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# K-12 Partnership Lesson Plan

# Emily Grman

# *Into Thin Air*

# *What happens to leaves when they decompose?*

## Overview

Students will expand on their understanding of carbon cycling and decomposition by measuring the concentration of CO2 over time in closed containers with decomposing materials. In Part 1, they will set up coffee cans in a natural area, in Part 2 they will set up student-designed experiments in the classroom or in the natural area. Students will gain experience using the Vernier LabQuest system. They will also gain experience with the scientific method: designing, conducting, analyzing, and presenting the results of an experiment.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Understand that decomposition is a central step in carbon cycling
* List several environmental determinants of the rate of decomposition
* Design and conduct an experiment, beginning with hypothesis development and ending in a classroom poster symposium

**Length of Lesson**

 **Part 1 (**observational survey of CO2 given off in a natural area):

* 90 minutes to introduce the topic, set up coffee cans, collect first CO2 datapoint, and sample soils and leaf litter
* 60 minutes to analyze soil samples in the lab
* 90 minutes to collect final CO2 datapoint and other environmental data
* 60 minutes to synthesize data and draw conclusions (or make hypotheses, if continuing to Part 2)

**Part 2** (student-designed experiments):

* two 60-90 classperiods to design and set up student experiments
* ~ 2 weeks to collect CO2 data, time required per day will depend on the number of Vernier probes available and the number of student experimental units
* two 60-90 minute periods in the computer lab to analyze student data and prepare posters
* 60 minutes for student poster symposium

**Grade Levels**

11th -12th grade

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **HS-LS1-5**: use a model to illustrate how photosynthesis transforms light energy into stored chemical energy
* **HS**-**LS2-3**: construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions
* **HS**-**LS2-4**: use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem
* **HS**-**LS2-5**: develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere

Cross Cutting Concepts:

* Cause and effect
* Energy and matter in systems
* Stability and change of systems

Science and Engineering Practices

* Asking questions and defining problems
* Developing and using models
* Planning and carrying out investigations
* Analyzing and interpreting data
* Using mathematics and computational thinking
* Engaging in argument from evidence
* Obtaining, evaluating, and communicating information

***Previous Michigan Standards Met:***

* **B1.1A**: generate new questions that can be investigated in the laboratory or field
* **B1**.**1B**: evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, andor the dependence on underlying assumptions
* **B1.1C**: conduct scientific investigations using appropriate tools and techniques (e.g. selecting an instrument that measure the desired quantity- length, volume, weight, time interval, temperature- with the appropriate level of precision)
* **B1.1D**: identify patterns in data and relate them to theoretical models
* **B1.1E**: describe a reason for a given conclusion using evidence from an investigation
* **B1**.**1f**: predict what would happen if the variables, methods, or timing of an investigation were changed
* **B1**.**1g**: use empirical evidence to explain and critique the reasoning used to draw a scientific conclusion or explanation
* **B1**.**1h**: design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables
* **B1**.**2g**: identify scientific tradeoffs in design decisions and choose among alternative solutions
* **B2.1B**: compare and contrast the transformation of matter and energy during photosynthesis and respiration
* **B2.2B**: recognize the six most common elements in organic molecules (C, H, N, O, P, S)
* **B2.2C**: describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids)
* **B2.4f**: recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP
* **B3.3b**: describe the environmental processes (e.g., the carbon and nitrogen cycles), and their role in processing matter crucial for sustaining life

**Materials**

 For Part 1:

* 10-20 large cans, such as coffee cans, all the same size and shape
* Vernier LabQuests and probes to measure CO2, soil moisture, pH, other interesting varaiables
* Soil thermometers
* Student worksheets
* Ziploc bags (1 per can)
* Paper bags (1 per can)
* Balances

For Part 2:

* Measuring devices as above
* Ziploc bags
* Soil
* Leaves
* Tupperware or other containers that seal; student can be asked to bring in their own for their experiments

**Background**

Decomposition is an important process, both for the functioning of ecosystems and for understanding human impacts on the global carbon cycle. Decomposition prevents dead things from building up, turning them into nutrients other organisms need (compost!) and gases like CO2 and methane. Essentially like cellular respiration (except performed by decomposers instead of consumers), decomposition breaks down complex energy- and carbon-containing molecules (like carbohydrates, fats, proteins, and nucleic acids). Decomposers live off the energy released in the process (like consumers get energy from their food). It is an essential step in the cycling of major nutrients like carbon, nitrogen, and phosphorus. It also contributes a large amount of CO2 to the atmosphere each year—far more than human emissions. However, humans are altering the rate of decomposition by disturbing the soil and altering factors which naturally affect the rate of CO2 (such as soil temperature, soil aeration, etc). More specific information is included in the Activities of the Session section below.

### Activities of the session

**Part 1**

Day 1

1. Begin by asking what the students know about what plants are made of. Hand out the student worksheets and fill out page 1. The data on the answer key give the percents of plant dry matter; these 6 elements are the most abundant in all living organisms (but exact percents do vary). The process tool is a visual representation of the matter and energy that go into various processes and the matter and energy going out. For example, CO2 and water (matter) and sunlight (energy) go into photosynthesis and C6H12O6 and O2 (matter) and chemical energy inside the bonds of glucose (energy) come out. Decomposition has chemical energy (inside chemical bonds of food energy), food, and oxygen going in; CO2 comes out, as does a different form of chemical energy (ATP and other molecules) that organisms can use to do their work (move around, reproduce, etc).
2. Where does leaf mass go when leaves decompose?
3. How important is it to understand this? Present global carbon cycle using the figure in the introductory powerpoint. Numbers in boxes are pool sizes—the amount of carbon that is sitting in various locations. Arrows and represent fluxes, or amounts moving from one place to another. Ask the students to compare the amount of carbon in soils (1500 gigatons (billions of tons) of carbon) to the amount in the atmosphere (775) or in all the plant matter in the world (vegetation=550). How important is decomposition? (Arrow going from soil to atmosphere is 50 gigatons per year.) How does that compare to the amount of fossil fuel combustion and cement production (6.2 gigatons per year)?
4. What could possibly control the rate of decomposition? Brainstorm some ideas, referring to matter and energy going into the process tool if necessary. Temperature affects the rate of all chemical reactions (of which decomposition is essentially an example), so students may generate that idea too.
5. Discuss the sampling scheme—set up cans in the woods, sealing the edge of the can to the ground by pressing gently into the soil, measuring CO2 before and after incubating for a few days. Also discuss other environmental measurements to take—to find out which things are associated with faster rates of CO2 release (which indicates decomposition). It may be best to collect leaf litter and soils immediately adjacent to the place the can will incubate, so the leaves can air dry for a week before weighing them.

Day 2:

1. Optional soil and leaf litter analysis in the lab:
	1. Measure pH of the soil by mixing 10g soil with 50mL water, letting settle for 10 minutes, then using the Vernier probe.
	2. Measure initial soil moisture with the Vernier probe.
	3. After leaf litter has air dried for about a week, separate leaf litter into different types (example, deciduous leaves from pine needles) and weigh each component separately to assess food quality and quantity.
	4. Count the number of decomposers found in the leaf litter
2. After collecting final CO2 data from the cans in the natural area, collect other interesting environmental data, such as soil moisture, soil temperature, earthworm density, and/or any other variables students are interested in.

Day 3:

1. Have the students compile all their data onto a data table drawn on the board or saved in an excel file. You may need to process the data, looking at the difference between starting and ending CO2 concentrations for each can, perhaps dividing by the number of days (if not all cans were incubated for the same amount of time).
2. Look for relationships among variables. For example, do cans with higher CO2 production also have higher pH or higher moisture? Generate potential explanations for variation in the rate of CO2 production using the results of the observational study.

**Part 2**

Days 3-5 or 4-5:

1. These potential explanations for the variation you observed are hypotheses for factors controlling the rate of decomposition. Develop a long list and encourage students to think of more.
2. Divide the class into lab groups and ask each group to choose a hypothesis to test and an experimental design to test it.
3. Discuss the importance of replication (4 replicates of each treatment is recommended) because of natural variability in biological processes.
4. If multiple student groups want to investigate the same hypothesis, make sure they are doing it somewhat differently (e.g., one group includes maple leaves and the other just soil).
5. Remind the students to control as much as they can in their experiments: weighing the amount of soil and measuring the water added to each container, etc.

Days 5-20:

1. Have students measure CO2 in their experiments, being careful to minimize gas exchange with the classroom air. It is not necessary for every group to measure every day—you could set up a 2 or 3 day rotation so each group samples every 2 or 3 days, and only half or 1/3 of the class is sampling every day.
2. Optional activities:
	1. Have students work on rough drafts of the different sections of their posters (introduction, hypothesis, procedures)
	2. Incorporate math by discussing variability and how to represent it on the graphs (means and standard deviations)

Days 21-22:

1. Allow students time in a computer lab to process their data, make figures in Excel (referring to “how to make figures in Excel” handout if necessary), and word process poster sections. Descriptions of what they should include on their posters are on the “poster rubric.doc” file (also used in evaluating posters)

Poster session day:

1. Circulate through the room, evaluating posters according to the “poster rubric.doc” and asking student presenters questions about their experiment, their results, how their results relate to the real world, and questions they would like to ask next.

**Resources**

* Student worksheet, answer key, powerpoint presentation, poster rubric, and how to graph in excel documents are found the “Into Thin Air” lesson page on the KBS GK-12 website
* Figure in student worksheet taken from <http://cdiac.ornl.gov/images/carbon_cycle.gif>