

# The Role of Microorganisms in the Ecosystem

Below is an overview of the activity [The Role of Microorganisms in the Ecosystem](#) (American Society of Microbiology, Mark Gallo and Shannon Ventresca) to incorporate information learned from Dr. Kerkhof's presentation and subsequent discussion.

## Lesson Overview

Students use a controlled experiment to demonstrate different rates of decomposition for a variety of man-made and natural materials.

## Lesson Rationale

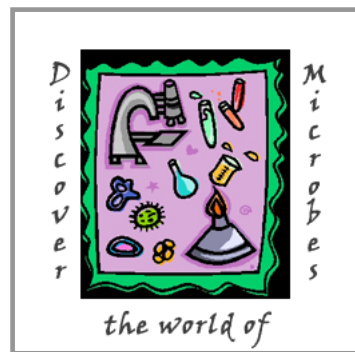
Microorganisms are ubiquitous in the environment, where they have a variety of essential functions. Microbes play an essential role in the natural recycling of living material. All naturally produced substances are biodegradable, which means that living organisms, such as bacteria or fungi, can break them down. Composting is an example of biodegradation that is easy to investigate in the classroom.

## Key Concept

Students will learn how to determine the rate of decomposition for each selected variable (material) based upon their data and how to compare and contrast the nutritional requirements for microbes and humans.

# Microbial Discovery Activity

## The Role of Microorganisms in the Ecosystem



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### Intended Audience

K-4	X
5-8	X
9-12	X

### Activity Specifications

Classroom setting	X
Requires special equipment	
Uses hands-on manipulatives	X
Requires mathematical skills	X
Can be performed individually	X
Requires group work	
Requires more than one (45 min) class period	X
Appropriate for special needs student	X

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MICROBIOLOGY

# Introduction

## Description

This activity uses a controlled experiment to demonstrate different rates of decomposition for a variety of man-made and natural materials.

## Abstract

Microorganisms are ubiquitous in the environment, where they have a variety of essential functions. Many microbes are uniquely adapted to specific environmental niches, such as those that inhabit the Dead Sea (*Halobacterium*), the bacteria and cyanobacteria that inhabit the boiling water springs in Yellowstone National Park, and *Chlamydomonas nivalis*, the algae that causes "pink snow." Microbes also play an essential role in the natural recycling of living materials. All naturally produced substances are biodegradable, which means that they can be broken down by living organisms, such as bacteria or fungi. Composting is an example of biodegradation that is easy to investigate in the classroom. An examination of conditions that foster or impede composting gives insight into growth conditions of microorganisms as well as the proper function of the ecosystem.

## Core Themes Addressed

Microorganisms and Humans

Microorganisms and the Environment

## Keywords

Bioremediation: the use of microorganisms to remove or detoxify undesired or toxic chemicals from the environment.

Bioaugmentation: the addition of necessary nutrients required to speed up the rate of degradation of a contaminant.

Xenobiotic compounds: compounds that are chemically synthesized and do not exist naturally.

Microbial plastic: a product produced by microbes that is an alternative to plastic, having similar qualities but is biodegradable.

## Learning Objectives

At completion of this activity, the learner will:

1. Understand the steps used in a controlled experiment.
2. Describe the variables in this experiment.
3. Analyze the data by determining the rate of decomposition for each material.
4. Compare and contrast the nutritional requirements for microbes and humans.

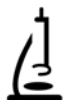
## National Science Education Standards Addressed

This lesson is aligned with the following National Science Education Standards:

**Standard 1:** Science as Inquiry - In completion of this activity, students develop skills related to conducting experiments and understanding scientific inquiry. Students complete a procedure and make observations regarding the role of microbes in the environment.

**Standard 3:** Life Science - In completion of this activity, students will discover the effect of microbes on biological systems in terms of the breakdown of garbage/waste.

**Standard 5:** Science and Technology – At completion of activity students will understand that biotechnology in its most general form is humans using the biological world for its particular purposes and hence composting is an example. More efforts have been made in the area of biodegradation of materials especially in light of the genetic revolution.

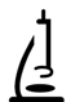


**Standard 6:** Personal and Social Perspectives-This lesson will aid students in developing understanding populations, resources, and environments. Also, students will develop understanding of the impact of our garbage on the environment, and relate it to the potential use of microbes as a beneficial aid in the breakdown of waste materials.

**This lesson is aligned with the following New York State Learning Standards:**

**MST Standard 4:** The Living Environment, KI 6, PI 1-Students will complete activities in which they discuss the flow of energy through food chains and food webs, more specifically the use of microbes to degrade material humans consider garbage.

**MST Standard 4:** The Living Environment, KI 7, PI 1-Students will identify the effects of human decisions on the environment. In this activity students will examine the process of composting using natural, microbial aids



# Teacher Handout

## The Role of Microorganisms in the Ecosystem

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### Necessary Student Background

Students should have prior knowledge of the concepts of landfills, compost piles, and an overview of bioremediation. This lesson will further investigate the concept of bioremediation, and how microbes can be beneficial in the maintenance of our environment.

### Teacher Background Information

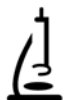
The term **bioremediation** is defined as the use of microorganisms to remove or detoxify undesired or toxic chemicals from the environment. While it was an unfortunate incident from the environmental and economic perspectives, a tremendous amount was learned about bioremediation from the Exxon Valdez oil spill in 1989. When the supertanker ran aground near Prince William Sound, Alaska, 11 million gallons of oil spilled into the water and washed onto the beaches. Through experimentation, scientists found that spraying the affected areas with non-organic nutrients, selected for the naturally occurring microorganisms that could degrade oil and resulted in an increase in the numbers of those cells and an increased rate of degradation.

**Bioaugmentation** is defined as the addition of necessary nutrients required to speed up the rate of degradation of a contaminant. Oil is rich in carbon and sulfur, but the organisms capable of degrading it also require nitrogen, phosphorous and oxygen as well as a number of other micronutrients. The addition of nitrogen and phosphorous in the form of fertilizer and the churning of soil or water to provide oxygen greatly speed the rate of clean-up of certain materials. The cost of the Valdez clean-up is estimated at \$1.5 billion. A spill of that magnitude required human as well as microbial clean-up. While microorganisms are very effective at degrading naturally occurring substances, they have even been shown to effectively degrade some **xenobiotic** compounds, those that are chemically synthesized and do not exist naturally. Herbicides and pesticides are common xenobiotics that contaminate the environment. A sulfate reducing bacterium *Desulfomonile* has been associated with the degradation of chlorinated pesticides. This is of great interest to environmentalists, since chloro-aromatic compounds are among the most frequently detected groundwater contaminants in the United States.

Studies of rates of biodegradation indicate that many synthetic polymers are not degraded by microorganisms and remain unchanged in landfills for decades. This knowledge has led progressive companies to utilize microbially produced, therefore biodegradable, alternatives to synthetic polymers such as plastics. The Wella company in England markets shampoo packaged in a bottle made of **microbial plastic**. Microbial lipid storage compounds can be regulated by controlling growth conditions to yield products with the desired qualities. Students might enjoy a study of packaging substances to determine if any are naturally produced and hence biodegradable.

### Class Time

This lesson requires one 45+ minute period to set up the experiment. Time must be allowed for examining the progress of the composting over a period of 4-12 weeks. This is a long-term experiment.



## Teacher Preparation Time

This lesson requires approximately 15 minutes to set up all of the materials for the class.

## Materials and Equipment

- Plastic flower pot or large cup
- Spoon or trowel
- Soil (from a variety of sites is best)
- Labels (marker pen, toothpicks and papers, etc)
- Items to bury (anything will do; pieces of apples, potatoes, oranges, etc.; some non-biodegradable items should also be included, but NO ANIMAL PRODUCTS! - they get smelly!)
- Water
- N/P fertilizer (any kind will do, liquid, granular, etc.)
- Bio"Booster" - lyophilized microorganisms

## Methods

1. Divide students into groups of at least five.
2. Give each student or pair of students a pot of soil from the same location.
3. Have each student or pair bury the same item to approximately the same depth.
  4. One student or pair should serve as the control. This sample (A) will receive no additional treatment, but should be kept at room temperature.
  5. One student or pair in each group should serve as the minimal water treatment. This sample (B) will be watered with approximately 3 tbsp. (amount depending on size of container) weekly to simulate a dry climate. B should be kept at room temperature.
  6. Another student or pair in each group could serve as the cold treatment. This sample (C) should be maintained at about 4°C, which is standard refrigeration temperature.
  7. Another student or pair in each group could serve as fertilizer or aeration treatment. This sample (D) will be watered with liquid fertilizer weekly or stirred (sample E) weekly to provide air. Samples D and E should be kept at room temperature.

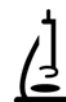
**Note:** Scientists found that the addition of nitrogen and phosphorous could greatly speed the rate of degradation. This process is termed "bioaugmentation". Aeration also speeds the rate of decay, which explains the need for "turning" a compost pile. (*Other variables: temperature, exposure to light, different objects, the addition of organic fertilizer such as manure, etc. The number of variables could be determined by the number of students participating or by the degree of difference students are capable of determining.*)

After one month, at weekly or longer intervals, students should dig-up the object and record its appearance. At least six weeks should be allowed for substantial degradation to become evident. Longer incubation might be needed to determine if some substances are biodegradable.

## Delivery

As this is an inquiry based activity there is the possibility to modify a number of the variables and note the effects of this on the outcome. Allow the students to make predictions as per the types of changes that may occur to the outcome as a result of their modification.

## Microorganisms



Bio"Booster" - lyophilized microorganisms and other microbes naturally occurring in the soil are generally harmless; however, students should keep soil and hands away from their eyes and mouth.

## Safety Precautions

Students should wash their hands and the tabletop before and after the experiment. All supplies should also be carefully washed to prevent cross contamination.

## Assessment

Students will be assessed on their successful completion of the project. This includes any answers to extension questions. Students will also be assessed on their ability to work as a cohesive group, and their level of responsibility and consistency in caring for their aspect of the project. Questions pertaining to this lab experience will be included on any unit test.

# Supplementary Information

### Possible Modifications:

This experiment can easily be modified to accommodate focusing on different concepts, student numbers, time frames, etc. Students will generally be more receptive to the information if they play an active role in the development of the activity, such as obtaining soil from different sites and observing the rate of degradation of different items that they provide. *This activity might be well suited for scheduling when there will be a holiday break from school or mid-term exams. Students may tire of investigating the sample frequently if there are not noticeable changes.*) This experiment allows for cooperative learning and permits a variety of formats for reporting results/conclusions. Many other skills could be utilized to make this more interesting. A simple lab sheet documenting observations is included. However, students could be encouraged to develop a poster presentation, a video taped "commercial" presentation, etc. Making it quantitative is also a valuable addition. One could measure the change in mass or height of materials in the container or pH or several other types of chemical constituents over time.

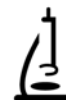
### Extension Questions/Suggested answers:

1. Why does the procedure specify that all soil must be from the same source? What do you think would happen if the soil was not consistent from sample to sample?

*Soil coming from the same source should presumably contain the same microorganisms and other materials. In any gram of soil there is estimated to be over 100 million bacteria and 1 million fungi!*

2. Which treatment provided the most rapid decomposition? Why do you think it worked faster?

*Oxygen is important for some organisms and hence its presence will speed up the process. Many chemical decomposition reactions are an oxidation or hydrolysis reaction therefore it is important*



*to produce conditions to optimize the growth of the microbes. The number of starting bacteria will also have an effect.*

3. What is meant by a balanced diet? Does it apply to microbial degraders? What nutrients were important for rapid microbial growth?

*Many organisms require an organic carbon and nitrogen source for rapid growth. These can be found in many food sources. Proteins contain fixed nitrogen whereas fats and carbohydrates contain fixed carbon. There are other nutrients that are needed as well such as calcium and potassium and magnesium and sodium*

4. Rapid and efficient composting of materials requires a good mix of what is referred to as “browns” (such as leaves) and “greens” (such as vegetables). What are these two categories and what does each supply?

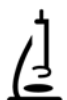
*Browns typically refer to high carbon and greens have higher nitrogen composition. An excess of the one without the other will not decompose very rapidly. Wood is an example of a brown, it takes a long time for its decomposition. Straw is as well. However mix something high in nitrogen and provide oxygen and decomposition will occur rapidly.*

5. How can you use the information you have gained from completing this experiment to improve how you dispose of garbage? *For starters make a compost pile in your backyard instead of throwing valuable nutrients into the garbage. Make sure you have an appropriate balance, with enough moisture and oxygen and decomposition will occur quickly. If any of the ingredients become low add them to get things going. For instance watering during dry spells helps as does continuing to mix the pile.*

6. Large scale community-wide composting facilities pile the material in long rows and turn frequently. Why is this turning important? *This ensures an adequate supply of oxygen and moisture to the microbes. It may also help to modulate the temperature of the pile.*

7. A number of years ago there was an oil spill in Alaska due to damage to the Exxon Valdez. What would impede the breakdown of oil by microorganisms in this environment? *The extreme low temperatures would slow chemical reactions because a microorganism's cellular temperature is the same as its environment. Also oil lacks nitrogen. There is also the problem that there are probably not many microbes in the area prepared to eat up oil.*

8. There was a process whereby they sprayed fertilizer onto the shore. Why would they do this? *This would stimulate the growth of microbes and increase their numbers as well as provide fixed nitrogen and any other lacking nutrients.*





# ***Student Handout***

## ***The Role of Microorganisms in the Ecosystem***

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**Student Name:** \_\_\_\_\_

### **Introduction**

Microorganisms are ubiquitous in the environment, where they have a variety of essential functions. Many microbes are uniquely adapted to specific environmental niches, such as those that inhabit the Dead Sea (*Halobacterium*), the bacteria and cyanobacteria that inhabit the boiling water springs in Yellowstone National Park, and *Chlamydomonas nivalis*, the algae that causes "pink snow." Microbes also play an essential role in the natural recycling of living materials. All naturally produced substances are biodegradable, which means that they can be broken down by living organisms, such as bacteria or fungi. Composting is biodegradation at its best. An examination of conditions that foster or impede composting gives insight to growth conditions of microorganisms as well as the proper function of the ecosystem.

### **Necessary Student Background**

Degradation is an important part of nutrient and material recycling on our planet. It is important to review the major food groups and consider the basic building blocks. There are also cycles of chemicals

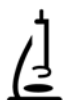
### **Vocabulary**

Bioremediation: the use of microorganisms to remove or detoxify undesired or toxic chemicals from the environment.

Bioaugmentation: the addition of necessary nutrients required to speed up the rate of degradation of a contaminant.

Xenobiotic compounds: compounds that are chemically synthesized and do not exist naturally.

Microbial plastic: a product produced by microbes that is an alternative to plastic, having similar qualities but is biodegradable.



## Safety Considerations

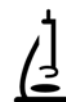
Wash your hands and the table top before and after the experiment. All supplies should also be carefully washed to prevent cross contamination. Bio"Booster" - lyophilized microorganisms and other microbes naturally occurring in the soil are generally harmless; however, keep soil and hands away from your eyes and mouth.

## Materials Checklist

Plastic flower pot or large cup	
Spoon or trowel	
Soil samples	
Labels	
Items to bury (anything will do; pieces of apples, potatoes, oranges, etc.; some non-biodegradable items should also be included, but NO ANIMAL PRODUCTS! - they get smelly!)	
Water	
Fertilizer	
Bio"Booster" - lyophilized microorganisms	

## Procedure

1. Within your group, each member will have a different treatment. Make sure you are clear as to which member has which treatment. There should be at least five students within your group.
2. Take your pot of soil. Label it with the appropriate treatment, your name, and the date. Note: All of the soil is from the same location.
3. Your group has an item to bury. Make sure each member buries the same item to approximately the same depth. Write the type of material and measured depth on the data table.
4. Apply the appropriate treatment to your sample:
  - a. One student or pair should serve as the control. This sample (A) will receive no additional treatment, but should be kept at room temperature.
  - b. One student or pair in each group should serve as the minimal water treatment. This sample (B) will be watered with approximately 3 tbsp. (amount depending on size of container) weekly to simulate a dry climate. B should be kept at room temperature.
  - c. Another student or pair in each group could serve as the cold treatment. This sample (C) should be maintained at about 4°C, which is standard refrigeration temperature.
  - d. Another student or pair in each group could serve as fertilizer treatment. This sample (D) will be watered with liquid fertilizer weekly.
  - e. The last student or pair will serve as aeration treatment. This sample (sample E) will be stirred weekly to provide air. Samples D and E should be kept at room temperature.
5. Your instructor will provide you with further instructions as to how long you will conduct the experiment, and what to look for. Each time you observe your material, rebury it at the same depth in the soil.



# Student Results

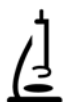
Name: \_\_\_\_\_

I. Record the type of material and description of physical condition; include color, size, shape, firmness and any obvious signs of decomposition:

\_\_\_\_\_

Depth buried in soil in cm: \_\_\_\_\_ Date buried \_\_\_\_\_

<u>Date</u>	<u>Days Buried</u>	<u>Size</u>	<u>Shape</u>	<u>Firmness</u>	<u>Decomposition</u>



## Additional Comments

II. Answer the following questions:

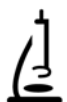
1. Why does the procedure specify that all soil must be from the same source? What do you think would happen if the soil was not consistent from sample to sample?

2. Which treatment provided the most rapid decomposition? Why do you think it worked faster?

3. What is meant by a balanced diet? Does it apply to microbial degraders? What nutrients were important for rapid microbial growth?

4. Rapid and efficient composting of materials requires a good mix of what is referred to as “browns” and “greens”. What are these two categories and what does each supply?

5. How can you use the information you have gained from completing this experiment to improve how you dispose of garbage?



6. Large scale community-wide composting facilities pile the material in long rows and turn frequently. Why is this turning important?

7. A number of years ago there was an oil spill in Alaska due to damage to the Exxon Valdez. What would impede the breakdown of oil by microorganisms in this environment?

8. There was a process whereby they sprayed fertilizer onto the shore. Why would they do this?

