Rationale

Students should derive their own rationale for the hypothesis.

Sample Experimental Procedure

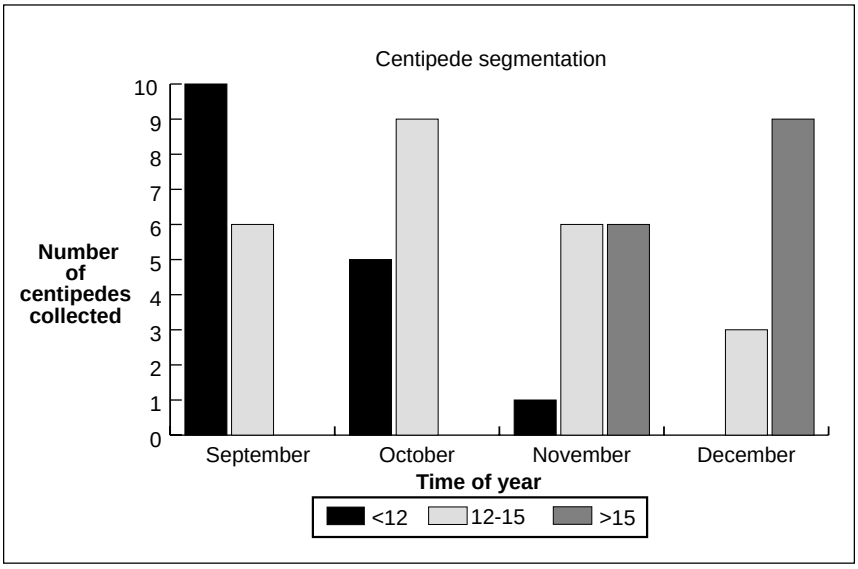
Collect soil-surface samples at various times during the year. Follow the sample procedure in the Core Experiment. Isolate the centipedes and determine the number of individuals of different ages by assuming that number of segments is correlated with age.

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 5. Hypothetical seasonal changes in the segmentation of a centipede population.

Month of collection	Number of centipedes in each size class		
	<12 Segments	12 to 15 Segments	>15 Segments
September	10	6	0
October	5	9	0
November	1	6	6
December	0	3	9



Graph C. Centipede segmentation over a four-month period.

Analyze these data for each size category by graphing the number of centipedes collected versus time of year. Advanced students can use Chi-Square Goodness of Fit Test to determine whether their results differ from a uniform distribution.

Interpretation

Accept the hypothesis only if data show consistent decreases in the number of small individuals and consistent increases in the number of large individuals. The hypothesis should be rejected if all size or age categories are present during every sampling period.

TEST QUESTION

If all members of one population within the community are similar in size and age, what does that tell you about the population?

Answer to Test Question

All members of the population belong to the same generation.

VARIATION 4
The Survival of Soil-Dwelling Organisms Following a Controlled Burn of Coastal Bermuda Grass

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 4.

SYNOPSIS

Students will collect and process Berlese-Tullgren samples from a Bermuda grass pasture before and after a controlled burn. They will evaluate the species diversity in both samples.

SAFETY PROCEDURE

The area should not be burned by the students. Fire departments and the park service do controlled burns. Any burn should be controlled carefully and should have been planned by one of these groups, not conducted solely for this exercise.

HYPOTHESIS GENERATION

Question

What effect does fire have on the organisms in the soil interface?

Sample Hypothesis

Fire will kill all the soil-surface organisms.

Rationale

Organisms cannot withstand the high temperatures and destruction of the fire's flames.

Sample Experimental Procedure

Collect soil-surface samples before and after a controlled burn of coastal Bermuda grass. Follow the sample procedure for the Core Experiment.

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 6. Number of species present in soil-surface samples before and after a controlled burn of coastal Bermuda grass.

Common name of grouped species	Number of species present	
	Before burn	After burn
Annelid worms	1	1
Spiders	3	0
Mites	5	3
Centipedes	1	0
Millipedes	2	1
Springtails	5	1
Grasshoppers & crickets	1	0
Thrips	1	1
Beetles and weevils	3	2
Cockroaches	1	1
Ants, bees, and wasps	3	2

TEACHING TIP

Students can take additional samples over the next several months to measure the rates of recolonization for various taxa.

Interpretation

The hypothesis should be accepted if the kinds of species differ before and after the fire. No individuals from any species will be present. Reject the hypothesis if some of every species group survive. Some taxonomic groups may be more heat-tolerant than others. Some may be less susceptible because of their position in the soil strata.

Answer to Test Question
60%

To analyze these data, calculate the total number of species collected before and after the burn. This number should be expressed as a percentage of the original density. Advanced students can use a diversity index to compare the samples. (See Core Experiment for instructions for calculating a diversity index.)

TEST QUESTION

Using the following information, what percent of mites survived after burning?

Table 7. Number of species present in humus samples before and after a controlled burn of coastal Bermuda grass.

Common name of grouped species	Number of species present	
	Before burn	After burn
Annelid worms	1	1
Spiders	3	0
Mites	5	3
Centipedes	1	0
Millipedes	2	1
Springtails	3	1

VARIATION 5
The Arthropod Fauna in Different Types of Compost

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 5.

SYNOPSIS

Students will collect and process Berlese-Tullgren samples from two compost piles, one containing mostly grass and the other containing mostly leaves. They will identify and count all representatives of major taxa.

HYPOTHESIS GENERATION

Question

Is there a difference in the number of organisms found between compost piles with leaves and ones with grass growing?

Sample Hypothesis

The relative abundance of animal species will be lower in samples from the compost pile containing mostly grass than in the compost pile of leaves.

Rationale

There will be fewer organisms in the compost pile with grass, as there will be less decaying matter as an energy source.

Sample Experimental Procedure

Collect samples of several types of compost. These types may include compost from leaves, grass clippings, vegetable scraps, or a mixture of leaves, clippings and vegetables. Follow the sample procedure for the Core Experiment.

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 8. Number of individuals in samples collected from several types of compost.

Common name of grouped species	Number of individuals present	
	Leaf-rich compost	Grass-rich compost
Annelid worms	4	6
Spiders	6	8
Mites	18	4
Sowbugs	10	8
Centipedes	3	7
Millipedes	6	6
Symphylans	15	9
Springtails	57	43
Thrips	12	5
Ants	10	4
Beetles	7	3

Analyze these data by ranking the identified arthropods by abundance. Determine which groups are most and least abundant and draw pie charts showing the relative abundance of each group. Advanced students can also use a diversity index to compare samples.

Interpretation

Accept the hypothesis if there is a difference in the rank order of the groups between compost piles. Reject the hypothesis if the ranking is similar for all types of compost.

TEST QUESTION

Which variable is LEAST likely to affect the abundance of insects in a compost pile?
A. Moisture content
B. Distance to woods
C. Temperature
D. Predators

Answer to Test Question

B

VARIATION 6
The Density of Small Annelids in Soils with Different Moisture Contents

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 6.

SYNOPSIS

Students will collect samples from sites with different percent moisture content and process in a Berlese-Tullgren. They will count all collected enchytraeid worms.

TEACHING TIP

Let students discover on their own that soils with 30 to 85% moisture will have fewer worms than soils with 0 to 20% moisture (Wallwork, 1976).

HYPOTHESIS GENERATION

Question

How does moisture content of soil affect worm population?

Sample Hypothesis

There will be more worms in moist soil than in dry soil.

TEACHER'S NOTES

Interpretation

If the number of worms increases with increasing soil moisture, accept the hypothesis. If the number of worms does not increase with increasing soil moisture, reject the hypothesis.

Rationale

Worms need moisture. Without it, they dehydrate and die. Therefore, worms should be found in higher density in moist soils.

Sample Experimental Procedure

Choose three sample collection sites that appear to have consistently different moisture content, such as a frequently watered lawn area and a lawn not well watered. Collect two samples from each site. One sample from each site will be treated according to the procedure from the Core Experiment. The second sample from each site will be examined for its moisture content. The moisture content can be determined by first massing the sample, and then drying it in an oven at 100˚C overnight before massing again. Use the following equation to calculate the moisture content:

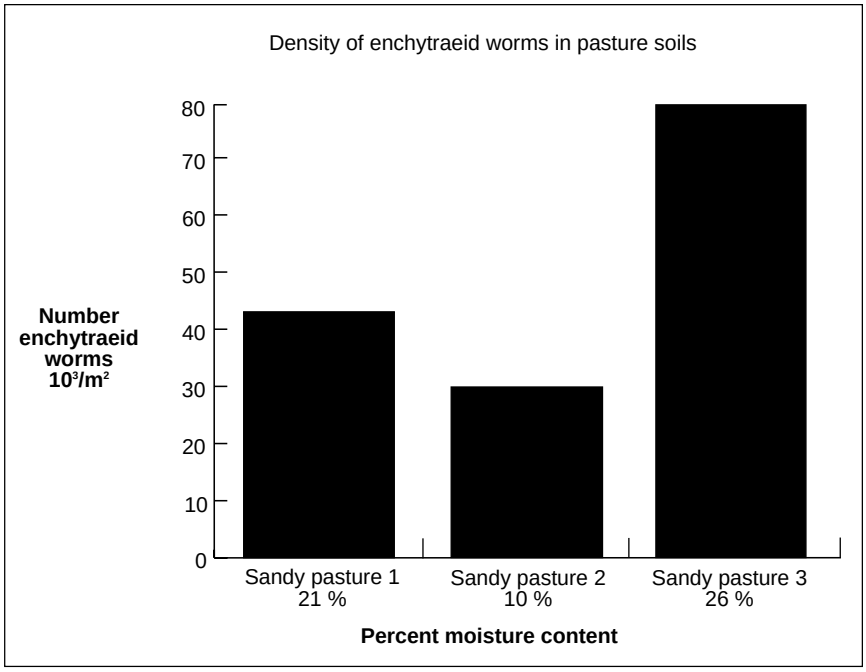
$$\frac{\textit{Mass of Dried Sample}}{\textit{Mass of Undried Sample}} \textit{ x 100\% = \% Moisture Content}$$

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 9. Density of enchytraeid worms in pasture soils. The worm density data are summarized from the literature in Wallwork (1970). The moisture content values are hypothetical.

Site	Number of enchytraeid worms ($10^3/m^2$)	Percent moisture content
Sandy pasture 1	44	21
Sandy pasture 2	30	10
Sandy pasture 3	74	26



Graph D. Enchytraeid worm density.

TEST QUESTION

How would you use soil moisture data to find the best site for collecting fishing worms if large fishing worms are influenced by soil moisture the same way enchytraeid worms are influenced?

Answer to Test Question

One would select soils with high moisture content over sites with lower moisture content because more earthworms are in moist soil.

VARIATION 7
The Soil pH and Diversity of Soil Organisms

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 7.

SYNOPSIS

Students will collect and process Berlese-Tullgren samples from sites with different hydrogen ion concentrations. They will identify, classify, and count all organisms collected.

MATERIALS NEEDED

- 1 vial Hydrion paper (pH 1 to 12)

HYPOTHESIS GENERATION

Question

How does soil pH affect species diversity?

Sample Hypothesis

Species diversity will decrease as the pH diverges from the neutral pH 7.

Rationale

Organisms survive within specific pH ranges. A neutral pH is optimum. Variance from this would be injurious to the organism.

Sample Experimental Procedure

Test the pH of soil from sites that you expect might have a different pH. Test the soil pH by mixing a match-head sized chunk of soil with about the same volume of water to make a paste. Use Hydrion paper to determine the approximate pH. Collect samples from soils of high, low, and neutral pH. Treat them according to the instructions for the Core Experiment.

TEACHING TIP

Acidic sites are likely to be found under pines or where acid rain is a problem. Basic sites are likely to be found in areas used by animals, lime-treated soils, or near lime outcroppings.

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 10. Number of soil organisms from soils of different pH values. The organism values are approximated from data summarized from the literature in Wallwork (1970). The pH values are hypothetical.

Common name of grouped species	Number of individuals collected per m^2 from:		
	Limestone grassland (pH 8.2)	Moor (pH 7.8)	Grassland (pH 6.9)
Ticks and mites	45,300	43,000	78,800
Collembola	77,900	38,900	55,900
Enchytraeid worms	18,500	195,000	123,000
Lumbricid worms	389	0	11

Calculate Simpson's Diversity Index. See the Core Experiment for directions.

Interpretation

Each group of organisms tends to have a pH that is specific to their survival.

TEST QUESTION

How does water pH affect diversity?

Answer to Test Question

Answers will vary with student creativity. They could search for bodies of water with different acidity or take water from one site and observe changes after altering the pH.

VARIATION 8
Carnivores and Herbivores in the Schoolyard

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 8.

SYNOPSIS

Students will determine the number of herbivores and carnivores in the schoolyard. Based on these findings, they will determine whether herbivores' or carnivores' survival is more adapted to this environment.

HYPOTHESIS GENERATION

Question

Are more herbivores or carnivores found in schoolyard soil surface?

Sample Hypothesis

More herbivores than carnivores will be found in a soil-surface sample collected from school grounds.

Rationale

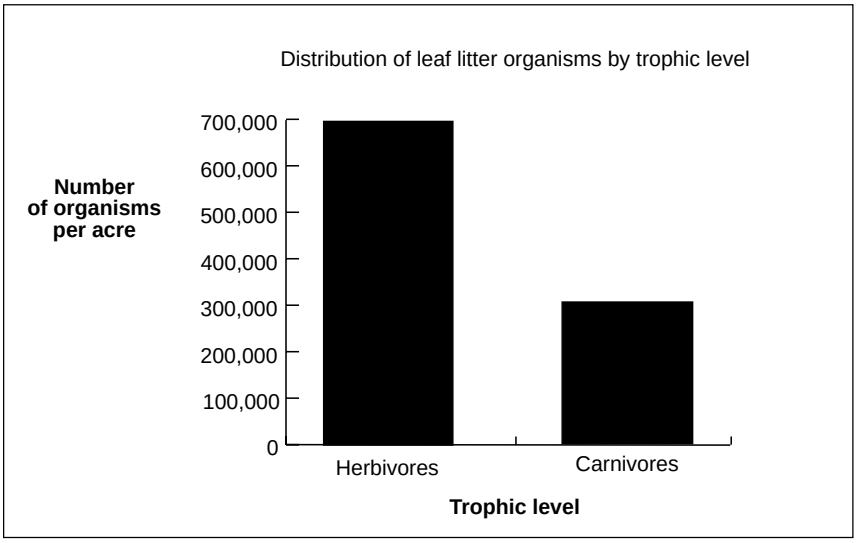
Students should derive their own rationale for the hypothesis.

Sample Experimental Procedure

1. Collect soil-surface samples from the school ground.
2. Follow the sample procedure from the Core Experiment.
3. Determine how many of these organisms were herbivores or carnivores.

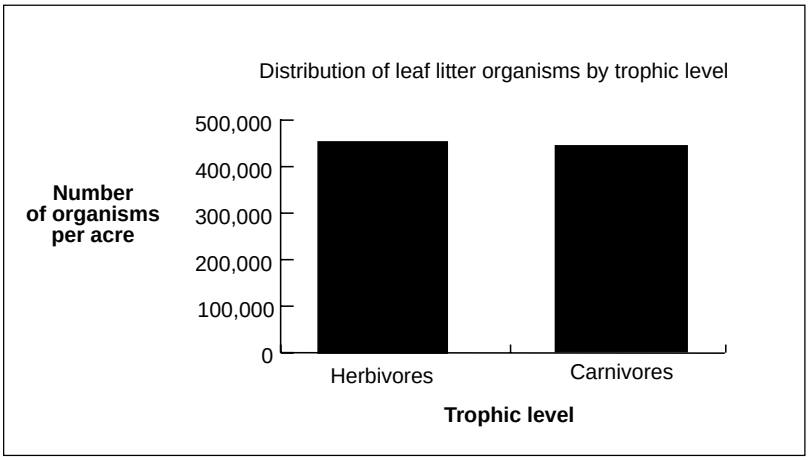
DATA ANALYSIS AND INTERPRETATION

Sample Data 1



Graph E. The number of soil organisms by diet collected per acre from leaf litter of a wet bottom area during spring.

Sample Data 2



Graph F. The number of soil organisms by diet collected per acre from leaf litter of a wet bottom area during spring.

TEST QUESTION

Examine the two graphs above. Account for the different ratios of herbivores to carnivores in the two communities.

Interpretation

More herbivores than carnivores were found in the sample of humus from the schoolyard, so the hypothesis is supported.

Interpretation

The same number of herbivores and carnivores were found in the sample of humus from the schoolyard, so the hypothesis is not supported.

Answer to Test Question

One would expect more herbivores than carnivores in a community because only 10% of the energy available to the herbivore is available to the carnivore that consumes it. This is based on the assumption that herbivores are smaller than carnivores. The second set of data, however, shows equal numbers of herbivores and carnivores—something unexpected. This may be explained by a larger biomass for individual species of herbivores than their carnivore predators. Also, the carnivores may consume other organisms such as decomposers, thus giving them an alternative food source. In any case, the carnivores will receive only 10% of the energy originally available to their prey.

TEACHING TIPS

- Results are likely to be different in soils of different textures.
- A calibrated ocular micrometer will facilitate sizing.
- Biomass also can be used to assess size. Although biomass values, such as those shown in Table 11, are more common in the literature, they will be very difficult for students to collect.

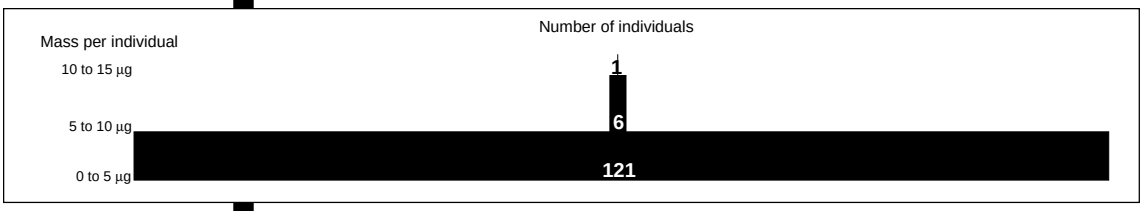
VARIATION 9
Organism Size Distribution

Note to Teachers: In addition to the information found in the Core Experiment, the following material has been provided for Variation 9.

SYNOPSIS

Students will collect and process Berlese-Tullgren samples from one site. They will count the number of organisms in each of several sizes of classes determined by body length.

Table 11. This pyramid of numbers, constructed from data presented in Engelmann (1961), shows the inverse relationship between body size and population density.



HYPOTHESIS GENERATION

Question

Is there a relationship between an organism's size and the number of individuals that will be found in a sample?

Sample Hypothesis

The number of individuals will increase as their size decreases.

Rationale

The smaller in size the organism, the greater the number of this species found in the sample.

Sample Experimental Procedure

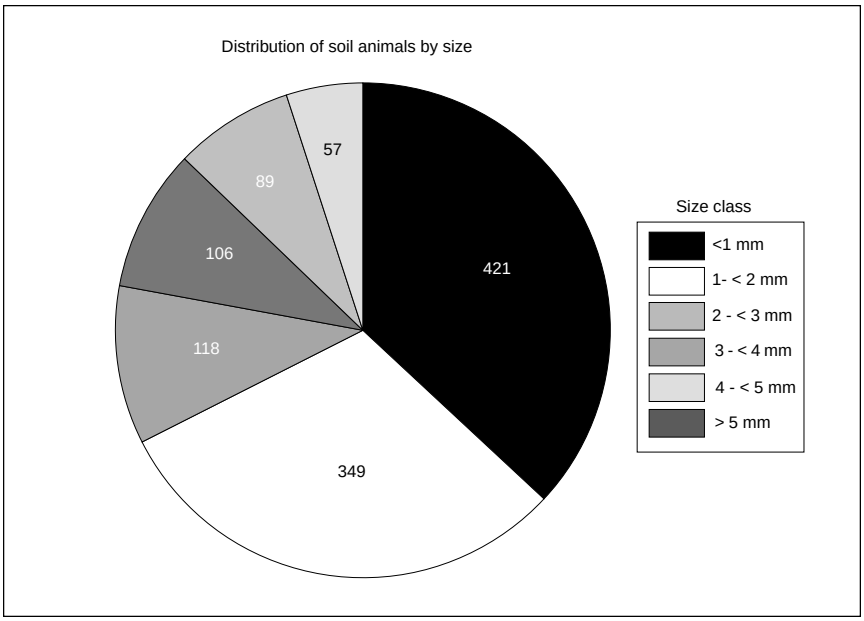
Collect a sample from forest or grassland soils and treat it according to the instructions for the Core Experiment. Establish size classes at millimeter intervals for organisms less than 5 mm long.

DATA ANALYSIS AND INTERPRETATION

Sample Data

Table 12. Distribution of soil animals by size. These data are for cryptozoa from South Africa forest soils (Birch & Clark, 1953).

Size class	Number of organisms
<1 mm	421
1-<2 mm	349
2-<3 mm	118
3-<4 mm	106
4-<5 mm	89
>5 mm	57



Graph G. Distribution of soil animals by size.

TEST QUESTION

Design an experiment to determine whether the size distribution of soil organisms varies with soil texture.

Interpretation

Accept the hypothesis if the number of organisms decreases with increasing size. Reject the hypothesis if there are more organisms in the larger size classes.

Answer to Test Question

Answers will vary, but should include sampling from at least two sites, analyzing the texture of the soil and counting organisms by size class.

A Community Underfoot: Density and Diversity of Invertebrates in Soil or Ground Cover

Directions for Students

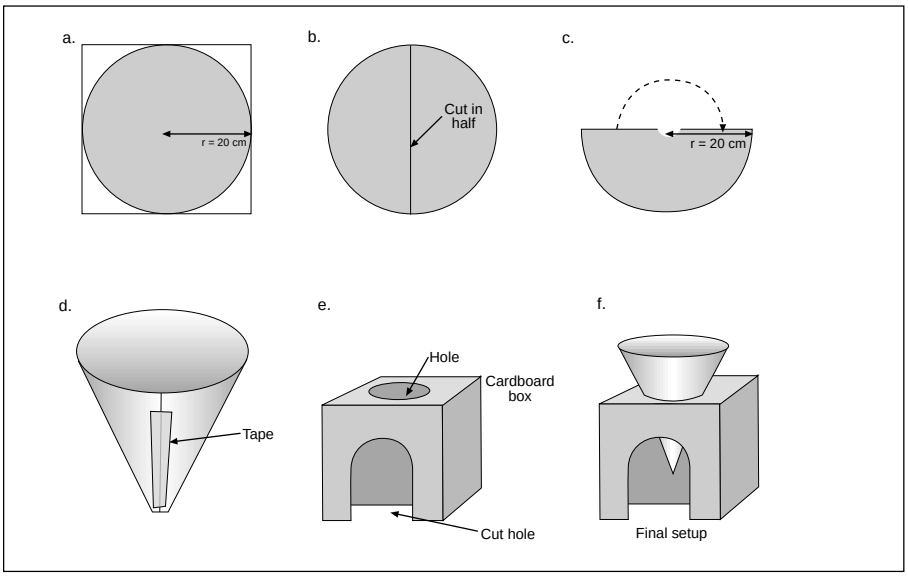


Figure 1. Extraction funnel assembly.

INTRODUCTION

Have you ever wondered what type of life exists beneath your feet? What do the organisms look like? How big are they? What do they eat? Do they benefit humans? You will explore the cryptic creatures of the below-ground world as you create and use a sampling device, learn to identify them, and construct simple trophic pyramids with your data.

OBJECTIVES

At the end of this lab, you should be able to:

- Construct a Berlese-Tullgren funnel to sample invertebrate fauna in soil or ground cover samples.
- Estimate the population density and diversity for different environmental conditions.
- Describe the effects of specific environmental variables on a target population or community structure.

SAFETY PROCEDURES

Wear gloves whenever handling soil samples and wash your hands at the beinning and end of the lab.

Do not use alcohol near an open flame, as it is flammable.

Do not drink the alcohol or inhale its fumes.

Have adequate ventilation in the classroom.

Reduce vapor levels by using a collecting jar that fits snugly with the funnel. Keep collecting jars and petri dishes covered.

Keep the 25-watt bulb at least 15 cm away from the larger Berlese-Tullgren funnel sample to prevent the ignition of any dry leaves.

Disturb the soil-surface as little as possible when collecting samples.

MATERIALS NEEDED

You will need the following for each group of two students in a class of 24:

- 3 2-L plastic soda bottles
- 1 pair scissors
- 3 10 x 10 x 5-cm soil-surface samples
- 1 pair of gloves
- 3 1-L (1-quart) sealable, plastic bags
- 3 10-cm^2 square 1/4 or 1/8-inch mesh hardware cloth or plastic needlepoint backing
- 3 500-mL glass jars with 7.5-cm diameter openings with tight lids
- 3 9-watt colorless light bulbs and 3 1-socket sections of a string of holiday lights or 3 25-watt shielded lights
- 1 stereoscope
- 1 eyedropper
- 1 forceps
- 1 9 x 14-cm (8.5 x 11-inch) sheet each of black and white construction paper
- 3 10-cm^2 square of aluminum foil or dark paper
- 5 sheets of newspaper
- 150.0 mL 70% isopropyl alcohol
- 1 garden trowel

STUDENT LITERATURE SEARCH SUMMARY WITH REFERENCES

Do a literature search on the topic of soil organisms and ecology. Summarize your findings and cite your references. Your teacher may be able to suggest some references.

HYPOTHESIS GENERATION

From the information you have on this topic, develop a hypothesis that could be tested in a controlled experiment that gathers quantitative data. Explain the reasoning behind your hypothesis.

Answer the following questions:
1. What is the question you are investigating?
2. Why is controlling variables important?

PLAN OF INVESTIGATION

Make a numbered list of the steps you will use to investigate your topic. Answer the following questions:
1. How many samples have you included?
2. What will you measure?
3. How can you show your results in a graph?

Design an experiment to test your hypothesis. Be sure that you include an experimental control and enough replicates to provide reliable data. Consider how you will analyze and present your results. Write the procedures you will follow.

You must have your teacher approve this protocol before you begin this experiment.

QUESTIONS AND ANALYSIS

Once you have collected and analyzed your data and graphed your results, answer the following questions:
1. Construct a bar graph showing kinds of organisms collected and their abundance.
2. Do your data support or refute your hypothesis?
3. Using your specific data, explain your answer to Question #2.

4. Compare your data with that of other groups. Are these data the same or different? Why or why not?
5. Why is it necessary to have repeated sampling?
6. Will the number or kinds of organisms found in a sample always be the same?
7. What could cause the difference? Be specific.
8. What did you learn from this activity?
9. Make a statement that represents what you learned about animal diversity in the soil.

DESIGN OF VARIATIONS OF CORE EXPERIMENT

After collecting and analyzing these data from the Core Experiment and sharing the results and conclusions with the class, brainstorm ideas for experiments you could do next. Think of questions that occurred to you as you conducted the Core Experiment on organisms found in the soil surface. Design an experiment that is quantifiable and write your procedure in a numbered list of steps. Questions other students have studied include the following:

- How will cattle grazing affect density of mites in a pasture?
- Is millipede density affected by exposure to north- or south-facing slopes?
- Is the age of a generation of centipedes similar?
- What effect does fire have on the organisms in the soil interface?
- Is there a difference in the number of organisms found between compost piles with leaves and ones with grass growing?
- How does moisture content of soil affect worm population?
- How does soil pH affect species diversity?
- Are more herbivores or carnivores found in schoolyard soil surface?
- Is there a relationship between an organism's size and the number of individuals that will be found in a sample?