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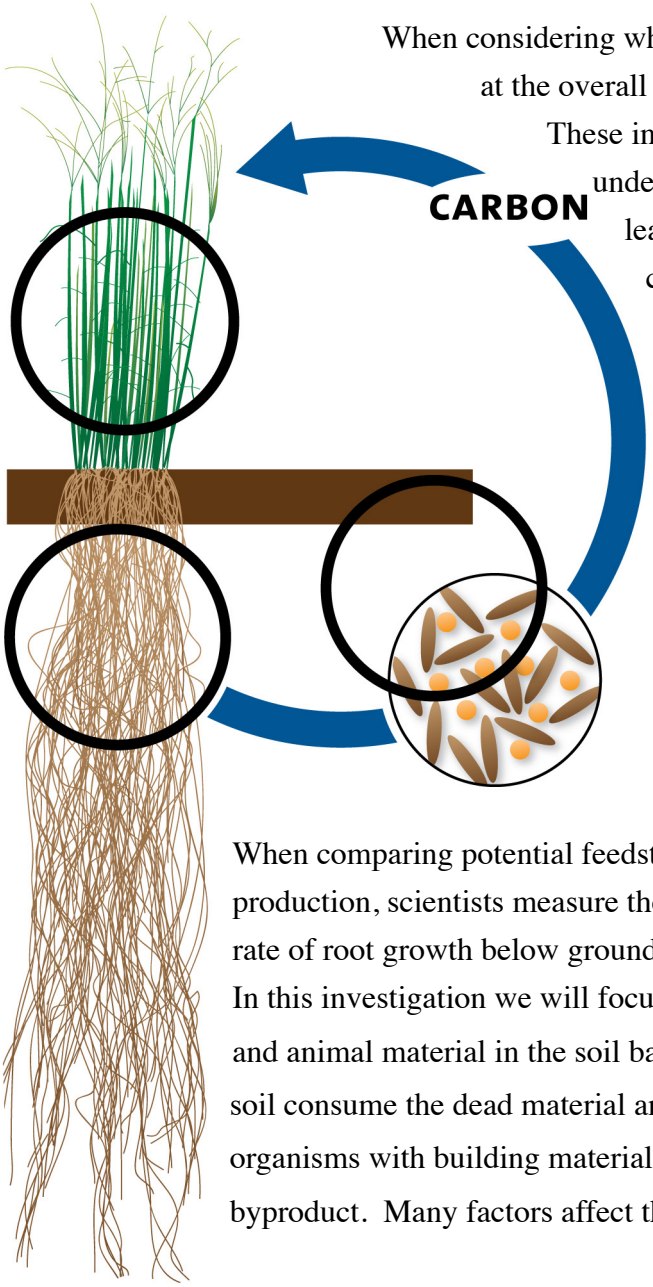
Measuring Soil Microbial Activity

Consider what you know about photosynthesis and cellular respiration. How does carbon become part of a plant? Which part of the plant? In what ways does the carbon get released from the plant? Where does it go?

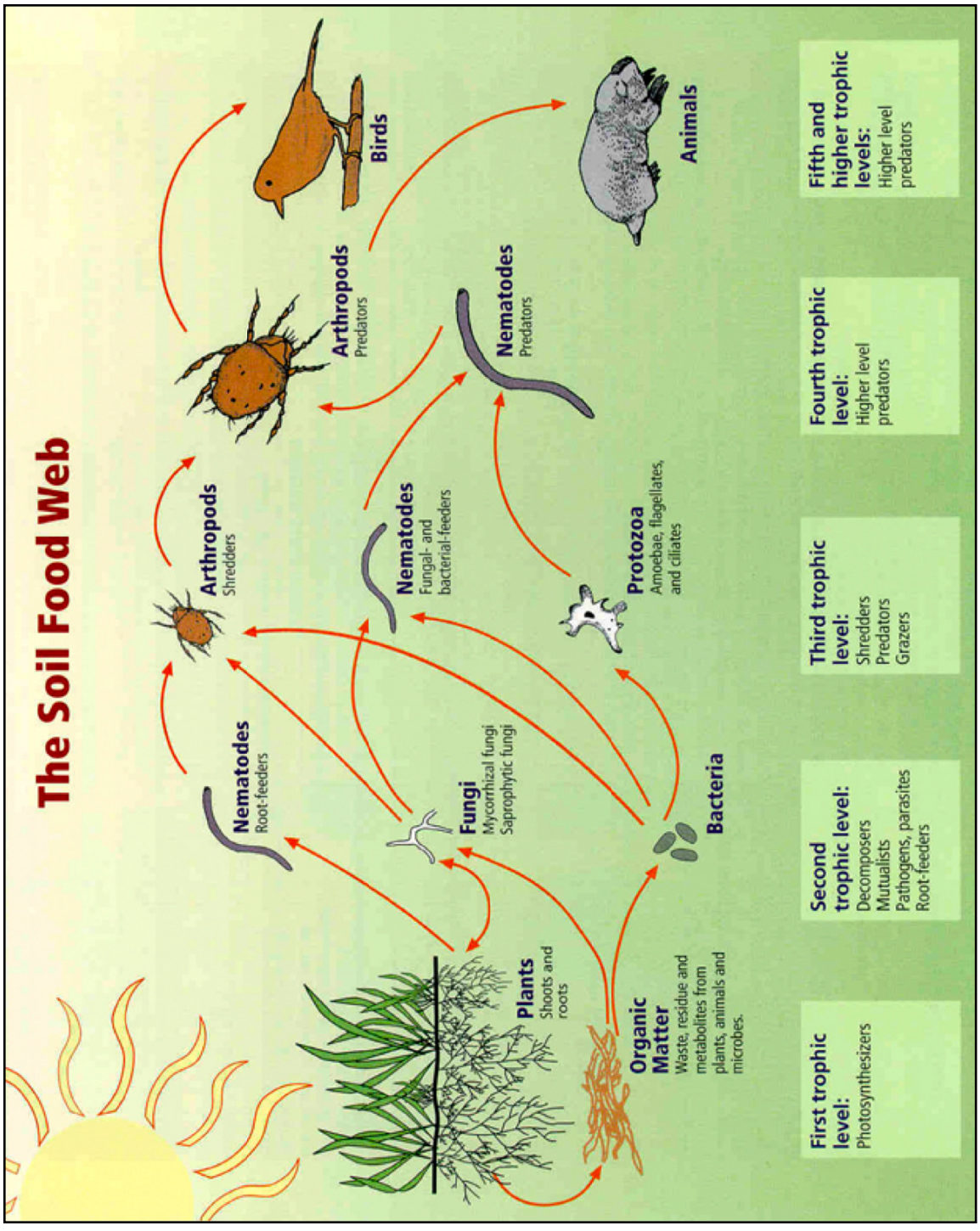


When considering what plants to grow for sustainable biofuels we must look at the overall carbon cycle of all the steps involved in production. These investigations focus in on what happens on the field and underground. Plants *sequester*, or capture, carbon in their leaves, stems and roots in a variety of molecules, including carbohydrates, which can be harvested to make biofuels. Normally, some of the plant is left behind on the field or underground after harvesting. Soil microbes may then consume those roots, or pieces of dead plants and return carbon dioxide to the atmosphere through cellular respiration. Decisions farmers make as to what to plant, how to plant and then later, how and when to harvest these crops affect soil microbial activity and decomposition rates--influencing how much and how quickly carbon from the plants is returned to the atmosphere.

When comparing potential feedstocks (crop options) and field treatments for biofuel production, scientists measure the amount of plant biomass produced above ground, the rate of root growth below ground, and the rate of carbon dioxide emissions from the soil. In this investigation we will focus on the rate at which carbon moves from dead plant and animal material in the soil back into the atmosphere. Bacteria and fungus in the soil consume the dead material and undergo cellular respiration, providing the micro-organisms with building materials and energy, and releasing CO_2 into the atmosphere as a byproduct. Many factors affect the rate at which this occurs.

In this activity, you will design an experiment to measure carbon dioxide released by soil microbes and determine some of the factors that affect the rate of respiration of these soil microbes.

Name_____ Date_____ Hour_____



Soil food web showing plants, organic matter, microbes, invertebrates, and birds and mammals.
Image courtesy of USDA Natural Resources Conservation Service, *http://soils.usda.gov/sqi*

How does carbon enter this system?

Name_____ Date_____ Hour_____

Background Questions

Use the information your teacher provides to answer the following questions:

1. How does carbon get into the soil? In what forms?

2. How is carbon in the soil returned to the atmosphere? Is it all returned at the same rate? Explain.

3. Experiments such as this one measuring soil microbe respiration in a jar or bucket, extrapolate small-scale research results to entire ecosystems such as a forest or prairie.
   a. How is this model useful?

   b. What are the limitations of this model?

Name_____ Date_____ Hour_____

Experimental Design

1. What question will you investigate? Why is this of interest?

2. Which technique will you use to collect data? How many replicates will you have? What are your variables?

3. (Optional) When and where will you do your sampling? (you may want to mark sites on a map) Over what period of time? Why?

4. What is your hypothesis? Explain what you predict will occur and **why** using solid scientific reasoning.

5. Describe the type of evidence you will collect and how it will be recorded. Use another piece of paper if necessary.

Name_____ Date_____ Hour_____

Site Description

Observer's name _____

Site name _____ Date of observation_____

Address or latitude/longitude _____

Time of observation _____

Habitat description:

Type of vegetation _____ # species ____

Annual or perennial or mixed? _____

Vegetation height _____

Size of habitat _____

Soil cover? *None* *dense vegetation* *litter cover* *other* _____

Soil moisture *Dry* *Average* *Saturated* *other* _____

Soil temperature _____

Site use history _____

Land management description (burned, tilled, fertilizer use, etc) _____

_____

Adjacent land use (wooded, grassland, agricultural, urban, etc) _____

_____

Weather:

Air temperature ___ Daily high/low _____

Cloud cover? *None* *mostly sunny* *mostly cloudy* *complete cover*

Wind speed _____

Precipitation at time of sampling _____

Precipitation in last 24 hours _____

Site sketch and other relevant observations:

Name_____ Date_____ Hour_____

Field Method: Carbon Dioxide Probe

Objective
To investigate decomposition and measure carbon dioxide levels emitted from the soils by microbes and other organisms living in different habitats.

Sample Questions
Does fertilizer use increase the rate of carbon dioxide released from soils?
Is more carbon dioxide released from annual or perennial cropping systems?
Is carbon dioxide released at the same rate over the course of a year in a corn field?

Materials list for each group

- White 5-gallon pails
- White 5-gallon pail tops
- Hacksaw or heavy duty utility knife
- Drill and bits
- #8 rubber stopper
- E6000 Adhesive or like product
- Trowel
- Lavatory pop-up drain gasket
- Spare 2 x 4 that spans top of pail
- Mallet
- Scissors or shears
- Vernier Lab Quest and CO_2 Probe, or equivalent
- Optional: Temperature Probe
- Optional: Garden gloves

Constructing the Gas Sampling Apparatus

1. Drill a hole 1.5” in diameter near the center of the pail lid.
2. Center the gasket over the hole so that the bevel sits on the lip of the drilled hole.
3. Glue in place using E6000 (or a comparable adhesive).
4. Measure 15 inches down from the top of the pail and carefully cut off the pail base.
5. Using a permanent marker, draw a line around the bucket 4 inches from the new cut bottom. This line marks the depth to which the pail must be hammered into the ground.

6. If you have a smaller 3.5 gallon bucket, cut the bottom of the pail off and draw the line 4 inches from the bottom. Regardless of bucket size, the goal is to have 10 liters of head space in the bucket once it is sunk into the ground.

Installing the Gas Sampling Enclosures

1. Decide where to place your pail, the middle of the field is preferable.
2. Using a trowel, follow along the outside of the pail, inserting the trowel into the soil and making it easier to subsequently hammer the pail into the ground. Do not disturb the soil more than necessary.
3. Once done, push the pail in up to the line from step 5 above. If necessary, place a 2x4 wood block over the pail and lightly hammer the pail until you are to the line.
4. Cut the plants within the pail down to ground level, unless instructed otherwise.
5. Let the enclosure sit for one week before taking measurements. It may stay in place for the entire season.

Measuring Greenhouse Gas Discharge

1. Place the cover over the pail. Wait 30-60 seconds after placing the cover. Insert the CO_2 prove into the hole and measure the CO_2 concentration. Take the measurement for 60 seconds.
2. Remove the CO_2 probe and place a #8 rubber stopper in its place to seal the pail.
3. Take a second measurement after 9 minutes. Take measurements at this rate for up to an hour. If you stagger the start of gas measurement for all of your groups, then you can take greater advantage of a limited number of probes. (Note GLBRC researchers do 20 minute intervals; this protocol was revised to better fit a class period).
4. When you finish, remove the cover.
5. Optional: measure soil temperature inside the bucket.
6. Graph your results.

Name_____ Date_____ Hour_____

Lab Method: Carbon Dioxide Probe

Objective
To investigate decomposition and measure carbon dioxide levels emitted from the soils by microbes and other organisms living in different habitats.

Questions
What soil treatments would have the greatest effect? Think about energy containing compounds such as carbohydrates (sugars, starches, etc) and key elements such as nitrogen.
What changes in the abiotic environment would affect soil respiration rates?
What would be an effective control for your treatments?
Be aware of what has happened to the soil recently before you dig it up. Was it fertilized, tilled, etc?

Materials list for each group

- Soil, at least 500 ml
  - -A good topsoil with loamy characteristics (not very sandy or clayey) will be best. Clean of rocks, leaves, roots, etc
  - -Should be somewhat moist, but not saturated/muddy
- 2 or more CO_2 probes (Vernier, or equivalent--probe-computer interface, software, etc) (Note: in a pinch you could use only one probe and do several runs in series.)
- 2 or more 250 ml Nalgene bottles with openings to fit probes
- 250 ml graduated cylinder
- 10 ml graduated cylinder or teaspoon
- 4 or more 9 oz (~250 ml) cups
- 2 or more spoons, for mixing solutions into soils
- Water (tap water or distilled) - optional

Protocol

1. Put 100 ml of soil in separate, clean labeled cup. Make one cup for each treatment and control.
2. Label the nalgene bottles with the types of soil they will receive.
3. Add 5 cc (or one teaspoon) of the appropriate treatments (Example: 1 teaspoon table sugar) to the soils and stir until the feedstock is evenly dispersed in the soil.
4. Promptly transfer these soils in the corresponding Nalgene bottle.

5. Promptly insert the CO_2 probes into the bottles and click the start button to begin collecting data.
6. Recommendations for data sampling:
    a. Run your analysis for at 30 minutes-3 hours. Two to three hours will likely be better in terms of getting a larger linear response time.
    b. Take data points every one to two minutes

Data Analysis

7. Can you identify different portions (curved verses linear) of your data?
8. Is there is a linear portion to the data for your samples?
9. If yes, run a linear regression on this portion of your data. Use the slope from this regression as a respiration rate for your soil with that treatment.
10. If you had multiple treatments, what kinds of data comparisons can you make? Is there a time-period in your experimental run where all results were linear? If so, use the corresponding data from this period to compare relative respiration rates.
11. Consider transferring your data to Excel, or equivalent, to do additional analysis or graphing.

Name_____ Date_____ Hour_____

Experimental Design Considerations for BTB Color Indicator

Based on what you know about biological activity in soil under different conditions, develop a hypothesis that tests a specific concept or idea about CO_2 production in the soil microbial community. Hypotheses may relate production to different soil types or habitats; treatments like compost, fertilizer, or sugars; different temperatures (ranging from 0-40° Celsius) or incubation times (from 1-14+ days). Next, decide how you might test your hypothesis in terms of specific variables. Think about why separate jars for replicates and controls are needed. Recall that replicates are identical microcosms set up within each treatment while controls are used to measure CO_2 in the air, without soil added to the jar. The results from the control are subtracted from all samples.

Before you design your experiment, be sure you can answer the following questions:

1. What is the role of the BTB? How does it work?

2. Explain why one control must be a jar with BTB, but without soil.

3. What other control do you need? Why?

Name_____ Date_____ Hour_____

Lab Method: Bromothymol Blue in a Closed System

Objective
To investigate decomposition and measure carbon dioxide levels emitted from the soils by microbes and other organisms living in different habitats.

Questions
What soil treatments would have the greatest effect? Think about energy containing compounds such as carbohydrates (sugars, starches, etc) and key elements such as nitrogen.
What changes in the abiotic environment would affect soil respiration rates?
What would be an effective control for your treatments?
Be aware of what has happened to the soil recently before you dig it up. Was it fertilized, tilled, etc?

Materials list for each group

- Soil, at least 600 ml
  - -A good topsoil with loamy characteristics (not very sandy or clayey) will be best. Clean of rocks, leaves, roots, etc
  - -Should be somewhat moist, but not saturated/muddy
- Bromothymol blue stock solution
- Petri dish
- 2 or more large, clear containers with air tight covers
- 250 ml graduated cylinder
- 10 ml graduated cylinder or teaspoon
- 2 or more spoons, for mixing solutions into soils
- Distilled water
- Small squares of white paper

Protocol

1. Measure 300 ml of soil and place in clear container, Make one container for each treatment and control
2. Label the containers with the type of soil they will receive.
3. Add 15 cc (or 3 teaspoons) of the appropriate treatments to the soil and stir until the feedstock is evenly dispersed in the soil.
4. Measure approximately 20 ml of BTB and pour into cover or base of petri dish.
5. Place small square piece of paper on top of soil and set the petri dish cover with BTB on top of the paper.
6. Cover the container and allow process to run over night.

Planning, Data Analysis & Interpretation Questions:

BEFORE THE EXPERIMENT: Answer these questions before running your experiment.

1. Research Question: State your research question.

2. Describe your experimental set-up. What treatments will you compare? What is your control?

3. PREDICT: What differences, if any, do you expect in color between the BTB in your treatments and control after 24 hours?

4. EXPLAIN: Why? Explain the reasoning behind your prediction.

AFTER THE EXPERIMENT: Answer these questions after the experiment.

5. OBSERVE: Describe the observed color changes in the BTB for each treatment after 24 hours. Draw a table to summarize your results below or on a separate sheet.

6. EXPLAIN: Do these results match what you predicted above? Why or why not? What do you think caused these differences?

Name_____ Date_____ Hour_____

Experimental Design Considerations for Titration

Based on what you know about biological activity in soil under different conditions, develop a hypothesis that tests a specific concept or idea about CO_2 production in the soil microbial community. Hypotheses may relate production to different soil types or habitats; treatments like compost, fertilizer, or sugars; different temperatures (ranging from 0-40° Celsius) or incubation times (from 1-14+ days). Next, decide how you might test your hypothesis in terms of specific variables. Think about why separate jars for replicates and controls are needed. Recall that replicates are identical microcosms set up within each treatment while controls are used to measure CO_2 in the air, without soil added to the jar. The results from the control are subtracted from all samples.

Before you design your experiment, be sure you can answer the following questions:

1. What is the role of the NaOH trap? How does it work?

2. Explain why one control must be a jar with an NaOH trap, but without soil.

3. What other control do you need? Why?

Name_____ Date_____ Hour_____

Lab Method: Acid-Base Titration

Preparing the microcosms

1. Following your experimental plan, gather mason jars, lids, 30 mL tubes, soil, water, and other supplies.
2. Use tape to label each microcosm with your name, treatment, replicate number, and date.
3. Weigh approximately 150 g soil, add it to each jar, and record the mass of soil added to each microcosm (it is not important to get exactly 150 g soil, as long as you note the actual amount).
4. Once the soil is in the jar (and before it is sealed), add enough water to make the soil moist, but avoid water pooling at the bottom of the jar. 15-20 ml of water is typically sufficient for this. If your experiment involves additives (like fertilizer or sugars), mix these in with the water before adding to the microcosm.

Preparing the CO_2 traps

Safety note: Sodium hydroxide (NaOH) is corrosive. Wear safety goggles and gloves when carrying out these steps. Promptly rinse any NaOH solution on hands, eyes, or clothing with water.

NaOH works as a carbon "trap" by reacting with the CO_2 gas in solution to produce carbonic acid, as shown in the following equation $2\ NaOH + CO_2 \rightarrow H_2CO_3 + 2\ Na^+ + O^{2-}$

5. Label one freestanding 30 mL centrifuge tube for each microcosm to match the labels on the mason jars.
6. Carefully dispense 15 ml of 1 M NaOH into each of the 30 ml centrifuge tubes; each tube is now a CO_2 trap.
7. Gently press the CO_2 trap for each microcosm into the soil far enough so that the opening of the trap is below the mouth of the jar by at least one centimeter. Do not put the lid on the tube trap. Set the lids aside for later. See Figure 1.
8. Carefully wipe all soil from the rim of the jar and slightly moisten the rubber seal in the mason jar lid with a damp paper towel.
9. Seal the lids of the jars (not the centrifuge tubes) tightly. See Figure 1.
10. Incubate your microcosms as your experimental design specifies. Be careful not to tip the CO_2 trap.

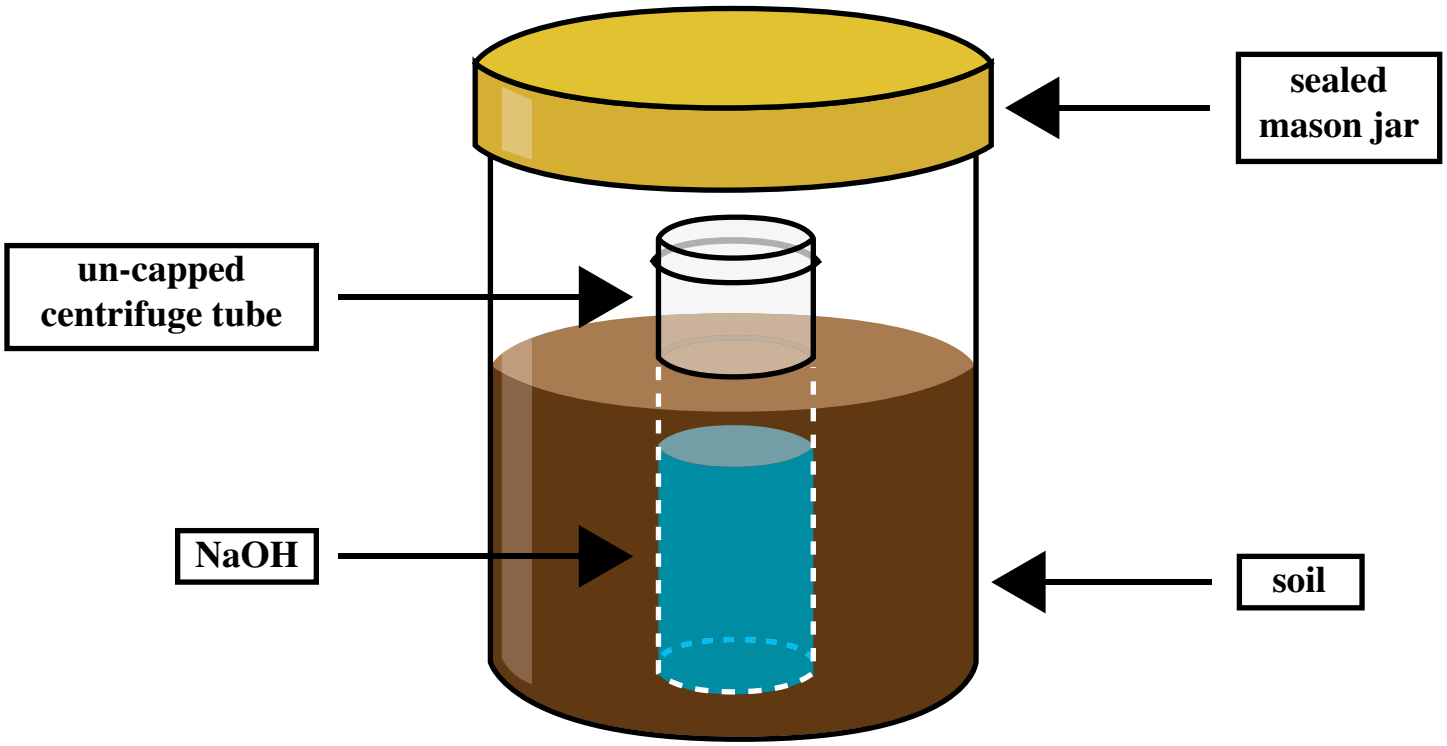


Figure 1. CO_2 trap ready for incubation

Figure 1. Carbon dioxide trap set up. Note that the Mason jar lid is on, while the centrifuge tube lid is off. Save the centrifuge tube cap for later.

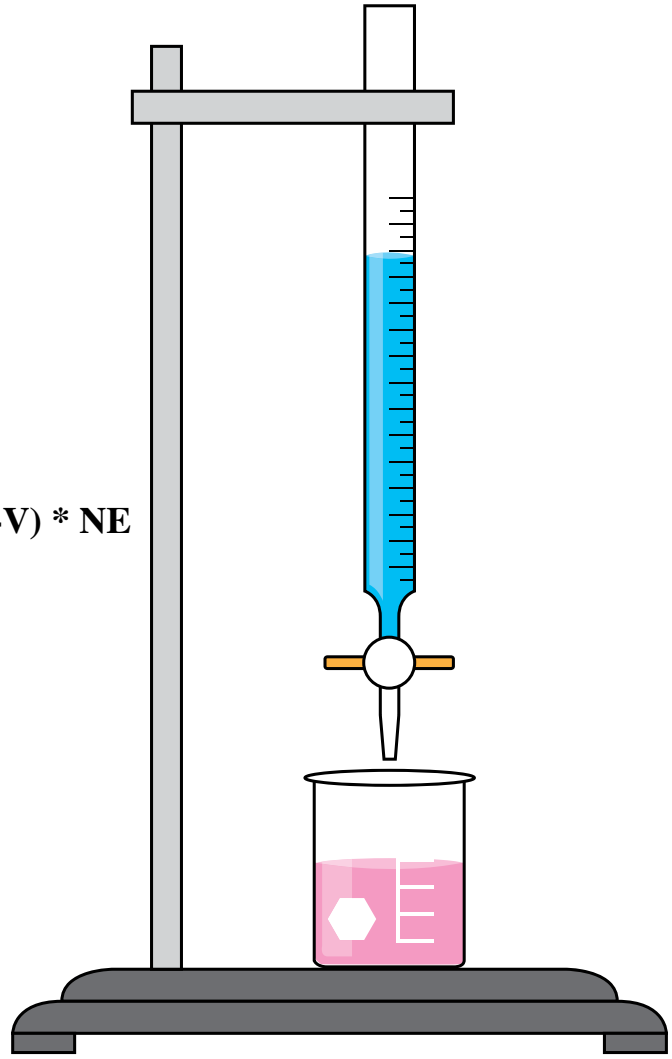
Determining the amount of CO_2 produced

Safety Note: NaOH and Hydrochloric Acid (HCl) are corrosive. Wear safety goggles and gloves when carrying out these steps. Promptly rinse with water any NaOH or HCl solution from hands, eyes, or clothing.

Phenolphthalein acts as a pH color indicator that changes from pink to clear at approximately pH 8.2. $BaCl_2$ precipitates carbonate (which may be present in distilled water used to make dilutions of NaOH and HCl) as insoluble barium carbonate. 1.0 M NaOH has a pH of 13.5; 1.0 M HCl has a pH of 2.

1. Open one microcosm at a time, carefully lift out the CO_2 traps, and seal them tightly with a cap. Avoid splashing any of the NaOH solution. The trap can be titrated immediately or stored at room temperature indefinitely in sealed titration trap.
2. Pour the NaOH solution into a 50 mL beaker and add 2-3 drops of phenolphthalein and 1.0 ml of 50% $BaCl_2$. You can rinse out the beaker and reuse it after step three.
3. Use a burette to titrate the NaOH solution with 1 M HCl. Titrate slowly (add 0.5 ml at a time)

and swirl gently until the solution changes from pink to white-clear. You will know the endpoint is approaching because the solution will shift from dark pink to light pink in color. Approach the endpoint slowly because the color change occurs quickly. Record the exact volume of acid required on the worksheet.



4. Calculate the amount of CO_2 produced using the following formula:

   Milligrams (mg) C or CO_2 = (B-V) * NE

   where:

   B = Volume (ml) of HCl to titrate NaOH in the CO_2 collectors from the control

   V = Volume (ml) of HCl to titrate NaOH in the CO_2 collectors from the samples

   N = the normality of the acid (for HCl, 1N = 1M, so N = 1)

   E = equivalent weight. If results are expressed in terms of carbon, E = 6; if expressed as CO_2, E = 22.

5. Divide the result for each microcosm jar by the mass of soil in that jar in order to express the results as mg of CO_2 produced per gram of soil.

Example: 150.5 grams of soil placed in a jar; B = 12mL; V = 9 mL

mg CO_2/g soil = (12-9) * 1 * 22 / 150.5

= 0.512 mg CO_2/g soil

Name_____ Date_____ Hour_____

Data Table for Soil Titration

(the 2 controls are started for you)

Jar #	Treatment	Replicate number	Incubation temperature	Mass of soil	mL HCl used in titration	mg CO_2/g soil
	Control - no soil--room temp	*1*	*°C*	*0 g*		
	Control - no soil--room temp	*2*	*°C*	*0 g*		

Name_____ Date_____ Hour_____

Analysis and Discussion Questions

Answer questions on a separate page.

1. After a class discussion on graphing and statistics, construct a graph to represent your data.
    a. Assess whether your data support your hypothesis.
    b. Using scientific reasoning, discuss possible reasons for the relationships you see in average CO_2 production between treatments.
    c. Discuss any sources of error in your experiment and explain how you would redesign your experiment to account for these.

2. Organisms above- and below-ground respire and produce CO_2, and they are assembled into complex ecosystems.
    a. How do organisms above- and below-ground function similarly in terms of respiration and metabolism?
    b. Draw a diagram which demonstrates how carbon moves through your study site. Include the plants, roots, soil organisms with linking verbs describing the processes that are occurring.

3. How do you think climate (especially temperature and moisture levels) affects the rate of soil carbon cycling in each of the following states: Alaska, Minnesota, New Mexico and Florida?

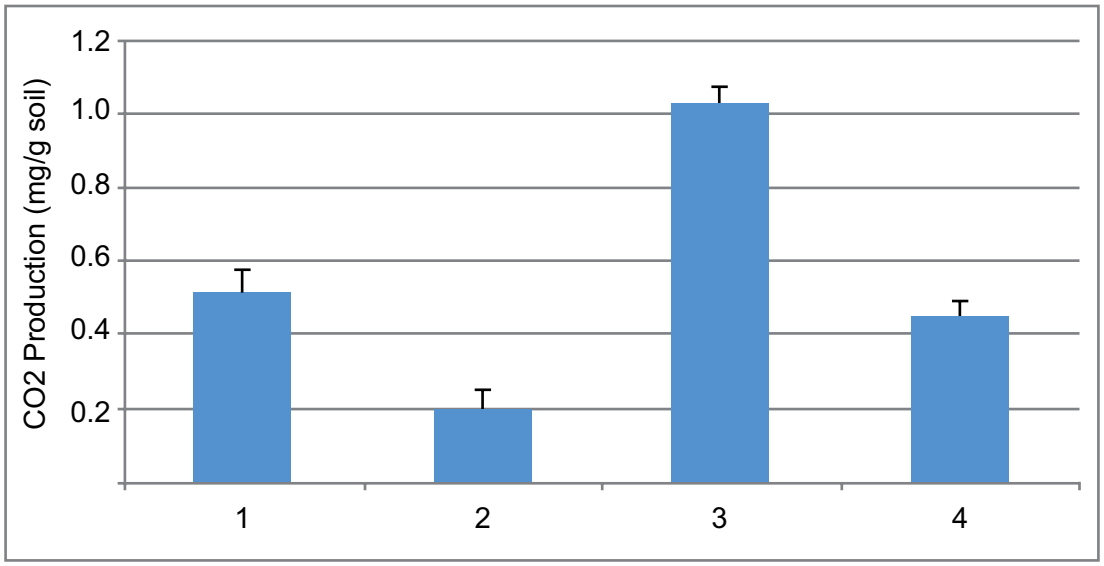
4. CO_2 production by soil microbial communities is often discussed in relationship to large-scale trends in atmospheric CO_2 concentrations and global climate change. Think about your answer to the previous question. The Arctic, including the permafrost in Alaska, is currently experiencing a significant rise in overall temperatures. How might this affect the rate of soil respiration in this region? Would you expect this change to lead to a global change in the atmospheric CO_2 levels?

5. In terms of greenhouse gas emissions from soils, what might be the advantage of growing perennial prairie grass plots for biofuels instead of annual crops, such as corn? Provide one additional piece of advice for a farmer who is trying to decide what to grow or how to grow crops to be used for biofuels if they want to reduce overall emissions from their field.

Name_____ Date_____ Hour_____

Making Predictions about Cellular Respiration by Soil Microbes

The data below show measured microbial activity from four soil samples from different habitats – corn field, old field (overgrown farmland), lawn, and forest.



1. Examine the data above for each soil type. Label each bar (1-4) with the corresponding habitat. Provide a rationale for your predictions. Feel free to use the back of this page if you need more space.

2. Were your predictions correct? Provide logical explanations for any discrepancies.

Types of Soil Microbes and their Function in Ecosystems

Table 1 summarizes the ecosystem functions carried out by soil microbes, and Table 2 indicates the relative density of the major groups of soil microbes in grassland ecosystems. Besides plant roots, soil microbes are by far the most abundant biotic component of soil. Although the values in Table 2 change from ecosystem to ecosystem (e.g., forests have a higher fungi:bacteria ratio due to their tendency to have moist, more acidic soil and the abundance of tough, woody material that fungi are better adapted to break down) this is a useful starting point.

Table 1. Essential ecosystem functions performed by different members of the soil biota.

Ecosystem Function	**Organisms Involved**
Regulation of soil water permeability	Burrowing invertebrates and plant roots
Gas exchanges and carbon sequestration	Mostly microorganisms and plant roots, some C protected in large compact invertebrate aggregates
Soil detoxification (e.g., biological breakdown of soil pollutants)	Mostly microorganisms
Nutrient cycling	Mostly microorganisms and plant roots, some soil and litter feeding invertebrates
Decomposition of organic matter	Invertebrates and microorganisms

Table 2. Approximate range of biomass of each major component of the microbial biota in a typical grassland soil. Earthworms and "other" (e.g., burrowing mammals) included for comparison.

Component of Soil Biota	**Biomass (tons per hectare)**
Plant roots	Up to 90 but usually ~20
Fungi	2-5
Bacteria	1-2
Actinomycetes	0-2
Protozoa	0-0.5
Nematodes	0-0.2
Earthworms	0-2.5
Other	0-0.5

Fungi

By weight, fungi are the dominant soil microbe biota. Their cells contain nuclei and are therefore eukaryotic, although some are unicellular with multiple nuclei. They reproduce both asexually and sexually by producing spores (Table 3) which are capable of surviving prolonged periods of nutrient deprivation. Because of their larger size, they are found in larger spaces between clumps of soil particles.

Their appearance is similar to that of the actinomycete bacteria, but they are much larger, with a diameter of 2-10 μm and a length up to 50-100 μm. In one extreme exception, researchers in northern Michigan (Smith et al., 1992) discovered a fungus estimated to be 21,000 pounds, 30 acres wide, and 1500 years old; other similarly large soil fungi have since been discovered. Though not as large as giant redwoods, these discoveries make fungi among the largest and oldest living things on earth.

Fungi are obligate aerobes, unable to survive in anoxic conditions. They have a variety of life history strategies, but their most important ecological role is that of decomposer. They are able to break down very tough molecules such as lignin and soil humic acids. They are able to tolerate acidic conditions better than bacteria, and in extremely acidic forest soils (such as in coniferous forests) they perform a task usually restricted to bacteria, that of fixing nitrogen

Bacteria

Soil bacteria are the most numerous (though not the largest by mass- see Table 1) component of the soil microbe community. They are typically 3 μm in size. Bacteria are often found adhering to soil particles via chemical bonds, and many are aquatic in that they survive in thin films of water adhering to soil particles. Some are capable of movement using one or more flagella that extend from their cell membrane (see Figure 2). They reproduce asexually by budding or, less commonly, binary fission. Some bacteria only survive in aerobic conditions (obligate aerobes), some prefer aerobic conditions but can tolerate anaerobic ones (facultative anaerobes), and some can only survive in anaerobic conditions (obligate anaerobes).

There is a wide variety of bacteria in the soil. When compared to bacteria grown in a lab culture, soil bacteria in their natural habitat are enveloped by a thick mucilaginous shell that is thought to protect them from changes in moisture, pH, and other conditions. Bacteria must be able to adapt to periods of severe lack of food or water by shifts in metabolic activity and structures such as the mucilaginous shell. Some species form spores under extremely dry conditions and will return to their normal shape when moisture returns.

The type of bacteria in the soil depends on the conditions of the soil. Oxygen-deprived soils, for example, are likely to be dominated by members of the genus Clostridium. Bacteria are also more common in smaller soil pore spaces where they are protected from predation by protozoa and nematodes.

Besides their important role in decomposition, bacteria are also key to nitrogen cycling, as they are the most important soil microbe involved in fixing atmospheric nitrogen into an organic form and also, in some groups such as those in the genus Nitrosomonas, mineralizing it to an inorganic form.

Actinomycetes are a type of bacteria that are often discussed separately because of their unique shape. Rather than being rod or sphere shaped as other bacteria are, actinomycetes form long stringy, hair-like networks called hypha (collectively called mycelium) that reproduce asexually via spores. Their growth is similar to that of fungi described below, but their hypha are considerably smaller (10-15 μm long by 0.5-2 μm wide). Actinomycetes decompose a wide variety of substances, many of which are difficult to break down and include chitin (the outer covering of fungi and many invertebrates) and cellulose. They are far more common in high pH soils and tend to be replaced by bacteria and fungi in lower pH soils. They are also more common in soils located in drier and hotter regions.

These microbes also have life history traits of wide interest to people. They are responsible for secreting many antibiotics now used in medicinal applications - such as streptomycin - which were discovered in the 1950s to be able to combat bacterial infections in humans such as strep throat. In their natural habitat, it is thought that these compounds play a role in protecting actinomycetes from predation by other soil microbes. A second interesting fact is that actinomycetes secrete an organic compound, geosmins, that contribute to the earthy smell of soil most easily noticed after a rainfall.

Protozoa

Amoeba, Ciliates, and Flagellates belong to a group of organisms known as protozoa – single celled but with a nucleus. They reproduce asexually and sexually. They are typically 10 μm in diameter and live in soil pore spaces of that size or larger. Flagellates have 1 to 4 whip-like projections called flagella that aid in locomotion; ciliates have many small hair-like projections (these can number in the thousands) that help them move. Amoeba move by use of pseudopods – extensions of their flexible membrane pushed forward by internal body fluids. They therefore continuously change shape as they move about the soil environment. Amoeba require relatively moist soil to be active, and research suggests that amoeba spend much of their life as cysts since soil conditions are often too dry.

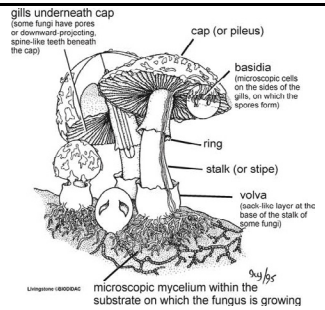
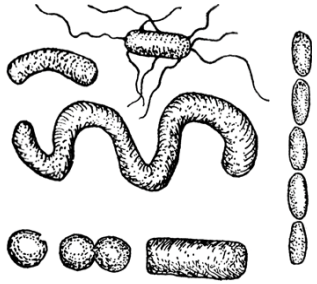
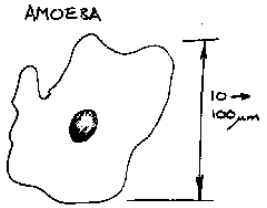
They are mainly predators, feeding on bacteria and some fungi, but they also process fine organic particles, either as free-living organisms or inside the gut of a host organism such as termites. Bacteria are able to protect themselves from some protozoan predation due to their ability to inhabit soil pores too small for amoeba to reach.

Nematodes

Nematodes are typically 1mm in length and 0.05 mm in diameter. They reproduce sexually. Nematodes are mostly parasites (of plants and other soil microbes) and predators; their role in causing diseases of agricultural crops makes them a frequent pest for farmers, but they also play an important role in the decomposition process. Nematodes are large and therefore inhabit films of water surrounding large soil pores. They are capable of forming cysts to survive drought periods.

Name_____ Date_____ Hour_____

Description of Soil Microbe Community

	How they look	Abundance (tons/hectare)	Habitat characteristics	Potential role in food chain and ecosystem
Fungi				
Bacteria				
Protozoans				
Nematodes				

adapted from Killham 1999