Where the GRASS is GREENER

Soil is Alive: Soil Microbes and Soil Health

INTENDED AUDIENCE:

6th-12th graders

TIME: 60 minutes + 7-14 days incubation (or use pre-grown plates); not including preparation time, best done over two days.

GROUP SIZE: 5-20 youth

EDUCATIONAL STANDARDS:

- NGSS MS-LS1-1: Conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells.
- NGSS MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- NGSS HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

MATERIALS:

- Local soil samples (1 cup serves ~20 learners; fresh soil is best)

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INTRODUCTION

Soil is more than bits of rock. Soil is a mixture of rock, air, and water, as well as living, dead, and decaying organisms. While soil contains larger organisms, such as insects and earthworms, it also hosts microscopic nematodes, fungi, and bacteria. A handful of soil contains more bacterial cells than the entire human population.

In this activity, youth will explore soil as a living ecosystem by culturing microbes from local soil samples and observing their growth over time. Through a hands-on investigation, they will learn how different types of microbes contribute to nutrient cycling, plant health, and overall soil function. By comparing growth on different agar plates and recording their observations, youth will begin to see how invisible organisms shape the environments that support crops, gardens, and natural ecosystems.

LEARNING OBJECTIVES

- Define the terms microbe, nematode, fungus, and bacteria.
- Explain how microbes contribute to soil health and crop production.
- Compare how different cropping or management practices influence soil microbes.
- Plan and carry out an investigation (culturing and observing microbes) and communicate evidence.

PREPARATION

These instructions are intended for facilitators to complete all advance preparation, including pouring agar and making water-agar plates, to ensure safe handling of heated materials, while allowing youth to participate safely by sprinkling soil onto the plates or having that step completed ahead of time as needed.

1. **How to Make Water Agar Plates**
   Water agar is a simple growth medium that supports fungal growth and makes nematodes easier to spot. It does not support bacterial growth well, which is why this activity uses two plate types.

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- Dissecting microscopes (underlighting preferred), or hand lenses
- Water agar plates (see preparation)
- Petri dishes (100 millimeters by 15 millimeters)
- Agar powder (for making water agar)
- Distilled water
- Heat-safe container (glass bottle, beaker, or flask)
- Microwave or heating plate
- Nutrient agar plates (see preparation)
- Microbe observation sheet (printed, 1 per youth)
- Perennial groundcover infographic; soil microbes infographic (printed or projected)
- Device and Wi-Fi to show a short video
- Parafilm (optional, see preparation)
- Additional cultures (optional, see preparation)
- Optional: Compound microscopes, slides, coverslips, tweezers, dropper water (for wet mounts)

Purchasing Note:

To complete the basic version of this activity, facilitators will need culture plates to start cultures from soil. This process will produce a mixture of organism that grow naturally in soil. To do this, you will need agar and petri dishes, or alternatively, use pre-made plates of nutrient agar or chromogenic agar.

These can be purchased from reputable biological supply companies. Common educational lab suppliers include Carolina Biological Supply, Fisher Science

a. Measure ingredients:
   - In a heatproof container, mix 15 grams of agar powder with 1 liter of distilled water.
   - Choose a container that will be only half full to prevent boiling over.

b. Dissolve the agar.
   - Microwave the mixture on high for 1-2 minutes, or until it begins to boil.
   - Remove carefully, stir, and repeat heating and stirring 3-5 times until all agar is dissolved. Watch carefully to prevent boiling over.
   - Safety Warning: The mixture and steam will be extremely hot. Use oven mitts or towels.
   - Alternative: Heat on a hot plate and boil for 15 minutes, watching closely to avoid boil-over.

c. Allow the container to cool until you can safely handle it, but make sure the agar is still liquid.

d. Pour the plates.
   - In a clean area, pour enough agar into each petri dish to cover the bottom. Avoid creating bubbles if possible.

e. Store properly: Use plates immediately or place them in sealed bags to prevent drying. Water agar plates should be used within a few days for the best results.

2. Nutrient Agar or Chromagar Plates (For Bacteria)

These plates are used because bacteria do not grow well on water agar.

- Nutrient agar plates can be purchased ready-made from biological supply companies.
- Chromagar plates are another option; they cause bacterial colonies to appear in different colors, which can help youth compare and identify colony types.
- No preparation is needed besides labeling and storing them at room temperature until use.

3. Using Parafilm (Optional, Recommended)

Parafilm can be used to seal the edges of petri dishes and retain moisture. It will help the plates last longer if you plan to view them several days after adding the soil. To prepare for the activity, cut thin strips (about 1-inch wide).

4. Incubating the Plates After Adding Soil

Once the youth add the soil to the plates, store them at room temperature, away from windows and direct sunlight. Let them incubate for 7-14 days. If you need something from youth to observe the same day, prepare plates a week earlier. Otherwise, you must return a week later to see the results.

Education, Flinn Scientific, and Ward's Science, all of which offer classroom-safe quantities and materials.

Additional supplies may be required for optional extension activities, which are described later. For assistance with purchasing, contact Maya Hayslett at hayslett@iastate.edu.

RELATED CAREERS:

- **Soil Scientist:** Studies soil composition, microbes, and nutrient cycles to understand how soil supports crops and ecosystems.
- **Microbiologist:** Researches microscopic organisms like bacteria and fungi, including those living in soil that affect plant health and nutrient cycling.
- **Agronomist:** Advises farmers on crop production and soil management practices that improve yield and long-term soil health.
- **Environmental Scientist:** Investigates how soil, water, and ecosystems interact and helps develop solutions to environmental challenges such as erosion or pollution.
- **Plant Pathologist:** Studies plant diseases, some of which are caused by soil microbes, and helps farmers prevent or manage them.

5. Optional: Preparing Additional Microbe Samples

To help youth see a wider variety of microbes, you may want to have additional examples on hand. Consider:

a. Soil from Different Locations: Collect small samples from multiple places, such as a field, farm field, lawn or turf, forest floor, garden, or others. Different soil environments often grow very different microbes.

b. Purchase Microbial Cultures: For an optional extension of this activity, consider purchasing selected cultures of soil microorganisms so youth can observe representatives from different groups firsthand. This allows for direct comparison of various types of soil life forms. See purchasing note for suppliers.

- *Chlorella vulgaris (algae)*
- Diatoms
- *Dictyostelium discoideum (slime mold)*
- *Rhizopus stolonifera (fungus; decomposer)*
- *Fusarium oxysporum (fungus; plant pathogen)*

c. Making Moist Chambers (Do-It-Yourself Mold/Decay Samples) These simple setups support the growth of fungi and other decomposers.

- Fruit: Place soft, fresh fruit, such as berries, in a resealable plastic bag with a damp paper towel. Leave at room temperature for a week or more to allow mold to develop.
- Leaves: Choose leaves with visible spots. Good options include apple, tomato, corn, and soybeans. Place them in a resealable plastic bag with a wet paper towel. Leave at room temperature for a week or more to allow mold to develop.

6. Print Participant Materials

Print a copy of the Microbe Observation Sheet for each youth or pair to record what they see during the activity. If your learning space allows, you may also want to print the two infographics used in the lesson for youth to reference during discussions and observations. These can also be projected on a classroom or meeting room screen with a projector or digital display, making it easier for the whole group to view and discuss the information together.

KEY VOCABULARY

- **Microbe/Microorganism:** A living thing too small to see without a microscope.
- **Bacteria:** Single-celled microbes: some are helpful to people and plants, some cause disease.
- **Fungus/Fungi:** Growing with long threads, these microbes are important decomposers.
- **Nematode:** These tiny roundworms are the most numerous animals on earth.
- **Protist:** Simple microscopic organisms that are not plants, animals, or fungi.
- **Agar Plate:** A shallow dish with gel-like food to grow microbes.

ADDITIONAL RESOURCES:

- USDA Soil Health Website: https://go.iastate.edu/LSMBJA
- USDA Natural Resources Conservation Service Website: https://go.iastate.edu/EXDL3B

- **Culture/Culturing:** Growing microbes in a controlled place (like a plate).
- **Colony:** A visible "spot" that forms when many microbes grow together.
- **Nutrient Cycling:** Movement of nutrients (like nitrogen) through soil and organisms.
- **Decomposer:** An organism that breaks down dead material, returning nutrients to the soil.
- **Pathogen:** A germ that causes disease in plants or animals.
- **Incubate:** Let microbes grow over time under set conditions (room temperature, dark).

DO

Run as two sessions (Parts 1-2, then incubation; Parts 3-4 later) or as a single block with pre-grown plates.

Part 1: Introduction (8-10 minutes)

Ask: "What is soil made of? What lives there?" Build a quick group list that includes rocks and minerals, air, water, and organic matter (living and dead), along with the many kinds of living organisms found in soil.

Watch this short video from BBC Ideas about the importance of soil: https://go.iastate.edu/AXZ3KW. Encourage youth to notice any examples of microbes or soil life mentioned in the video.

Say: "We'll try to see soil life by growing microbes from our soil samples." Connect to crop production by explaining that microbes influence nutrient cycling, plant health, and soil structure, all of which are essential for healthy crops and ecosystems.

Facilitator Tip: Ask participants to name one group of soil microbes and one reason it matters (hands or sticky notes). Aim for bacteria, fungi, nematodes, or protists, and nutrients, plant health, or soil health, as answers.

Facilitator Note: Before moving on to Part 2, take a moment to teach or review the key vocabulary. Making sure youth understand these key terms early will help them recognize what they see later in the activity and make more meaningful observations.

Part 2: Culturing Microbes (15-20 minutes)

1. **Review Key Concepts Before Starting**
   Review the soil microbes infographic as a group.

   Ask: "What are some different types of microbes? How do microbes help plants grow?"
   Highlight that microbes can break down dead material, release nutrients plants need, help roots take up water, improve soil structure, and protect plants from some diseases (depending on the microbe).

2. **Frame Today's Activity**
   Explain that microbes are too small to see with the naked eye, but we can observe their growth by culturing them on agar plates and examining them under a microscope. Tell youth: "Today you will try to culture

(grow) microbes from soil so we can observe some of the living organisms that make soil so active and important."

3. **Introduce the Two Types of Culture Plates**
   Explain that the youth will use two different types of agar because different microbes grow best on different media:
   - Water agar: Supports fungi and makes nematodes easier to see (not great for bacteria).
   - Nutrient agar: Supports bacterial growth and forms visible colonies.

4. **Demonstrate the Culture Procedure**
   Model the steps visually before youth try them:

   a. Label the plate (youth/group name, date, and agar type)

   b. Sprinkle a very small amount of soil onto the surface.
      - Youth should still see clear spaces on the plate.
      - Too much soil prevents colonies from being visible later.

   c. (Optional) Seal plates with parafilm by cutting 1-inch strips, then gently stretching and pressing them around the edges to cover the area where the two plates meet along the outside edge, sealing the two halves together.

   d. Store the plates at room temperature, away from windows or direct sunlight.

   e. Remind young people that plates must incubate for 7-14 days before viewing.

Facilitator Tip: Circulate and ask pairs to explain why a small amount of soil is best. Have one young person point to an area with good coverage, and another to an area with poor coverage.

Part 3: Viewing Water-Agar Plates (10-15 minutes; later session or pre-grown)

Turn on the microscope light and use underlighting if available. Underlighting illuminates the plate from below, making it easier to see clear microbes like nematodes. If the microscope doesn't have this feature, use the top light instead. If microscopes aren't available, you can also use hand lenses or other magnifiers.

Start with the lowest magnification. Place the plate on the stage and look through the eyepieces, gently adjusting the focus knobs until the plate specimen comes into view. If there is too much condensation on the lid, remove it briefly to get a clearer look. Participants can increase magnification and refocus as needed.

Ask young people to look for fuzzy or powdery areas, which are signs of fungal growth. Encourage them to watch closely for movement, as tiny worm-shaped nematodes often wriggle among soil particles. They may also see other organisms, such as protists, amoeba, or small insect larvae.

Have participants record the types of microbes they observe, either as fungi, bacteria, nematodes, protists, or other kinds of organisms, on their observation sheet. This helps them connect visible traits to specific groups of organisms.

Facilitator Tip: Ask pairs to point out one fungal area and explain how they know it's fungi.

Part 4: Viewing Nutrient-Agar Plates (10-15 minutes; same session as Part 3)

Switch the microscope to overlighting (top light), since bacterial colonies show up best when lit from above. Participants should again begin on the lowest magnification to get an overall view of the plate.

Encourage youth to explore the surface slowly. Bacterial colonies often appear as round, wet-looking spots that may be clustered around soil particles or scattered across the agar. On nutrient agar, colony differences are important. Young people should look for differences in shapes, sizes, colors, and textures.

Ask young people to count how many different colony types they can identify. Have them make a quick sketch of at least one colony, focusing on the pattern, outline, or color, whatever stands out most to them.

Facilitator Tip: Have participants share one sentence starting with "Our nutrient agar shows…" to summarize what they observed about microbial complexity.

REFLECT

Ask:

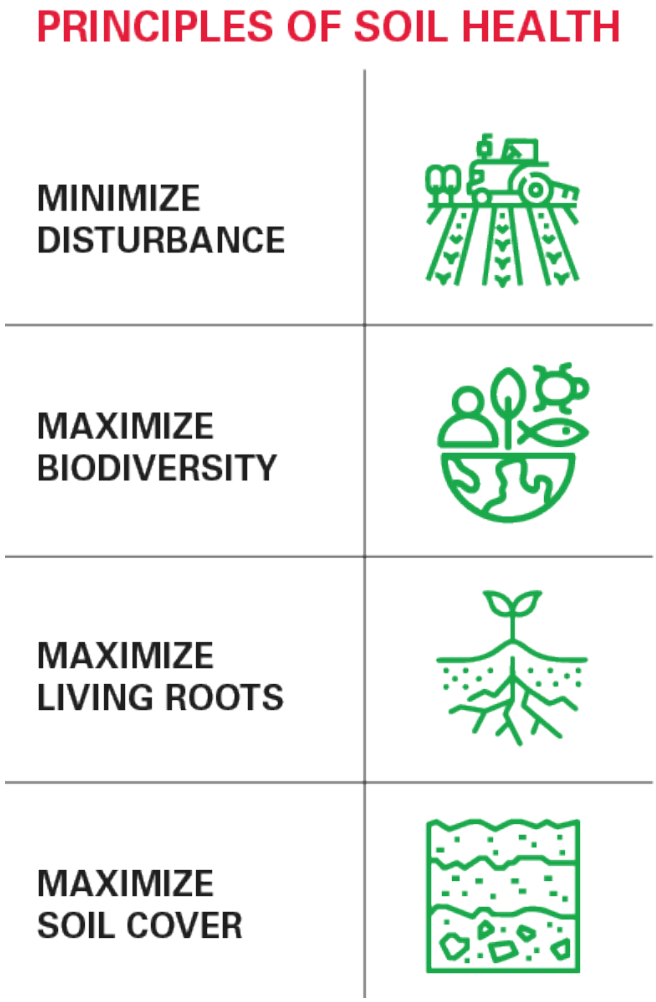
- Why are microbes important?
- Where did you see the biggest differences? Water or nutrient agar? Why might that be?
- How does microbial diversity relate to soil health in your observations?

Answers should include that, generally, a more complex microbial community indicates healthier soil. This means that the more diverse the types of microbes available for growing crops, the better the plants will grow.

Ask: What can be done to keep soil healthy?

The National Resource Conservation Service suggests four ways to protect soil health:

1. Minimizing Disturbance: This involves reducing physical disruption to the soil, such as tilling or heavy machinery use, to minimize soil compaction. Less disturbance helps preserve soil structure, microbial life, and organic matter—essential for long-term fertility and erosion prevention.
2. Maximizing Biodiversity: Incorporating a variety of plants, animals, and microorganisms into the ecosystem supports a balanced soil food web. Biodiversity enhances nutrient cycling, pest control, and disease resilience, making the soil healthier and more productive.
3. Maximizing Soil Cover: Keeping the soil covered with plants, mulch, or crop residue protects it from erosion, water loss, and temperature extremes. It also reduces weed pressure and supports beneficial organisms by maintaining a stable environment.
4. Maximizing Living Roots: Maintaining living roots in the soil year-round—through cover crops or perennial plants—feeds soil microbes and improves soil structure. Living roots help retain nutrients and water, while also preventing compaction and erosion. Conservation practices, such as perennial groundcover, cover crops, reduced tillage, no-till farming, and crop rotation, help keep the soil healthy, allowing it to continue producing food, fuel, and fiber.



APPLY

To connect their learning to real-life experiences, ask youth to consider where they might encounter soil microbes or soil health challenges beyond this activity. Invite them to reflect on how the ideas they explored today show up in gardens, farms, parks, yards, forests, or other places where plants grow. Encourage them to share examples from their own lives, maybe they've seen garden soil dry out quickly, watched plants struggle to grow, or noticed differences in soils from different locations. These are all situations where soil microbes play an important role.

Prompt youth to consider how they might use what they learned in similar or different situations. For example, ask:

- How could knowing about soil microbes help you take care of a garden or houseplants?
- If you were helping on a farm or in a community garden, what practices could improve soil health based on what you learned today?
- How might land managers, farmers, or conservationists use information about soil microbes when making decisions?

OPTIONAL EXTENSION ACTIVITIES

If time allows, consider these:

Explore Other Microbial Cultures: If you have additional cultures available, such as fungi, protists, algae, or microbial samples prepared earlier, invite youth to examine them and compare what they see to the microbes on their own plates. Encourage them to identify the types of organisms present, noting similarities or differences in appearance, texture, or movement.

Use Compound Microscopes for Closer Observation: If compound microscopes are available, youth can create wet-mount slides from their culture plates to view microbes at higher magnification. Begin by modeling how to make a proper slide: place a small drop of water on a slide, then use tweezers to collect a tiny sample from the culture: just large enough to see, but not too big. Gently place the sample in the drop of water. Add a cover slip, making sure it lies flat; if it rocks or tilts, the sample is too large and needs to be reduced.

Once the slide is prepared, participants can observe it using the compound microscope. Have them start with the lowest magnification, center the sample under the lens, and then slowly adjust the focus. They may need to move the slide slightly to locate the organism of interest. Once they have a clear image, they can increase magnification and refocus to view finer details such as hyphae, bacterial clumps, or nematode movement. After observing, youth can compare their findings with a partner and discuss any differences they notice between their slides and the slide and what they saw on the agar plates.

ASSESSMENT

Choose one commonly found soil microbe, such as a fungus, bacterium, nematode, or protist, and research its role in the soil ecosystem. Write one well-developed paragraph that explains what type of organism it is, what it eats, and how it interacts with other organisms in the soil, including whether it is helpful or harmful to crop production and why. Include two photos or labeled drawings that show what your microbe looks like or how it functions in the soil.

After your research paragraph, write a short, creative piece titled “A Day in the Life of a Soil Microbe.” Use what you learned from your observations and research to describe what your microbe experiences underground, including where it lives, how it finds food, what challenges it faces, and how it helps (or affects) plants. Your story should show accurate scientific ideas while imagining what life might be like from the microbe’s point of view.

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Microbe Observations Worksheet

Water Agar Plates

Without a microscope, you may see things that are fuzzy or powdery. This is fungal growth. If you see slimy areas or round wet spots, that is bacterial growth.

Look for movement. If you see worm-shaped organisms, these are likely nematodes. You may also see tiny insect larvae, amoeba, or other organisms.

To use the dissecting microscope:

- Turn on the microscope's light. If the microscope has underlighting (that shines up from the bottom of the stage), turn that on and leave the overlighting off. If it does not have underlighting, use the top light instead.
- Set the magnification to the lowest setting.
- Place the plate on the stage. You may be able to see the culture through the lid, but if there is a lot of condensation, you may need to remove the lid.
- While looking through the eye piece, turn the focus knobs to bring the specimen into focus.
- You may now increase the magnification if you wish and refocus as needed.

List the types of microbes you observe on the water agar plates (fungi, bacteria, nematodes, protists, or you may see other kinds of organisms).

Nutrient Agar Plates

You will likely see round wet spots around or separate from the soil particles. With or without the microscope, examine the bacterial colonies on your plate. Use the overlighting on the microscope.

How many different types of colonies (shape, size, color, texture) do you have?

Draw one or more colonies you saw.

Compound Microscopes (optional)

Examine the microbes more closely by creating a slide and using a compound microscope. Use one of the culture plates to take a sample.

To make a wet mount slide:

1. Place a drop of water on a slide.
2. Use tweezers to take a small sample of the culture. The sample should be just large enough to see with the naked eye, but not much larger.
3. Place the sample in the drop of water.
4. Place a cover slip on top. If the cover slip will not lie flat, your sample is too large.

To observe using a compound microscope:

1. Turn on the light.
2. Set to the lowest magnification lens.
3. Place the slide on the stage and position it so that the sample is centered under the lens.
4. While looking through the eye piece, turn the focus knobs to bring the specimen into focus.
5. You may need to move the slide around to find the specimen. Clip the slide in place when it is in the proper position.
6. You may now increase the magnification if you wish and refocus.

List types of microbes you observed (fungi, bacteria, nematodes, protists, or you may see other kinds of organisms).

Share your observations with a partner. Did they find anything different than you?

Benefits to the Environment

Pest Control: Perennial ground cover can be habitat for beneficial insects that prey on crop pests.

Reduced Soil Erosion: Ground cover holds soil in place and reduces erosion. More water, nutrients and carbon in the soil: by increasing the amount of living and decomposing soil, perennial ground cover improves soil so more water, nutrients, and carbon are kept in the soil.

Better Microbe Activity: Improving soil health also supports important microbes in the soil that are benficial to crops.

Better Water Quality: By reducing erosion and increasing nutrients held in the soil, perennial ground cover can reduce pollutants entering waterways.

Benefits to People

Less Management: Less management and cost of management as compared to other cover crop systems.

More Ecosystem Services: Better soil nutrients and pest control can mean less cost for things like pesticides.

Reduced Flood Risk: Communities could have less damage and loss from flooding.

Better Air and Water Quality: A healthier environment for people with less water and air pollution.

More water held in the soil.

More nutrients held in the soil.

More carbon held in the soil.

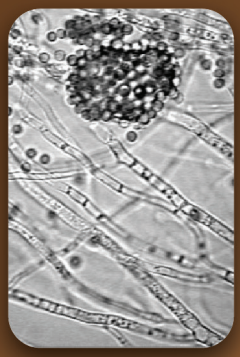
KNOW YOUR

Soil Microbes

Fungi

Microscopic strands growing in the soil and in and around roots

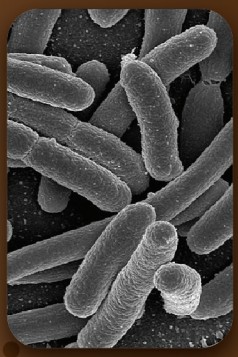
You may see mushrooms which produce spores (like seeds) for reproduction



Bacteria

Single-celled organisms

Some cause disease but some are beneficial as decomposers or plant symbionts



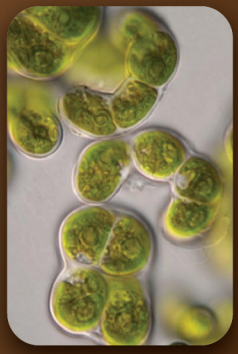
Nematodes

Microscopic animals

With many different species, they eat a variety of things in the soil including bacteria and plants

Protists

Protists are a diverse group of organisms including algae, diatoms, amoeba, water molds and many other microscopic living things in the soil



How soil microbes can benefit plants

- Decomposers that eat dead organisms, returning nutrients to the soil for plants to use
- Symbiotic microbes that live on or in plants providing them with additional nutrients
- Protectors that eat or inhibit harmful organisms like pathogens or herbivores