal insight into why the soil in different sites might differ?
- ❑ Did they make and record thorough observations?
- ❑ Were they able to use the information they recorded to make generalizations and ask new questions?
- ❑ Do they understand that decomposing plants that become part of the soil benefit living plants by providing nutrients and retaining moisture?

Extensions

Root Races. Have students find out whether roots prefer growing in plain vermiculite, or in a mixture of vermiculite and compost. They can set up this investigation by taping a vertical plastic divider (e.g., plastic wrap) three-quarters of the way up the middle of a clear plastic cup that has bottom drainage holes. They should put vermiculite on one side of the divider, compost with vermiculite (1 part compost to 5 parts vermiculite) on the other side, and vermiculite across the top of both sides. Then students can plant a seed in the center of the cup within the upper layer of vermiculite. As the plant grows, they can compare the volume and length of roots showing through each side of the cup to see which planting medium encourages more root growth. Students will need to cover the sides of the cup with dark paper to keep the roots shaded.



Plant Ups and Downs. Either dig up several plants with their root systems intact, or purchase root vegetables that still have their greens attached. Cut a hole in the bottom of a paper bag for each plant. Place the plants in the bags so that the roots come out through the holes, but the stems and leaves are hidden inside the bags. Have students guess what kind of plant is attached to each type of root. Another way to do this is to cut up pictures of plants, and have students try to match the upper and lower portions of the plants.

Soil Chemistry Tests. Purchase soil chemical test kits, such as for nitrogen, phosphorus, potassium, and pH, through a science supply catalog or gardening center. Students can work in groups to learn to use one type of test kit, then teach the procedures to the other groups. They can test soil samples in different outdoor locations, and/or test compost, vermiculite, and potting soil.

Growth of Plants in Different Soils Test. Have students collect soil from different outdoor locations, then set up a controlled experiment testing the growth of one kind of plant in the different soils.

Perc Tests. In order to have land approved for installing a septic system, soil must pass a "perc" (percolation) test to show that it has good drainage. Students can scope out two or more hypothetical housing sites and do perc tests on soil samples they collect from each. They can put a measured amount of soil in a funnel resting in a jar, then pour a measured amount of water at a constant rate on top of the soil. Students should time how long it takes for water to start dripping out of the soil into the jar, and how much water drips through over time. The soil sample that water flows through most quickly is the best for a septic system. Students can also experiment with how percolation differs when they modify the soil samples by adding materials such as sand, clay, or organic matter.

Mystery Soils. Collect three soil samples that have different textures and colors from an outdoor area. Take students to the area, show them the three samples, and challenge them to predict, and then find, where each one came from.

Biography of a Scientist. Have students do research on a scientist, either by interviewing a local scientist, or by consulting books and articles. They could present the story of that scientist's life and research in creative ways, such as through a scrapbook or diary. Students could also take on the persona of that scientist and be interviewed by their classmates.

Plant Happenings, Above and Below: The Work of Ecologist Dr. Charlie Canham

Dr. Charlie Canham, an ecologist at the Institute of Ecosystem Studies in New York State, has been helping to solve a big problem for electric companies—how to prevent trees from growing under their power lines.

Electric power companies run overhead power lines across miles and miles of land to bring electricity to their customers. In the northeastern United States, in places like New York, trees grow under the power lines. When the trees get so tall that their branches touch the lines and cause the power to short out, the utility company has to stop transmitting electricity.

Utility companies can spray the land under power lines with herbicides to kill tree seedlings. But since many herbicides are bad for the environment, they want to figure out better ways to manage their "right-of-ways"—the strips of land under the power lines. Another option is to cut down the trees, but a lot of hardwood trees sprout back up from stumps, so cutting them doesn't solve the problem.

Dr. Canham and his colleagues have been doing experiments for nearly ten years to figure out what kinds of natural conditions make it difficult for tree seedlings to survive underneath power lines. One of their studies began when Dr. Canham noticed that trees are less likely to grow where the land is covered with SHRUBS—woody plants that don't get as tall as trees. Dr. Canham decided to investigate what prevents trees from growing where there are shrubs, so that perhaps electric utility companies could make this work in their favor.

What do you think might prevent tree seedlings from growing where shrubs are already growing?

Pause for discussion.

Dr. Canham had several ideas. Maybe young trees don't grow well where there are shrubs, because the shrubs shade them so they don't get enough light. Or maybe the roots of shrubs take up so much water and nutrients that new trees can't get enough to survive. Another possibility was that maybe light and root COMPETITION together prevent tree seedlings from getting established in shrub communities.

To test these ideas, Dr. Canham and his colleagues chose two places that were covered with shrubs: 1) a dry site where the soil did not have many nutrients, and 2) a site where the soil had a humus layer, so was moist and had more nutrients.

Dr. Canham set up several plots in each site. In each he planted tree seedlings in the middle of a group of shrubs. In some of the plots at each site, he wired back the branches of the shrubs so the tree seedlings could get full sunlight. In other plots he dug a trench around the tree seedlings, and put down a special fabric to prevent the roots of the shrubs from getting the nutrients and moisture from the soil where the young trees were planted. In other plots he did both treatments: he gave the tree seedlings full sun, and he prevented shrub roots from competing with the young tree roots. Finally, he had a control group of tree seedlings planted in a clump of shrubs where nothing was altered.

Pause to show "Shrub Invaders" overhead, covering Part B with paper.

Where do you predict the tree seedlings would grow the most? The least? Why?

Pause for discussion.

Dr. Canham and his research team measured how much the tree seedlings grew in their study plots during a spring and summer. They found out that on the sites with poor soil, cutting out the roots of shrubs helped the tree seedlings grow better than giving them extra light. In sites with good soil, letting extra light in by wiring back the shrubs helped the young trees grow more than cutting back the roots of the shrubs.

Pause to show Part B of the "Shrub Invaders" overhead.

This information is useful to power companies because now they know that they should take the soil conditions into consideration when planning ways to keep tall trees from growing beneath their power lines.

Dr. Canham and his colleagues have also done greenhouse experiments to figure out what goes on underground in different soil conditions. They called these experiments "Root Races." They wanted to find out if roots of different shrubs and trees can find patches of nutrients in poor soil. Even in poor soil that is low in nutrients, there can be patches of nutrients where an animal died and decomposed, or where a dead log is rotting. Do you think plant roots would be able to find these patches?

Pause for discussion.

The scientists made big boxes in which to plant seedlings. One end of the boxes was wood and the other end had a root observation window made of Plexiglas. When the scientists weren't making observations they kept the window covered, since roots grow better in the dark.

Pause to show "Root Races" overhead, covering Part B with paper.

To set up the experiment, Dr. Canham and his team put sand in each box, and planted a tree or shrub seedling in the middle. In one half of the box they put different amounts of fertilizer, with the most fertilizer in the layer of sand closest to the observation window. This area imitated patches of soil outdoors that are high in nutrients. They didn't add any fertilizer to the sand between the seedling and the wooden end of the box. They kept the boxes in a greenhouse where the conditions were good for growing plants.

As soon as they saw that roots had reached the observation window in a box, Dr. Canham and his colleagues measured how much the plant had grown, and how many roots had grown in each section of sand. They found that the kinds of trees and shrubs that usually grow in soils without many nutrients grew more roots, more quickly, in the parts of the boxes that had the most fertilizer. That means that plants that grow in poor soil are good at finding patches where nutrients are concentrated, and can beat other plants to those patches.

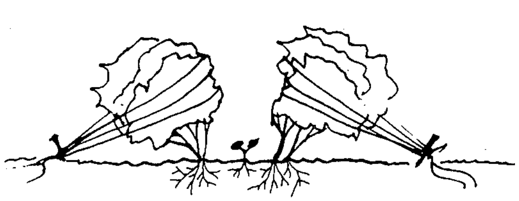
Pause to show Part B of the "Root Races" overhead.

The scientists discovered that the roots of plants that grow in better soil didn't race to patches of good soil as quickly, perhaps because they usually get enough nutrients without having to use extra energy to grow more roots in a certain direction. This information helps utility companies identify which trees are most likely to grow tall and create problems where power lines are in places with poor soil.

The discoveries made by Dr. Canham's research team have helped utility companies and other scientists realize that what happens below ground, where plants get water and nutrients, can be as important in determining where plants can grow as what happens above ground, where plants compete for sunlight. Hopefully this information will help utility companies use the natural processes of plant competition to prevent tall trees from growing under their power lines.

Shrub Invaders

Part A — Experiment Setup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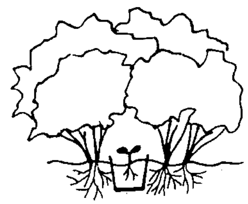
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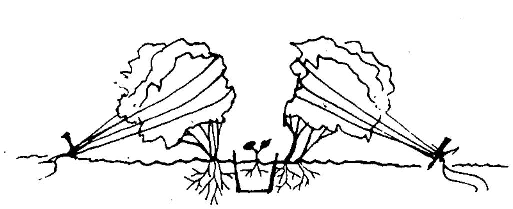
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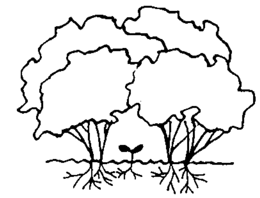
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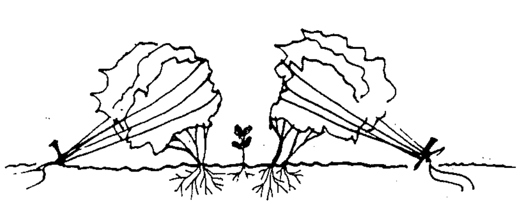
Part B — Results

Poor Soil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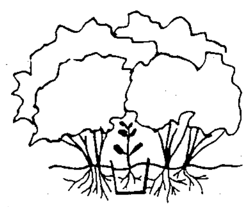
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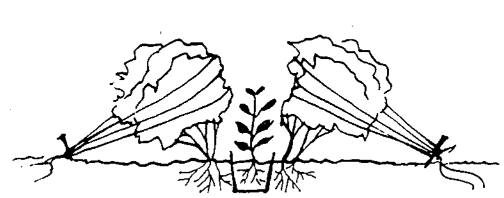
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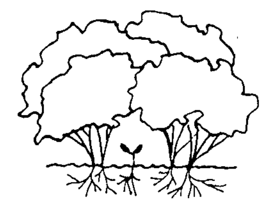
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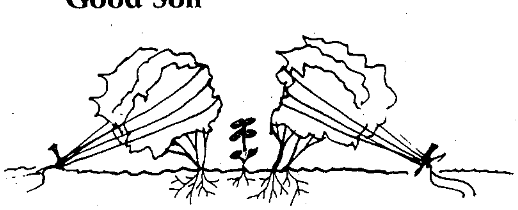
Good Soil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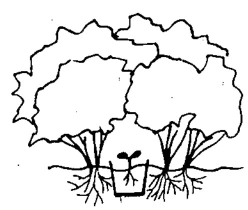
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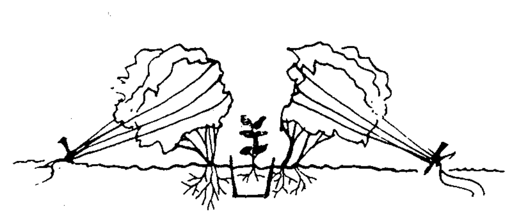
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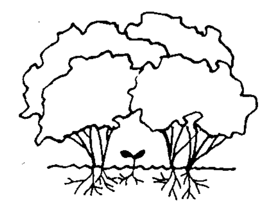
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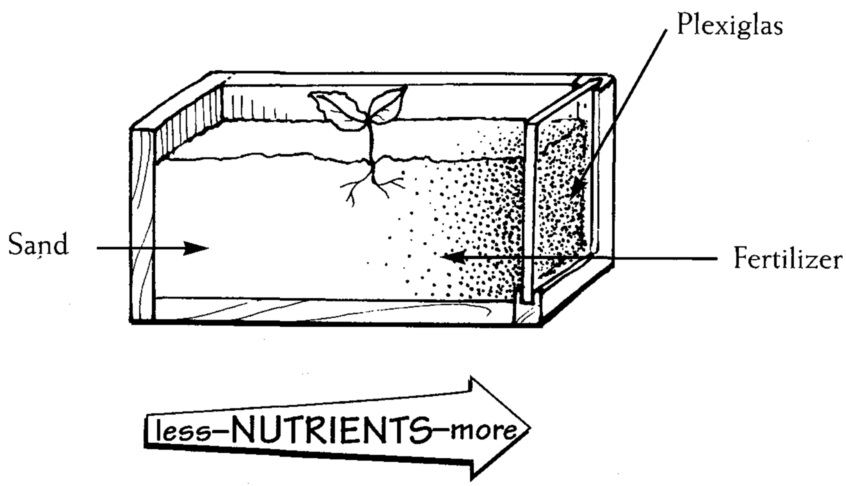
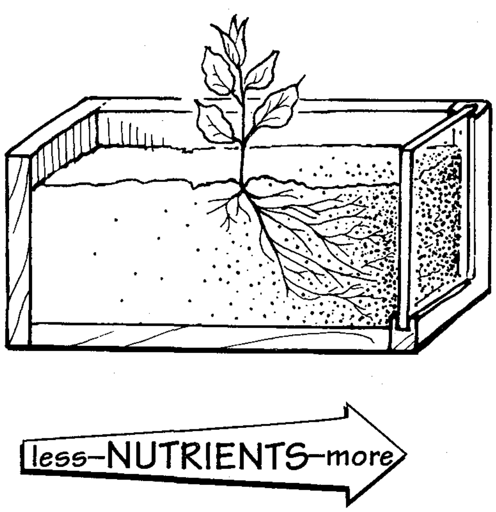
Root Races

Part A — Experiment Setup

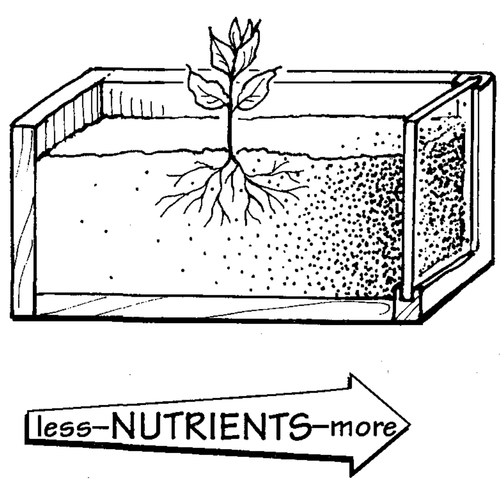


Part B — Results

Plants that grow in low nutrient soil:



Plants that grow in high nutrient soil:



NAME(S)____ DATE______________

PLANT & SOIL CONNECTIONS DATA SHEET

Directions

1. Look for two sites where you think the soil will differ. Give each place a name. Write the names at the top of the two columns.
2. Write a question that you'd like to answer by comparing soils at your two sites:

____

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3. At each site, first fill out Part 1 of the data table.
4. Dig a sample of soil from each site and put them on your tray. Observe the samples.
5. Fill out Part 2 with your observations of the soil.

	SITE #1	SITE #2
	NAME:______________	NAME:______________
Part 1: SITE 1. Describe features of the site that might affect the soil. *(Is it shady or bright? Flat or sloped? Are plants growing there? What types? Many or few? Is there leaf litter on the ground? How deep is it?)*		
2. What do you predict the soil will be like? Why?		
Part 2: SOIL 3. Describe the soil. *(How does it look, smell, and feel? Is it moist or dry? Does it stick together or crumble? Are there roots in it? Are there living things in it? Are there layers?)*		