****

**Alaska Indoor Gardening Curriculum**

**Biological Fertilizer Lesson**

**Author/Source(s):** Laura Weingartner, Scott Faulkner

**Suggested Grade Levels:** 6-12

**Time:** 3 hours over two days

**Teaching Goals:**

To introduce students to a forest- or tundra-based fertilizer “Memetic Onetai” and give them a better understanding of how microbes benefit plants

**Learning Objectives:**

Students will gain a better understanding of what microbes are

Students will learn what plants need that microbes help them get

Students will be able to describe the role of decomposers in nutrient recycling and their importance in maintaining the flow of energy through an ecosystem.

Students will be able to compare modern farming practices with what happens in nature

Students will practice making observations and interpreting those observations

**Core Ideas:**

* Nutrient Uptake
* Plant nutrient needs
* Decomposers
* Agriculture
* Fertilizers
* Organic vs. Commercial Fertilizers
* Plant Dynamics (circulation and nutrient uptake)
* Decomposition of Vegetation
* Composition of Compost (Macro and Micro Organisms, Oxygen and Aeration, Temperature)

**Alaska Science Standards:** MS-LS2-3, LS2.B, MS-LS1-5, LS1.B, MS-LS2-4, MS-LS2-1, HS-ESS3-4

**NGSS Standards:** MS-LS2-1, MS-LS2-3, ESS3.C

**Materials Needed:**

Initial Batch Ingredients & Materials – 14-day brewing process

* 500g (2 cups) Health biologically active soil from near school
* 200g (7 oz) Fresh-cut green plant material (i.e., lettuce, kale, chickweed) (~2 fistfuls of leaves)
* 15L (4 gal) Fresh water
* 5-gallon bucket
* Blender
* Airline
* Pump
* Aerating stones
* Classroom hydroponics system/ classroom plants/ set-up for seed propagation
* Liquid bleach
* Scale
* pH strips (optional)
* Thermometer (optional; pool thermometer is recommended: can live inside the bucket)

Booster Ingredients- add every 14-28 days (add more often during heavy use)

* 250g (1 cup) Health biologically active soil from near school
* 100g (3.5 oz) Fresh-cut green plant material (~1 fistful of leaves)
* Add fresh water as needed to maintain 15L (4gal)

**Vocabulary:**

1. *Nutrient Cycling*: the cyclic flow of nutrients in an ecosystem by which nutrients are moved from the physical environment, into living organisms, and the recycled back into the physical environment.
2. *Hydroponics*: A method of growing plants in water without soil, by providing plant roots a consistent complete nutrient mixture in water.
3. *Macronutrient*: a nutrient required by living organisms in large amounts. For plants these include carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, calcium, and potassium. Carbon, hydrogen, and oxygen are obtained from air and water while the others are obtained from the soil
4. *Microbe*: a blanket term literally meaning “small life” that could refer to many organisms from various groups. The most common types are bacteria, fungi, and viruses. There are also microbes called protozoa.
5. *Fertilizer*: any substance that is added to soil (or water) that promotes plant growth
6. *Food web*: a system of interdependent and overlapping food chains showing feeding relationships within an ecosystem or a community
7. *Aerobic*: requiring air or oxygen to survive. Aerobic bacteria require oxygen to live.
8. *Anaerobic:* living in the absence of oxygen, or not requiring oxygen. Anaerobic bacteria can survive and grow in environments with no oxygen.
9. *Primary producers*: organisms that produce their own food/organic matter from light energy (i.e., plants and algae). Also known as autotrophs
10. *Consumers*: organisms that cannot produce their own food and must eat plants and/or animals for energy. Also known as heterotrophs. There are primary, secondary and tertiary consumers depending on their place along the food chain.
11. *Decomposers*: organisms that eat dead plant, animal, or microbe matter, breaking down tissues and converting them into simpler organic forms. Thus, decomposers are a crucial part of the nutrient cycle because they make important nutrients available to an ecosystem’s primary producers.
12. *Limiting factor*: Any variable in an environment that constrains a population’s size and slows or stops it from growing

**Background for Teachers:**

Plants need LAWNS to survive: Light, Air, Water, Nutrients, and Space. They receive most of their nutrients from the soil. Wild plants rely on decomposers to break down organic matter returning nutrients to the soil that the plants can then use. Many farmers and gardeners rely on fertilizers- some of which also use decomposers. Plants require 17 different essential elements for successful growth and reproduction. Some, like carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium are considered macronutrients because plants need them in relatively large quantities. The eleven other minerals are needed in much smaller amounts and are considered micronutrients. These elements exist in the natural world, and are recycled, meaning they are used by primary producers, eaten by consumers, and eventually returned to the soil by decomposers.

These elements are also part of commercial fertilizers, which are either mined (mineral fertilizers), produced through chemical reactions (industrial fertilizers), or made from manure and compost (organic fertilizers). Decomposers are an important part of nutrient recycling in the wild and in organic fertilizers.

Decomposers feed on dead plant material, dead animals, dead fungi, and animal waste. Some decomposers are specialists only feeding on a certain kind of dead organism and some are generalists, breaking down many different types of materials. Many different types of organisms are decomposers including bacteria, fungi, and protozoa. All of these are considered microbes.

Bacteria are single-celled organisms that can live on their own and are found almost everywhere on earth. A very small percentage of bacteria (<1%) can cause diseases in humans. Fungi can also live in many different environments. Some well-known fungi include yeast, mold, and mushrooms. Protozoa (or protists) are mainly unicellular, but there are also some multicellular protists such as kelp. Protists generally require a moist habitat and are found in any body of water even hot springs and hypersaline lakes. There are parasitic protists, such as the protist that causes the disease malaria, but many are free-living that feed on organic matter, often feeding on bacteria. Bacteria, protozoa, and some types of fungi can only be seen under a microscope, while many types of fungi can be seen with the naked eye

Bacteria, fungi, and protozoa are important soils microorganisms due to their role in nutrient cycling. They are the characters that provide the natural world its “fertilizer.” All the nutrients the plants in the forest use are continuously recycled because of these decomposers. Modern agricultural practices have a different approach because they are trying to grow lots of food to feed our population.

Nutrient availability are often the limiting factor for plants to be able to grow in an area. To be able to grow lots of plants in a limited amount of space, farmers add fertilizer to their soil. There are many different varieties of fertilizer but most contain nitrogen (N), phosphorus (P) and potassium (K), which are macronutrients for plants. Farmers are harvesting most of the plants they grow, so dead plant matter isn’t always available to be decomposed, so nutrients aren’t returned to the soil. This means farmers need to add fertilizer to their soil every growing season.

Both crops and wild plants are affected by pests, which can be bacteria, fungi, protozoa, and invertebrates like insects and slugs. Farmers often spray their plants with pesticides to prevent these microbes and other pests from harming their crops. Spraying removes both the harmful and the beneficial microbes. Because these microbes are killed by the pesticides, they are not decomposing organic matter and returning nutrients to the soil.

Modern agricultural practices require a lot of input from farmers, while wild ecosystems recycle all their nutrients, and don’t require outside interference. This means the soil in the wild is teeming with “good” microbes. We want to use these microbes to decompose plants and use that as fertilizer, mimicking the way it happens in nature (Memetic Onetai).

**Signs of a healthy Memetic Onetai system**

Students should be able to use their senses to tell whether the Memetic Onetai system is healthy and useable.

* Smell: The majority of microbes need oxygen to propagate, so a stinky system means anaerobic bacteria have been able to thrive, while a nice forest-floor smell signals the system is healthy and nicely aerated.
* Sight:
	+ Foaming & Frothing: the system should by foaming soon after feeding it. This is a sign that the microbes are breathing, growing, and reproducing.
	+ Color: should be a strong ice-tea color .
		- Too dark: it likely overfed and the microbes aren’t decomposing all the food available.
		- Too light: there’s not enough food and the microbe colony is reducing.
	+ Chunks: There should not be large organic pieces floating in it. No whole leaves or anything bigger than a pea: those items won’t decompose fast enough to be useable and might clog hydroponic pipes.
* Listen for whether the air pump is on: the microbes need air to survive

Students can also measure other aspects of the solution to gain practice interpreting results.

* pH: The pH should be slightly \_\_\_\_\_ (acidic or basic). (Optional activity: compare pH levels of fertilizer solution to pH levels of collected soil. Should be similar to provide an ideal environment for the microbes)
* Temperature: different microbes can handle different temperatures….

**Advantages and disadvantages of modern farming methods**

|  |  |
| --- | --- |
| Advantages | Disadvantages |
| High yields: farms can feed a lot of people in a small space by eliminating competition for nutrients Efficient: applying fertilizer is fast and less labor intensive compared to using compost or allowing natural processes to take place | Loss of biodiversity due to pesticide use, and the common practice of monocultureEnvironmental impact: there can be negative effects due to fertilizer and pesticide use. High cost: requires investments in regular inputs |

**Procedure:**

**Activity One: Making and maintaining Memetic Onetai fertilizer**

1. Have students read ahead of time “[Who Feeds the Plants? Microbes](https://kids.frontiersin.org/articles/10.3389/frym.2021.604096)!” to get some background on soil microbes.
2. Start with a conversation about agricultural systems vs. the forest (or tundra depending on area). We get food from both places, but farms and even gardens often require a lot of input in the form of fertilizer, while wild areas have their own system of recycling nutrients.
	1. Ask students what does fertilizer provide plants (nutrients)
	2. Ask students why they think the forest/tundra does not need fertilizer (plant and animal matter are broken down by microbes to restore nutrients to the soil)
3. Explain what microbes are (fungi, bacteria) and that the ones plants rely on live in soil.
	1. Ask students how do the plants in the hydroponics system get nutrients if there isn’t soil? (presumably, they are adding nutrients to the water from commercial fertilizer?)
	2. Discuss the advantages and disadvantages of using of commercial fertilizer. Have students make a list on their own, or make a list together as a class. Ask students to think about how their classroom can mimic the forest outside.
4. Making the Memetic Onetai system
	1. Collect microbes: dig up soil from near the school
		1. Find a mostly wild place near the school (not too near roads, away from agricultural land, preferably in the forest or tundra).
		2. Remove vegetation mat and organic layer (refer to soil cross-section). Collect at least 4 cups (up to ~1/2 gallon) of “rich” soil
		3. Remove major roots from soil collection
	2. Prepare water: remove pathogens that could harm your beneficial microbes
		1. The day before, take 4 gallons of water and add 2 teaspoons of liquid bleach (0.5 tsp bleach per gallon of water)
		2. Allow the bleach to off gas from your water for at least 30 minutes (recommended to do this the day before)
		3. This can be skipped if using city water
	3. Prepare food for the microbes: blend plant matter with prepared water
		1. Use chickweed, clover, arugula, or other greens that are easy to grow or you have easy access to
		2. Add 200 g of green plant matter to a blender. Blend with prepared water until there are no chunks (which could clog pipes in hydroponic system)
	4. Prepare bucket: Clean it and add everything
		1. Use a new bucket, or one without scratches in it. Clean with any cleaning product (i.e. bleach, vinegar/baking soda). Then rinse well.
		2. Make a permanent mark at the 4-gallon line (this can be approximate)
		3. Add air stones to the bottom of the bucket and hook up tubing to pumps to ensure constant air flow
		4. Add soil, blended plant matter, and the rest of the 4-gallons of water
5. Maintaining Memetic Onetai system
	1. Regularly feed your microbes with booster packs: 250g of soil + 100g blended fresh-cut green plant. Add this to the system every 2-4 weeks depending on how often you use it (feed more often if you are regularly using the fertilizer)
		1. These can be made ahead of time when you make your original microbe food and frozen
	2. Clean exposed surfaces if films start to form
	3. Add disinfected water as needed to keep level at ~3 gallons.
6. Use your senses to know if the system is healthy!
	1. Ask students to make observations 1-3 days after first making the “fertilizer” (or after adding a booster pack) and record what they see, smell, and hear. Discuss how you know if the system is healthy (in background information)
	2. Have students reflect on their observations and write about what each observations means
	3. Students could observe daily for a few days, then do a write-up where they reflect on their observations and data collection and explain what environmental conditions they observed seem to be most hospitable to microbe growth and activity.

**Activity Two: Using the Memetic Onetai solution**

1. Apply the fertilizer
	1. to the hydroponics system at 1:16 ratio, or 1 cup of Memetic Onetai solution for every 1 gallon of water, or 1 Tbsp solution for every 1 cup water
		1. Opportunity for experiments here to see if plants respond differently to the forest fertilizer vs commercial
		2. Could use plant and root growth monitoring charts from the Hydroponic Plant Growth Lesson to track plant changes
	2. Apply it to seeds by spraying them with the full-strength fertilizer
		1. Opportunity for experiments here to see how it affects seeds: put on at different rates, different timing, different types of plants etc.
2. Draw a food web, include producers, consumers, and decomposers
	1. Have students include at least primary and secondary consumers (i.e., tundra microbes, willows, caribou, wolves, microbes).
	2. Have students show major nutrients being transferred between groups.

**Activity Three: Discover microbes under the microscope**

1. Lesson in using microscopes, preparing slides, staining, and identifying different types of microbes
2. Look to see if things are moving: is my tea alive? How active is it?
3. Draw what you see: ID it as fungus, bacteria, protists, or something else

**Extensions:**

* [Hydroponic Plant Growth Lesson](https://www.fairbankssoilwater.org/user-files/Hydroponic%20Plant%20Growth%20Lesson.docx)
* [The Right Diet for Your Plants Lesson](https://agclassroom.org/matrix/lesson/346/) by National Agriculture in the Classroom

**Cross Curricular Ideas:**

* Have students listen to an episode of Teaming with Microbes with Jeff Lowenfels podcast and summarize the main points in a one-pager. <https://podcasts.apple.com/us/podcast/teaming-with-microbes/id1680963208>
* Connect the information about microbes to human/animal bodies/diseases
* Talk about human nutrition and what nutrients we need, and how microbes help us get those nutrients
* Collect soils from different habitats (i.e., tundra vs black spruce bog vs birch forest). Compare the fertilizer solutions: smell, frothiness, color, effectiveness on plant growth to gain a better understanding of how different microbes live in different habitats
* Use this as a jumping off place to talk about nitrogen fixing bacteria, and/or mutualistic relationships (and other symbiotic relationships).
* Fungi are important decomposers and there is lots of interest in mushrooms across pop-culture. Consider having a mycologist or mushroom-enthusiast lead students in a mushroom walk and talk about the different roles fungi have in the environment (and in human lives).
* In a Time of Change (ITOC) Microbial Worlds: Virtual exhibition: relevant and amazing example of science and art crossover. Artwork can be seen here: <https://itoc.alaska.edu/mc-art-work/> . Have students use this lesson and the ITOC art as inspiration for their own art.
* Take a field trip to a waste water plant. Have students compare what the microbes are doing in their fertilizer solution to the microbes used in waste water treatment.

**Assessment:**

1. Assess their food webs for accuracy
2. Review their observations and interpretations
3. Assess their experiments: review the data they collected and the conclusions they drew

**Resources**

**Books:**

Teaming with Microbes: The Organic Gardener’s Guide to the Soil Food Web by Jeff Lowenfels & Wayne Lewis

The World of the Microscope: A Practical Introduction with Projects and Activities by Chris Oxlade

**Podcasts:**

[Teaming with Microbes](https://podcasts.apple.com/us/podcast/teaming-with-microbes/id1680963208) with Jeff Lowenfels. Some especially relevant episodes:

* Soil food web season
* Soil microbes and early preparation
* Superheroes in the soil
* Unlocking the secrets of essential plant nutrients,
* Time to garden with science and the soil food web
* Soil food web critters with an emphasis on fungi
* Navigating the Spring soil food web

**Websites:**

Who Feeds The Plants? Microbes! <https://kids.frontiersin.org/articles/10.3389/frym.2021.604096>

Is Too Much Fertilizer a Problem? <https://kids.frontiersin.org/articles/10.3389/frym.2020.00063#:~:text=Fertilizers%20provide%20crops%20with%20nutrients,of%20every%20organism%20on%20Earth>.

**Analysis of the solution: is it healthy?**

Date of observation\_\_\_\_\_\_\_\_\_ Days since feeding\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |
| --- | --- | --- |
|  | **Observations and biological data** | **Interpretations: what do your observations and data tell you about the environment the microbes are living in? What do they tell you about how the microbes are doing?** |
| Smell |  | Does it smell good or bad? What does the smell indicate? |
| Appearance |  | Are there any signs of life that you can see? What does the color indicate? |
| Sound |  | Are there sounds indicating the system is working the way it is designed to? What do these sounds tell you about microbes? |
| pH |  | Is the pH level acidic or basic? Do you think these microbes could survive in an environment with a different pH? Compare your pH levels to that of the soil you dug up. |
| Temperature |  | Think about where these microbes came from: what kind of temperatures do you think these microbes can survive? What temperature does it seem like they thrive in? |

Write a paragraph below summarizing the environmental conditions you’ve observed seem to be most hospitable to microbe growth and activity.