Science Unit: *Climate Change*
Lesson 5: *Dirty Decomposers*

School year:	2008/2009
Developed for:	Shaughnessy Elementary School, Vancouver School District
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Grade level:	Presented to grades 5 - 7; appropriate for grades 4 to 7 with age appropriate modifications.
Duration of lesson:	1 hour and 10 minutes

Objectives

Students will be able to: describe the role of decomposer organisms in nutrient recycling and their importance in maintaining the flow of energy through an ecosystem, relate the presence of soil-dwelling organisms to soil quality, and describe physical conditions that are favourable to these organisms.

By designing their own experiments, students will develop the following abilities necessary to do scientific inquiry:

- asking questions that can be answered through scientific investigations
- design and conduct a scientific investigation
- use appropriate tools and techniques to gather, analyze, and interpret data
- use mathematics in all aspects of scientific inquiry
- develop descriptions, explanations, predictions, and models using evidence
- communicate scientific procedures and explanations
- think critically and logically to develop the relationship between evidence and explanation

Background Information

An important feature of the biosphere is the cycling of materials such as carbon, water, and other nutrients between the *biotic* (living) and *abiotic* (non-living) components of the environment. This cycling of materials is dependent on soil-dwelling decomposer organisms, including earthworms, snails, millipedes, and insects. Although we can't see them, bacteria and fungi are the microbial decomposers that outnumber all the other decomposer organisms combined, with billions of individuals existing in a single handful of soil. These microbes are vital to the breakdown of dead and discarded organic materials, thereby supplying the plants growing in the soil with a continuous source of nutrients.

Humans have capitalized on the work and abundance of decomposers for centuries, if not millennia. Farmers spread manure on their fields to fertilize them, and suburban gardeners use composted grass clippings to enrich their flower beds and vegetable patches. By breaking down proteins, starches, and other complex organic molecules that were once part of a living organism, decomposers, as products of their own metabolism, convert elements such as nitrogen, phosphorus, calcium, and sulphur into forms that can be utilized by plants. What factors affect the ability of soil microbes to do this work? Like all chemical reactions, increased temperatures cause more rapid decomposition reactions, unless the temperature is so high that the microbes are adversely affected. Moisture content of the soil also affects decomposition, with most decomposers benefiting from moist conditions. However, waterlogged soils can become anaerobic, thereby killing some decomposers but allowing others to thrive. Since many of the soil microbes do their work underground, light may also adversely affect some decomposers.

Soil microbes have evolved along with the once-alive-but-now-dead organisms they usually encounter, so decomposition of “organic” materials such as animal flesh, fecal material, fallen leaves, and nut shells will occur fairly rapidly.

Human-made materials such as paper, cardboard, and cotton fabric, which consist largely of cellulose, are also decomposed, but not as quickly as unaltered plant material. The chemical changes in the cellulose fibers produced by the high temperatures involved in manufacturing processes, and those brought about by additives such as sulfur and dyes, can also hinder the work of decomposer microbes. (An example of a human-made material that has aroused a great deal of controversy is the insecticide known as DDT—dichloro-diphenyl-trichloroethane. One of its important characteristics is that it is *non-biodegradable*, bacteria and fungi cannot break it down. This makes it affective as an insecticide, because it doesn’t have to be reapplied very often. Unfortunately, in addition to killing pests, DDT proved to be quite harmful to many different kinds of other, more beneficial organisms. Rachel Carson, in the 1960’s, published *Silent Spring*, which documented some of these harmful affects. Some bird species were killed outright by DDT. Others laid eggs with thin shells that cracked before the babies were born. Beneficial insects were killed just as readily as the harmful ones. And DDT has even been implicated in certain kinds of cancer in humans. Though it is now banned in the United States, it continues to be used in other parts of the world.)

Metals and plastics eventually can be broken down by weathering processes, but ordinarily soil microbes have little or nothing to do with their decomposition. However, both microbiologists and other scientists involved in the plastics industry are currently at work developing products that can be broken down by soil microbes. The emphasis is on making plastics that are based on vegetable starches rather than petroleum products. The backbone of starch molecules consists of carbon-oxygen bonds, which can be more easily broken by microbial enzymes than the stronger carbon-carbon bonds of petroleum-based plastics. Although it is unlikely that microbes alone will be the answer to our waste disposal problems, their traditional role in ecosystems should not go unrecognized. This exercise will allow students to see for themselves what decomposer microbes can accomplish, even if they can’t actually see the microbes. However, it is important that students not be misled in their thinking of *how* this work is actually done. A soil microbe does not eat the material being decomposed, like a miniature Pac-Man, but rather, it releases digestive enzymes that make their way into the paraplasmic space between the cell membrane and the cell wall. Through holes in the cell wall, the enzymes make contact with the material to be decomposed. The enzymes then break its large organic molecules into smaller molecules that can be used by the microbe. For example, cellulose can be split into glucose and phosphate molecules. The microbe will use the glucose for its own cellular needs, and release the phosphate into the soil, where it can be taken up by plant root cells.

Materials

- several triple-beam balances accurate to 0.1g (or digital balances)
- 2 one-pint plastic bags with zipper closures *per student*
- 8-20 pounds, more or less depending on class size and student plans forexperiments, of good quality potting soil (the most expensive you can afford)
- several garden trowels, large spoons, or plastic cups for digging and scooping soil
- 12 medium carrots
- very inexpensive watercolour paintbrushes, one or two per group, for brushing dirtfrom the carrots prior to weighing

Depending on what questions the student groups decide to test, you may also need:

- other types of soil (e.g., soils with high clay or sand contents, topsoil from a nearby woods, garden, or inconspicuous area of lawn, etc.)
- refrigerator space

- incubator space (A makeshift incubator can be made from a large cardboard box, such as one that computer components are shipped in, which has been lined with aluminum foil. A 25-Watt lightbulb screwed into a base obtained for a few dollars at a hardware store serves as the heat source, or a very small desk lamp can be used. **For safety and fire hazard reasons**, only use the incubator during the school hours, unplugging it overnight or running it off a timer.)
- several thermometers
- several small beakers, graduated cylinders, and bowls for mixing soil, or adding measured amounts of water or other substances

In the Class

Science Activity/Experiment

Experiment Title: Dirty Decomposers

Purpose of Experiment: Students will design and conduct experiments to determine what environmental factors favour decomposition by soil microbes. They will use chunks of carrot for the materials to be decomposed, and their experiments will be carried out in plastic bags filled with dirt. Every few days the students will remove the carrots from the dirt and weigh them. Depending on the experimental conditions, after a few weeks most of the carrots will have decomposed completely.

Experimental Treatments: State variable to test.

Control treatment	Ziplock bag, carrot and dirt
Test treatment	Ziplock bag, carrot and what the students choose as their independent variable(s)

Procedure

Students should work in groups of 3 or 4. After reading the background information in the student pages, each group should be able to come up with an idea for an experiment. The experiments are intended to identify physical characteristics of either the soil or the environment that can affect the decomposition rate of a carrot. Use the student lab report sheets attached or create your own.

Examples of questions students have asked in the past include:

- How does temperature affect decomposition?
- Will wet soil cause faster decomposition than dry soil?
- Will the carrot decompose faster in soil from the woods than it will in soil from the playground?
- Will fertilizer help the carrot decompose faster?

These are only examples, however. Be sure to allow students enough time to generate their own questions. If they need help you can ask leading questions such as, “Do you think an apple core tossed on the ground in northern Alaska will decompose at the same rate as one tossed on the ground in an Amazonian rainforest?”; or, “Do you think one left in the mud in Burns Bog will decompose faster or slower than one in the sand of the Sahara desert?”; and, “How could you do an experiment *here* to simulate those conditions and let you know if your prediction is likely to be right or not?”

Students can easily design a simple experiment to test the effects of different environmental conditions on the decomposition of an organic substance, such as a carrot. By giving every student two plastic bags to use as the decomposition chambers, they will each have one experimental chamber and one control chamber. By working in a group of 3-4 students, they will have 3-4 trials for their experiment. Of course, this means that the group will first have to agree on one question to test.

Students may ask to test substances other than a carrot, simply because they are curious and carrots may not be among their favourite foods. While comparing the decomposition of different materials is a worthwhile undertaking, the curricular goals of this exercise are related to environmental conditions such as temperature, water content, and types of soil. We have found carrots very suitable for this experiment, since they stay relatively intact throughout the experiment. Carrots also have large enough starting masses and small enough surface areas so any adhering soil particles make up a relatively small proportion of the total mass. In other words, errors in the mass measurements due to soil sticking to the carrots are reasonably small. Fruits and vegetables that are softer or have higher water contents than carrots do not share these desirable characteristics. However, if students are still curious *after* conducting their experiments on carrot decomposition, they should be encouraged to do another experiment comparing carrots to other fruits or vegetables -- or any other testable questions they are interested in. It is fine to reuse the bags and soil from their first experiments, but it would be best to combine and thoroughly mix all the soil from their chambers before starting over.

Discussion

Since their experiments will take several weeks to complete, ask each group to report on their observations periodically. Some of them may be surprising! For example, if students tested the effects of cold temperatures on decomposition, they probably found that refrigeration caused their carrots to *increase* in mass at first. If so, ask them why they think this happened. Most likely, it was because the carrots absorbed moisture from the damp soil. After the first few days, the mass of the carrots probably remained unchanged for the rest of the duration of the experiment. The cold temperatures prevented the microbes from doing their job; we keep fruits and vegetables in the refrigerator for the same reason.

If students saturated their soil with water at the beginning of the experiment, they probably discovered a very foul odor when they opened their plastic bags a week or two later. In this case, the waterlogged conditions favored the *anaerobic* bacteria living within the soil, who then went to work decomposing the carrot. A by-product of their respiration is hydrogen-sulfide gas, which has a characteristic, swampy aroma. (We have found that air-freshener spray helps keep the student complaints down.) Students should notice, however, that these anaerobic decomposers work just as quickly, if not more quickly, than their aerobic counterparts. Be sure to ask the class what the sources of error are in their experiments. The most obvious is the fact that some dirt remains adhered to their carrots each time they weigh them, and depending on the conditions they test, this amount of dirt may vary throughout the experiment. Point out that they can get some idea of the amount of error from the difference between the initial and first experimental masses of their control carrots. Since the decomposers will not have had much effect in such a short period of time, any initial weight gain in the carrots is mainly due to dirt adhering to the carrot. Later in the experiment, depending on the conditions tested, some carrots may break into several small pieces, and students must be sure to find all the pieces and weigh them together. In general, students should be able to recognize the major error sources as being measurement errors and errors due to adhering dirt.

Extension of Lesson Plan

When most of the carrots are nearly or completely decomposed, have each group share its findings with the rest of the class. A good way to do this is to have each group prepare a poster. Scientists frequently use posters as an efficient and timely means of communicating with each other when they get together at meetings devoted to a particular topic area. Their posters contain the same type of information a formal paper published in a scientific journal would:

- a descriptive title
- an abstract -- a few sentences stating the purpose, results, and conclusions of the experiment
- a description of the methods used to conduct the experiment, including diagrams if appropriate
- the results of the experiment, shown in tables and graphs, and summarized in words
- . the conclusions drawn from the data

We recommend that you allow students a day or two of class time to prepare a "semi-formal" poster to display in the classroom. The poster should be formal in the sense that it must give a succinct and objective reporting of the experiment, be neat, and use good grammar and correct spelling. However, students can still be allowed to exercise their creativity in the way they lay out and embellish their posters with color, illustrations, etc.
Because there are several components of the poster's preparation, all students will have opportunities to contribute in ways that highlight their own particular strengths. When their posters are done, each group should present its poster to the rest of the class with a brief summary of the results and conclusions. Other students should be encouraged to ask questions and give feedback to the presenting group.

References:

Hebrank, Mark. (2000). Dirty Decomposers. Center for Inquiry-Based Learning. Dept. of Biology, Duke University, Durham NC.

An Introduction to the Decomposers
Information for Students

What happens to the litter so often found along our roadsides? How would an apple core or a Styrofoam hamburger carton change in appearance over time? Many of the visible changes in an apple core lying on a roadside are the result of insects, birds, or other animals feeding on it. Other changes are the result of physical features of the environment. For example, sunlight will dry the apple and cause it to shrink. Styrofoam⇔, on the other hand, will likely remain intact for a long time. Only physical events will have much effect on its appearance. It may get squashed flat and break into smaller pieces if a car runs over it, and eventually the ultraviolet light from the sun (the same form of light that gives people sunburns) will loosen some of the strong chemical bonds that make plastic so durable.

This process takes years, however. Meanwhile, the apple core, or what's left after the insects are through with it, is exposed to the air and is also in contact with soil. Both the air and the soil contain bacteria and fungi that feed on dead tissues. This is not surprising, because the bacteria and fungi are essential to preserving life on earth. One of their main jobs is to decompose dead or discarded biological materials, breaking them down into simple chemicals that can be used as plant nutrients. The bacteria and fungi don't exactly *eat d*ead plants or animals, but they do *digest* them, at least partly. Bacteria are one-celled organisms, and they can produce special proteins that will pass through their cell membranes. These proteins, called *enzymes*, come into contact with the dead materials and break them down into simpler, liquid components. Then the bacteria cells can take the liquid back into themselves, through the cell membrane, as a source of food.

The fungi do basically the same thing, although some of the details are a little different. Both the bacteria and the fungi get food from the dead material, which we describe as "rotting" once they have gone to work on it. (That's when the material gets slimy, smelly, and/or has fuzzy stuff growing on it.) What is especially useful, though, is that while the bacteria and fungi are getting their nutrition, some of the chemical parts of the rotting material are left behind in the soil. The parts left behind contain minerals that living plants can use to help them grow. So the decomposers are important ecologically because they cause natural recycling to occur. The minerals that were once in a living plant or animal get returned to the soil by decomposers when the plant or animal dies. Many people take advantage of these organisms by composting their food scraps or yard waste. When a gardener makes a compost pile, he or she is providing good conditions for decomposition to occur, and the result is a dark, crumbly material that makes excellent fertilizer. And while the material may smell bad for a while along the way, the finished compost looks and smells like rich, moist earth. There are many factors that can affect the decomposition process, and if you can imagine yourself as a fungus or bacterium living in the soil perhaps you can guess what some of these are. Like most living things, the decomposers usually do best when they have good supplies of air and moisture, and without both of these they can't very well break down our trash and garbage. So no matter how biodegradable it is, trash and garbage that gets taken to a landfill is quickly buried deep underground, away from air and moisture. As a result, if your grandchildren were to go digging in your local landfill fifty years from now, they would probably be able to read the backs of the cereal boxes you ate from today!

Designing an Experiment

Besides air and water, there are other physical features of the environment that can affect decomposition and how quickly it occurs. In your group, list some of the things you think are likely to affect decomposition, and then choose one of these ideas to test in a scientific experiment. You can design a good experiment using carrots as the material to be decomposed, and burying them in dirt that has been put into a zipper-type plastic bag. Every 3 - 5 days or so you can remove the carrot and find its mass. As the carrot is decomposed, it will get smaller and therefore have less mass. You can compare carrots in two different experimental conditions by seeing how their masses change over time.

The following suggestions will be helpful as you design your experiment:

1. Use a chunk of carrot that is about 2 cm wide and about 3-4 cm long.
2. Put only one carrot chunk in each bag of soil.
3. Be sure to weigh the carrot chunks at the start of the experiment.
4. Put equal volumes of soil in all the bags. (Why is this important?)

Prepare a written proposal describing your experiment before you begin setting it up. Your group's proposal needs to answer these questions:

1. What is the question you are asking?
2. How will you try to answer it?
3. How many trials will you do?
4. How will you record your data?
5. How will you report your results quantitatively?
6. What will be your controls?
7. What is your hypothesis?

Dirty Decomposers

Question: What effects do certain materials have on the decomposition of organic material and their importance in maintaining the flow of energy through an ecosystem?

Hypothesis: ____
____
____

Variables: Independent: ____

Dependent: rate of decompositions and temperature

Control: Ziplock, carrot, amount of soil, _________________

Materials:

- digital scales
- 2 one-pint plastic bags with zipper closures *per student*
- 250g of good quality potting soil (the most expensive you can afford)
- several garden trowels, large spoons, or plastic cups for digging and scooping soil
- 2 carrots cut into 5 cm pieces
- very inexpensive watercolour paintbrushes, one or two per group, for brushing dirt from the carrots prior to weighing

Data & Observations:

Date		Temperature	Weight	Observations
	C 1			- - -
	C 2			- - -
	C 1			- - -
	C 2			- - -
	C 1			- - -
	C 2			- - -
	C 1			- - -
	C 2			- - -
	C 1			- - -
	C 2			- - -

C1 = control
C2 = experiment

Analysis:

Conclusion:

Application: