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Cornell Institute for Biology Teachers

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Title: **Food Preferences of Slugs** and **The Vermiculturist's Experiment**

Authors:
Diane Emord, Henninger High School, Syracuse, NY
Lindsay Goodloe, Learning Skills Center, Cornell University, Ithaca, NY
Mary Colvard, Cobleskill-Richmondville High School, Cobleskill, NY
Dan Flerlage, Alternative Community School, Ithaca, NY (created the "Vermiculturist's Experiment.")

Appropriate Level: Life Science, High School, Honors, and Advanced Placement Biology

National Science Standards:

- **Abilities of Scientific Inquiry**
  Identify questions and concepts that guide scientific investigations.
  Design and conduct scientific investigations.
  Recognize and analyze alternative explanations and models.

- **Understanding About Scientific Inquiry**
  Scientists usually base their investigations on the existence of questions or causal-functional questions.
  Scientists conduct investigations for a variety of reasons.

Living Environment **1-Inquiry, analysis, design**: 2-Research plan, hypothesis: 2.1, 2.3a-c, 2.4; 3-Analysis of results: 3.1, 3.3, 3.4all; **4-Content**: 5-Dynamic Equilibrium: 5.1a,b,d-f, 5.2a, 5.3a,b

Abstract:

Students will investigate the food preferences of garden slugs (*Arion subfuscus*) using simple equipment including margarine tubs, graph paper, scissors, and common plants, both wild and cultivated. The exercise is genuine scientific research in that: a) the student devises his/her own "research question" about slug feeding behavior, and b) the results are truly unknown to the student-experimenter (and possibly to the instructor) prior to the experiment. In carrying out the complete set of experiments described below, students learn that one way to achieve precision and accuracy is by designing experiments with many replicates.

The following laboratory write-ups are included:

I. *Slugs and the Scientific Method:* This exercise uses slugs to teach the difference between "observation" and "opinion" and introduces the concepts of "controls" and "hypothesis testing."
II. *The Vermiculturist's Experiment:* This paper exercise illustrates the importance of controls, variables, and replicates in experimental design.
III. *Food Preferences of Slugs:* Students design and carry out their own experiment to test a slug's preference between two or more food sources.
IV. Food Preferences of Slugs (continued)*: Students will also benefit from the opportunity to further practice their experimental design skills by looking more closely at the complex question of "How do you determine what a slug really likes?" This lab should be undertaken at a time of the year when slugs can be collected easily (see* ***Tips on Collecting Slugs*** *at the end of the Teachers Section.)*

Time Required: Approximately five 45-minute lab periods of in class time are necessary to carry out all parts of the lab. Minimal teacher preparation time required.

Additional Teacher Information

Information with which students should be familiar

- Students must be familiar with the importance of controls and variables in designing a scientific experiment.

Materials Required for Each of the Labs Presented:

Slugs and the Scientific Method:

- Slugs (at least one per team of students)
- Plastic container with lid to serve as "slug home"
- Slug food such as lettuce, other leafy plant material, and fruits
- Large petri dish to place slug into while making observations
- Metric ruler
- Hand lens
- Dissecting microscope (optional)

The Vermiculturist's Experiment: No additional materials required.

Food Preferences of Slugs and Food Preferences of Slugs

- Slugs - allow at least 2 per team of students (any species of slug or land snail will do)
- Plastic container to serve as "slug home"
- Slug food such as lettuce, other leafy plant material, and fruits
- mm graph grids photocopied onto transparency film
- Metric ruler
- Scissors

Preparation Instructions

- Virtually any species of slug or land snail could be used for this exercise, although some might be too large or small to be ideal. *Arion subfuscus*, a moderate-sized (50-60 mm), orange-brown species, is easily collected from lawns and gardens in Ithaca, New York and is well suited for this purpose. Other species of gastropods may be more common in other areas and could certainly be substituted. Land snails (*Helix*) may be ordered from a biological supply house.

- 8 ounce margarine tubs with perforated lids work well as small feeding containers for each slug or pair of slugs. If collection time is limited, you can often purchase small plastic tubs at your local delicatessen counter.

- A "slugararium" (a slug-filled aquarium with a lid) is an excellent way to display the animals before beginning the lab. If possible, set the slugararium up several days before the lab activity to heighten student interest in the slugs.

- The instructor's preparation time might be as little as 15 minutes per class, if students are enlisted to collect plants and slugs, to obtain empty margarine tubs (with lids), and to punch air holes in the lids. At least one hour of preparation time will be required, if the instructor assumes total responsibility for these tasks, including slicing fruits and vegetables into comparably thin sections,

- Slugs can be kept in the refrigerator for several weeks prior to doing the lab and while accumulating enough of them to supply each lab group. Air holes must be made in the lid of the container if none exist. The bottom of the container should be partially covered with water (~1mm) to provide a moist environment. Scraps of lettuce make satisfactory food. Be sure to set the slugs out of the refrigerator at least 24 hours before beginning the experiment.

- Plant material of various kinds can either be gathered from the yard and garden or purchased at the grocery store. The possibilities for food plants to use in this exercise are virtually endless. Since slugs are often found in gardens and lawns, they might be provided with a selection of plant species found in these areas. Leafy vegetables (lettuce, cabbage, spinach, etc.) can be cut easily into 20 mm x 20 mm squares, as can thinly sliced pieces of carrot, turnip, and onion scale leaves. Both grasses and broad-leaved weeds (dandelion, plantain, ground ivy, etc.) are also good choices for food, though some (such as grasses) may be rejected completely. A difficulty with grasses and some other plants is the small size or narrowness of the leaves. In such cases, students can cut two or more pieces of leaf (rectangles or smaller squares) to equal a single standard-sized piece. But if smaller pieces are used, the instructor should point out that all other foods offered to the slug(s) in the same experiment should be cut up in the same way to insure that the shape and size of the food plant samples are not uncontrolled variables.

- Slugs will also feed on filter paper squares that have been soaked in plant extracts for a few minutes. If students are investigating the basis of a food preference, this procedure would allow them to eliminate texture as a variable. The filter paper may also be soaked in food coloring (e.g., red versus green), or seasonings (e.g., a sugar solution, monosodium glutamate (MSG), mustard, vinegar). Of course, in any experiment involving filter paper squares, a piece soaked only in water should be placed in the feeding chamber as a control, but the instructor may wish to let his students come up with that idea.

- One potential problem is keeping track of which pieces are which since marks made on the sample may be eaten by the slugs. The best approach is to indicate the positions of the different squares by using appropriately labeled pieces of masking tape affixed to the outside of the feeding tub at the point nearest to the position of the corresponding square inside. Even this technique may fail if the slugs move the squares from their original positions. Though unlikely to occur, this may necessitate smelling the remains in order to establish positive identification!

Helpful Hints

- This exercise has been used very successfully as the first laboratory in September. It is a way to truly have students do "biology" during their first lab of the new school year. An objective of this exercise is to give students the experience of closely observing a living, familiar member of an important group of invertebrates: the gastropod mollusks.

- This exercise can be used successfully with students of widely different abilities and backgrounds. It can be used without modification at both the Life Science and High School Biology levels. It can also be adapted for Honors and Advanced Placement level Biology by requiring more sophistication in the types of experiments designed, by introducing one or more formal statistical tests for the analysis of the data, and/or by requiring a more extensive lab write-up.

- Students should be encouraged to observe the slugs with a dissecting scope in order to see the details of such structures as the eye and breathing pore. If a flat, clear piece of glass or plastic is available, or if the slugs are kept in clear containers, students can better observe the ventral surface of the slug as it moves, and the action of its radula as it feeds. They could be asked to make a drawing that illustrates and identifies any visible structures, or to write a paragraph concerning their observations of slug behavior. For example, "the extension and retraction of the tentacles is a fascinating process: during retraction they are pulled into the head in a manner similar to the inversion of the fingers of a glove."

- The student design component is very simple in conception and execution. The student is asked to consider the general topic of the feeding behavior of slugs and think of a question that he/she could attempt to answer by measuring the quantity of food consumed by one or more slugs. Below is a list (not all-inclusive, to be sure) of questions that students could investigate. Although you might be tempted to give selected items from this list to your students, it is preferable to ask the students to generate their own "research questions." The list includes some that require more than one day to answer. The instructor may wish to extend this lab for several days, or give interested students the opportunity to conduct individual research projects on slugs for as long as necessary to answer their questions.

    1. Is food "A" preferred to food "B"?
    2. Does the same pattern of food preference emerge when only two foods are compared as when a larger number of food types are presented together?
    3. Do slugs show individual food preferences?
    4. Is a given food preference based on taste or texture? (Investigate using filter-paper squares soaked in juice extracted from the plant source.)
    5. Are cultivated plants generally preferred to non-cultivated species?
    6. Are alien (European) species of plants generally preferred to native species?
    7. Are plants that have strong and/or unpleasant odors and tastes, as perceived by human beings, avoided by slugs?

8. Do individual slugs seek a "balanced diet" by periodically changing from one food preference to another?
9. Does hairiness or fuzziness of leaves influence food choice?
10. Are young leaves, or other plant parts, preferred to old?
11. Are moist, fresh leaves preferred to dry ones?
12. Does temperature (or light or sound) influence food consumption?
13. For a cultivated plant of which only one part is eaten by humans (e.g. tomatoes, carrots), do slugs prefer the same part as humans?
14. Do any plants (e.g. marigolds) suppress feeding behavior?
15. As a class, are non-green parts of plants (flowers, fruits, roots) preferred to green parts?
16. Will slugs eat mushrooms? Do they prefer them to green plants? Do slugs distinguish between poisonous and non-poisonous mushrooms (or poisonous and non-poisonous green plants)?
17. What is the effect of "food additives" (e.g., sugar, vinegar, MSG, pepper) on food choice?
18. Do different species of slugs exhibit the same food preferences?
19. Does a dry environment (or any other environmental variable) affect feeding behavior?

- It is important for students to snap the lid of the tub on tightly after putting in the slug. Slugs are remarkably adept at squeezing through very narrow openings!
- The method suggested for determining the amount of food eaten by the slugs is to measure the area consumed, estimated with the aid of graph paper. Since the slug's food is often wet and it causes the graph paper to become wet, it works well if you can copy the graph grid onto an acetate sheet. The plastic is transparent and easy to mark on and doesn't fall apart when wet. It is important to use graph paper with 1 mm rulings to insure reasonably accurate estimates. Area consumption was chosen over mass consumption as the means of estimating food intake because a) satisfactory balances may not be readily available, and b) mass change estimates are probably less reliable than area change estimates because of osmotic uptake of water by plant tissue. The accuracy of area change estimates as a measure of consumption is, of course, completely dependent on the assumption that all squares of food are of equal thickness. When the food consists of thin leaves, this assumption is probably safe, but it could be drastically in error if thicker leaves or slices of carrot, etc. are used. If plant materials requiring slicing are to be among the food choices, it may be best for the instructor to prepare the slices before class, using a razor blade or sharp knife.
- One of the most important results of this exercise is that students will be exposed to the variability of biological data. It is very possible that not all slugs will show the same feeding preferences, and they all will certainly not consume the same amount of food. A. P. classes might be introduced to statistical procedures such as the Chi-square, t-test, or Mann-Whitney U test, which are used to analyze and interpret variation in quantitative data. In any case, after performing and discussing the results of the experiments, all students should have gained an increased awareness of the importance of collecting quantitative data and of performing several replications of an experiment in order to draw reliable conclusions.

Answers to Questions

Pre-lab reading:

1. The slug is an example of an "introduced species" that has become a pest. Can you think of other introduced species that have become pests?

   The Gypsy moth, Mediterranean fruit fly, and Japanese beetle are examples of introduced insect pest species; starlings and house sparrows are examples of exotic bird species.

2. What reasons can you suggest for the fact that introduced species tend to be ecologically and/or economically destructive?

   The usual explanation for rapid population increase of an exotic species is that in its new environment it has escaped natural population control mechanisms, which include parasitism (disease), predation, and competition.

The Vermiculturist's Experiment:

- Trial 3 Conclusions:

  The variable is the % sand. There is no real difference in the rate of reproduction when % sand is decreased from 15% to 10%. The number of egg cases decreases by 2.

- Trial 4 Conclusions:

  The variable is the amount of food supplied. There appears to be a modest increase in the rate of reproduction when the food is increased from 10 - 15 grams per square foot.

- Trial 5 Conclusions:

  The variable is the % moisture in the soil. There is no difference in the rate of reproduction when soil moisture is varied between 20% and 25%.

- Trial 6 Conclusions:

  The variable is whether the soil is covered. Covering the soil leads to a significant increase in the rate of reproduction.

- How did the vermiculturist ensure that they had replicates? Was each trial able to be repeated? What are some assumptions the vermiculturist had to make?

  The conditions under which the experiment was conducted (% moisture in the soil, amount of food given per square foot, etc.) were carefully recorded and monitored. It was possible to repeat the experiment many times under the same conditions because of the detailed record keeping done by the vermiculturist. Each trial was repeated every 24 hours for one month. Thus each trial had approximately 30 replicates. Some assumptions made might be: a. that the worms would continue to produce eggs after their initial production of cases; b. that the worms would not be killed by the changes made in their environment.

Annotated References

- Barnes, Robert D. *Invertebrate Zoology*, 5th ed. W. B. Saunders Company, Philadelphia, 1987.

  An authoritative general guide to the biology of all invertebrate groups, including the Mollusca. It includes interesting technical information about all aspects of the gastropods: evolution, ecology, anatomy, and physiology.

- Brown, Luther, and Jerry F. Downhower. *Analyses in Behavioral Ecology*. Sinauer Associates, Inc., Sunderland, Massachusetts, 1988.

  Useful for its clear descriptions (with examples) of many statistical tests used in studies of animal behavior

- Burch, John B. *How To Know The Eastern Land Snails*. Wm. C. Brown Company, Dubuque, Iowa, 1962.

  Indispensable for species identification of slugs and snails, and a good source of information about the general biology and ecology of terrestrial gastropods.

- Fernald, Merritt Lyndon. *Gray's Manual of Botany, a Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada*. Van Nostrand Company, New York, 1970.

  Notes the origin (native or introduced) of nearly every plant found in the northeastern U.S.

- Gill, John and Pauline Howell. "Food choice in the common snail (*Helix aspersa*)," *Journal of Biological Education* 19 (1): 6-7, 1985.

  The source of both the general concept and most of the specific procedures of this laboratory exercise.

- Raven, Peter H., Ray F. Evert, and Susan E. Eichhorn. *Biology of Plants, 5th ed*. Worth Publishers, Inc., New York, 1992.
  An accessible reference describing the process of plant-- herbivore coevolution, with some interesting examples of plant chemical defenses.

The Sea Slug forum, which is a wonderful online reference that focuses primarily on sea slugs, can be found at:

http://www.seaslugforum.net/

Graph Paper

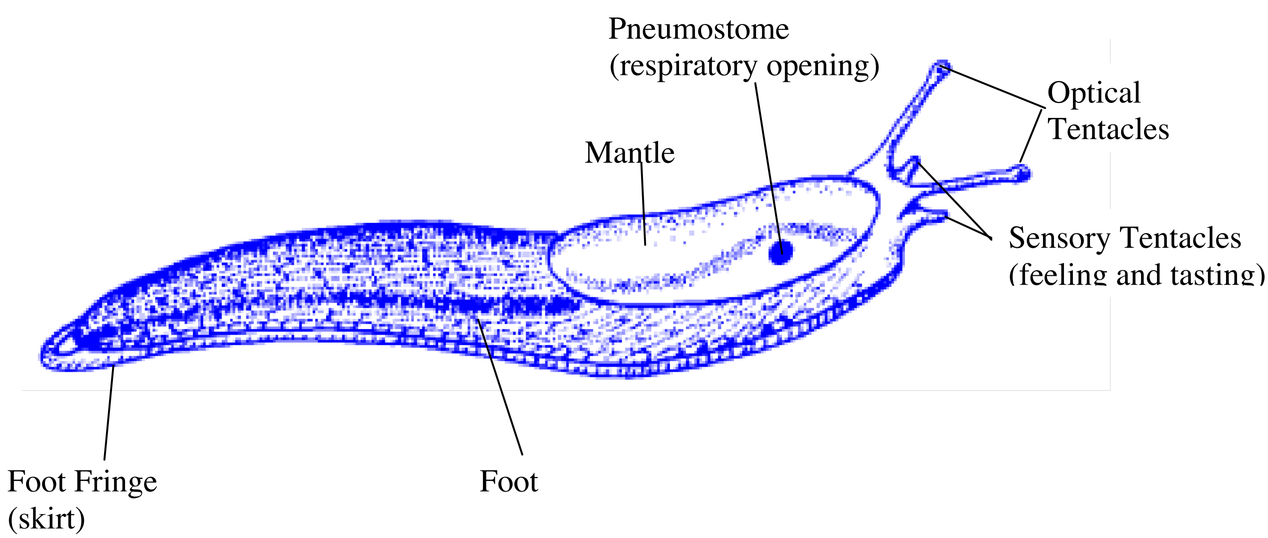
The Biology and Natural History of the Common Garden Slug

This passage should be read before doing the experiment entitled *Food Preferences Of Slugs*.

Slugs are generally from 1 to 2 inches long. They may be gray, black, white, amber, yellow, brown, spotted, or blotched with irregular black areas. The foot is usually yellowish and produces a copious amount of milky mucus. The head has 2 pairs of feelers, the longer pair with eyes at the tips.

Slugs are mollusks and along with snails are classified as gastropods. The name "gastropod" ("stomach-foot") refers to the fact that snails and slugs appear to crawl on their bellies. Like other gastropods, slugs have the standard molluskan body plan which includes:

- a ventral muscular foot used for locomotion.
- a dorsal mantle which in most mollusks secretes the shell.
- a visceral mass which contains the internal organs (viscera) such as the digestive and reproductive organs, and is located between the foot and the mantle.
- a radula which is a ribbon-like feeding structure containing many tiny teeth which the slug protrudes through its mouth and uses to rasp off particles of food. (Mouth is located underneath the head)



Although the majority of the 40,000 species of gastropods live in the oceans or in fresh water, many species have evolved adaptations enabling them to live successfully on land. One of the most important of these is the evolution of a lung for breathing air. Anatomically, the lung is formed from the mantle cavity - the space between the bottom of the mantle and the top of the visceral mass. Air enters and leaves the lung through a breathing pore visible at the lower edge of the mantle on the right side. Its precise location is a feature used to help identify the different kinds of slugs.

In at least one respect, snails and slugs do not seem to be as well adapted to life on land as insects and the terrestrial vertebrates. Whereas these groups have a waterproof exoskeleton or skin, the land-dwelling snails and slugs have a water-permeable skin. As a result, they are vulnerable to dehydration (drying out) and death when confronted with hot, dry environmental conditions. At such times, snails can retreat into their shells, but slugs don't have that option. Instead, they have two other strategies for survival. First, they can survive a water loss equal to 80% of their body weight. (A human being, in contrast, can only tolerate a 12% water loss.) Second, they avoid potentially stressful situations by hiding under leaf litter, logs, rocks, etc. during the heat of the day. They emerge to feed when conditions are cooler and damper, particularly at night or following a rain.

Slugs are hermaphrodites with reciprocal mating. Each slug produces from 500 to 800 eggs. Each egg is from 1/16 to 1/8th inch long, whitish, and laid in moist soil among plant roots. The eggs are usually deposited in groups of 50 and hatch in 3 weeks (or over winter). Adult slugs that survive the winter may lay eggs in May. By October, the newly hatched eggs should have developed into slugs sufficiently mature to mate and lay eggs.

The slug was introduced into the U.S. from Europe, during the early part of the last century. It first appeared in port cities such as Boston, New York, and Philadelphia. It is now widely distributed over the eastern U.S. The common species of slugs found in this region are generally herbivores, feeding on a variety of plants. Because many of these plants are cultivated fruits, vegetables, and ornamentals, some kinds of slugs are considered pests. When present in high numbers, they can be very destructive in gardens and greenhouses.

1. The slug is an example of an "introduced species" that has become a pest. Can you think of other introduced species that have become pests?
2. What reasons can you suggest for the fact that introduced species tend to be ecologically and/or economically destructive?

New York State Learning Standards

Food Preferences of Slugs

Standard 1: Inquiry Analysis and Design

Key Idea 2: Scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

2.1- Devise ways of making observations to test proposed explanations.

2.3- Develop and present proposals including formal hypotheses to test explanations; i.e., predict what should be observed under specific conditions of the explanation is true.

2.4- Carry out a research plan for testing the explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary.

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into natural phenomena.

3.1- Use various methods of representing and organizing observations (i.e., diagrams, tables, charts, graphs, equations, matrices) and insightfully interpret the organized data.

3.3- Assess correspondence between the predicted result contained in the hypothesis and actual result, and reach a conclusion as to whether the explanation on which the prediction was based is supported.

3.4- Based on the results of the test and through public discussion, revise the explanation and contemplate additional research.

Standard 4: Content

Key Idea 5: Organisms maintain a dynamic equilibrium that sustains life.

5.1- Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

TIPS ON COLLECTING SLUGS

Terrestrial snails and slugs are generally nocturnal creatures that avoid sunlight and adverse conditions such as extreme heat and cold, and low humidity. They are most active at night, on dark, cloudy days, and also after a rainfall, when they emerge to feed and/or search for mates. When light levels increase (such as in the early morning), or when conditions become increasingly dry, they will take refuge under an object where it is shaded and where there remains some humidity.

In order to successfully collect snails and/or slugs, the mollusks' preferred conditions need to be kept in mind. Collecting on a warm summer night after a light to moderate rainfall will be the most productive time, when these mollusks are active and out in the open. At any other time, therefore, one must look for suitable microclimates where they will have taken refuge:

- under rocks,boulders, boards, fallen trees, flower pots that are lying on the ground surface, where there are spaces between the object and the ground for humidity to collect and space enough for the mollusk to hide.

- in damp leaf litter (not wet or soggy), where it is cooler and moist enough to attract a mollusk, but not so wet as to drown it,

- in greenhouses, where optimum conditions for warm temperate and tropical plants are also ideal for snails and slugs,

- inverted melon rinds (i.e. half a watermelon) outside on the ground over night are very good attractants,

- Follow slime trails: terrestrial mollusks leave behind them a characteristic glistening trail of mucus that can be used to track them down.

Slugs and the Scientific Method

Objectives

In this lab you will:

- make observations of slug behavior.
- accurately record observations.
- understand the difference between an observation and an inference or an opinion.
- discuss findings with other class members.

Introduction

There are certain basic skills necessary for successfully carrying out any scientific investigation, be it the analysis of enzyme activity or the dissection of a worm. One of these skills is the ability to observe carefully and accurately. You will come across the word "observe" many times in your labs. Scientific observation is very different from observing a film or television show. First of all, observing is not limited to seeing. All of your senses may be used, and your senses may be extended with equipment such as microscopes. Therefore, odors, textures, tastes (but don't do it in lab), sounds, measurements of length, volume and mass are all considered observations and are the basis of data collection in lab. Ask yourself questions about the reasons for and the significance of what you observe. Record your observations carefully and accurately. Your conclusions will be based on your observations, so try not to fall into the trap of molding your observations to fit a preconceived notion of a "right answer."

Scientists must be aware of the distinction between true observations, inferences, and interpretations of observations and opinions. Carefully consider the following definitions when recording information as a part of an investigation.

- **Observations:** Data collected with any of the senses or tools such as thermometers, graduated cylinders, balances or rulers.
- **Inferences:** Conclusions or deductions based on observations; they may be very subtle and you may at first be unaware you are making them.
- **Opinions:** Everyone has them and everyone's opinion should be respected, but they should be left out of our data collection and analysis.

Materials

- Slug
- plastic container with lid to serve as "slug home"
- slug food such as lettuce or other leaves
- large petri dish to place slug into while making observations
- metric ruler
- hand lens
- dissecting microscope (optional)

Safety Precautions

- Good laboratory practice should be followed at all times during this laboratory.
- Treat the slug humanely. It is a living organism!
- Never consume laboratory specimens!

Procedure

1. Obtain a slug in a plastic container with a lid.
2. Make 12 observations of your slug - these may be anything about the slug's physical appearance or behavior - anything you can observe. Write these observations in the data chart on the next page.
3. When finished, exchange your data table with your partner and evaluate each others' observations; state whether each observation is really an observation, an inference, or an opinion.

Analysis

1. Take any 2 of your *observations* and intentionally make *inferences* about them. Express each of these inferences in a complete sentence.

2. Again using a complete sentence, state an *opinion* about slugs.

Slug Observation Data Table

Observer: ____________________ Record your observations below.	Evaluator: ________________ Indicate the type of statement
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

The Vermiculturist's Experiment

For Middle School

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Objectives

In this part of the lab you will:

- examine an experiment for the integrity of its design.
- recognize when an experiment has a valid control.
- be able to explain the importance of replicates.
- analyze and interpret data.
- state possible hypotheses for the different trials

Introduction

Several of the labs we will do this year will require you to design an experiment that will provide the answers to scientific questions. In designing your experiment, it is important that you understand the use of "controls."

A *control* is an established reference point. It allows you to make comparisons that generate valid information. The key to the use of a control is to be sure that, in any experiment, only one *variable* is changed relative to the control.

In this exercise you will be provided with data collected from a series of experiments designed to identify factors that optimize the production of earthworms. You will analyze the results of these experiments to learn the importance of *controls*, *variables*, and *replicates*.

Materials

- no special materials other than this lab write-up.

Procedures

A person involved with "vermiculture" (the raising of worms) is trying to determine the optimal (best) conditions for maximizing the reproductive rate of worms (the # of egg cases laid/24 hour time period). This person has identified the following variables that they would like to investigate:

- % moisture content of soil by weight
- whether the soil is covered or not
- the amount of food (cornmeal) spread on each square foot of soil.
- % sand in soil by weight
- % sand in soil by volume

Below is a chart of the conditions used for the past month with the averaged results (# of egg cases/24 hours).

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54

The vermiculturist decided to determine the effect of changing the variables. The following trial was tried for a period of one week and the results were once again averaged.

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
2	25%	10%	Yes	15 grams	92

Look closely at the two trials. On the next page list the variable (s) that the vermiculturist changed and their effect on the number of egg cases produced in a 24-hour period:

Variable changed | **Effect of number of egg cases produced**

Variable changed	Effect of number of egg cases produced
1)________________________________	______________________________________
2)________________________________	______________________________________
3)________________________________	______________________________________
4)________________________________	______________________________________

With the information provided, can you determine what caused the large increase in the number of egg cases laid in a 24-hour period? Please explain.

____

____

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After looking at the set-up and the results of the two trials, the vermiculturist realized that it was impossible to be sure of what actually caused the huge increase in egg production because there are too many variables in this experiment. So, the tireless worm farmer decided to try a number of additional trials in order to determine which variables had what effect. The results of these trials along with the data from the original trial are given in the next page.

Your job:

For each trial, using Trial #1 as the "control," **circle** the variable that the vermiculturist changed, then **fill in the blanks**.

Trial #3.

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54
Trial #	**% Moisture in soil (weight)**	**% Sand in soil (Volume)**	**Soil Covered (Yes/No)**	**Amount of food given per square ft.**	**RESULTS # egg cases (in 24 hrs)**
3	20%	10%	No	10 grams	52

Variable changed in Trial #3:____

What could be a possible hypothesis for Trial #3?

____

_________________________________.

What was the effect on the number of egg cases produced in a period of 24 hours?

____.

What could the vermiculturist learn from changing this variable:

____

______________________.

According to the data, is the hypothesis accepted or rejected?

_______________________.

Trial #4.

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54
Trial #	**% Moisture in soil (weight)**	**% Sand in soil (Volume)**	**Soil Covered (Yes/No)**	**Amount of food given per square ft.**	**RESULTS # egg cases (in 24 hrs)**
4	20%	15%	No	15 grams	64

Variable changed in Trial #4:____

What could be a possible hypothesis for Trial #4?

____.

What was the effect on the number of egg cases produced in a period of 24 hours?

____.

What could the vermiculturist learn from changing this variable:

____.

According to the data, is the hypothesis accepted or rejected?

________________________.

Trial #5.

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54
Trial #	**% Moisture in soil (weight)**	**% Sand in soil (Volume)**	**Soil Covered (Yes/No)**	**Amount of food given per square ft.**	**RESULTS # egg cases (in 24 hrs)**
5	25%	15%	No	10 grams	53

Variable changed in Trial #5:______________________________________

What could be a possible hypothesis for Trial #5?

____.

What was the effect on the number of egg cases produced in a period of 24 hours?

____.

What could the vermiculturist learn from changing this variable:

____.

According to the data, is the hypothesis accepted or rejected?

____________________.

Trial #6.

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54
Trial #	**% Moisture in soil (weight)**	**% Sand in soil (Volume)**	**Soil Covered (Yes/No)**	**Amount of food given per square ft.**	**RESULTS # egg cases (in 24 hrs)**
6	20%	15%	Yes	10 grams	82

Variable changed in Trial #6:____

What could be a possible hypothesis for Trial #6?

____.

What was the effect on the number of egg cases produced in a period of 24 hours?

____.

What could the vermiculturist learn from changing this variable:

____.

According to the data, is the hypothesis accepted or rejected?

_______________________.

The important thing about the set-up is that for each comparison, only one variable at a time is actually different. This makes it quite easy to determine the effect of that **specific** variable by always comparing it to the control. So far, we know that a good experiment must:

- have a control
- test only one variable at a time

In addition, a good experiment must have *replicates*, *be able to be repeated*, and have a *minimum number of assumptions*. Write a paragraph that uses information from the experiment to explain how the vermiculturist took care of the above requirements. A full table showing the results of all the trials is enclosed in the following page. You can use it to complete this part of the lab. **Be sure to use complete sentences.**

All Trial Data

Trial #	% Moisture in soil (weight)	% Sand in soil (Volume)	Soil Covered (Yes/No)	Amount of food given per square ft.	RESULTS # egg cases (in 24 hrs)
1	20%	15%	No	10 grams	54
2	25%	10%	Yes	15 grams	92
3	20%	10%	No	10 grams	52
4	20%	15%	No	15 grams	64
5	25%	15%	No	10 grams	53
6	20%	15%	Yes	10 grams	82

Food Preferences of Slugs

Objectives

In this lab you will:

- design and carry out a biological experiment.
- make observations of slug feeding behavior.
- accurately record observations and organize data.
- draw conclusions and make deductions based on data.
- discuss findings with other class members.

Introduction

In this lab you will design an experiment, collect data, and analyze your results to test the feeding preferences of the common garden slug, *Arion subfuscus*.

Materials

- slug
- plastic container to serve as "slug home"
- slug food such as lettuce or other leaves
- graph grids transferred to transparency film
- hand lens
- metric ruler
- scissors
- dissecting microscope (optional)

Safety Precautions

- Good laboratory practice should be followed at all times during this laboratory.
- Treat the slug humanely. It is a living organism!
- Never consume laboratory specimens.
- Be careful when using scissors.

Procedure

In this lab, you will be asked to consider the feeding behavior of slugs and to also think of a question that you will then attempt to answer by measuring the quantity of food consumed by one or more slugs. While the example of the worms and the vermiculturist has nothing to do with the problem you will be facing in your lab this week, the process is similar. What are five characteristics of a good experiment? (Record your answer below.)

1.
2.
3.
4.
5.

Your experimental design should include each of the five characteristics you listed. You should also think about how you will collect your data and how you will analyze the data.

1. Formulate a question about the feeding behavior of slugs. For example, you might ask, "Do slugs have a color preference in the foods they eat?" Make sure your question is testable with the materials and the amount of time available. On a separate piece of paper, and using complete sentences, write down the following:
   a. State the **hypothesis**.
   b. Identify the **constants**.
   c. Identify the **experimental variable(s)**.

d. How will the **data** be collected?

e. How many **replicates** will there be?

f. List three **assumptions**.

g. Check with your instructor to be sure your question and approach will be appropriate.

2. Decide what two food materials are necessary for your experiment and get them.

3. Cut a 20 mm x 20 mm square of graph grid.

4. Put the square on the leaf. Carefully cut around the square with scissors. Repeat this until you have obtained two 20 mm x 20 mm squares of each of the two types of food you are testing. (If the leaf is too small or narrow to cut squares of this size, cut 20 mm x 10 mm rectangles or other shapes as directed by your instructor. Regardless of the size and shape of the pieces, it is important that all items of food have the same size and shape, and be added to the feeding container in the same total quantity.)

5. Examine the thickness of the squares. Since it is important that the volume of all the pieces be approximately the same, use a razor blade to cut any unusually thick squares down to a uniform size, or ask the instructor to do so.

6. Place the leaf squares on the bottom of the feeding container provided. Figure out a good and water-proof system for labeling your containers and squares.

7. Add 1 ml (about a quarter of a teaspoonful) of water to the container.

8. Deposit a slug in the container with the food and securely place the lid on the container. Be sure that the lid has numerous small air holes in it!

9. Label your container(s) and ask where they should be placed.

10. Examine the container after 24 hours and count the number of small squares consumed for each food sample. Calculate the percentage of food consumed for each sample. To do this divide the number of squares consumed by the total number of squares of the food sample. (For example, if a slug ate 15 small squares of food A and 7 small squares of sample 2, then for sample A, 15/25 = 0.6, which is 60%. For sample 2, 7/25 = 0.28, or 28%.)

11. Record your results on the following page & clean out your slug container as directed by your teacher.

Data

Type of foods tested: Food A: ___________________________________

Food B: ___________________________________

Food A: ___________________		**Food B:** _____________________	
Amount (# of squares) of **Food A** *sample 1* eaten	(a) = _________ squares eaten	Amount (# of squares) of **Food B** *sample 1* eaten	(a) = _________ squares eaten
% of **Food A** *sample 1* eaten (% = number of squares eaten/ total squares available)	(b) = _________ % sample eaten	% of **Food B** *sample 2* eaten (% = number of squares eaten/ total squares available)	(b) = _________ % sample eaten
Amount (# of squares) of **Food A** *sample 2* eaten	(c) = _________ squares eaten	Amount (# of squares) of **Food B** *sample 2* eaten	(c) = _________ squares eaten
% of **Food A** *sample 2* eaten (% = number of squares eaten/ total squares available)	(d) = _________ % sample eaten	% of **Food B** *sample 2* eaten (% = number of squares eaten/ total squares available)	(d) = _________ % sample eaten
Average % eaten **Food A** note: (b+ d)/2 = average	_______________ average % eaten	Average % eaten **Food B** note: (b+ d)/2 = average	_______________ average % eaten

Calculations

Show your calculations for each step on your own paper.

Analysis

Using complete sentences, answer each of the following questions on **your own paper**.

1. Make a conclusion based on the results of your experiment. Write your conclusion in the form of a hypothesis.
2. Does the data support your hypothesis?
3. Design at least one other experiment to further test your hypothesis.
4. What were some possible sources of error in your original experiment?
5. How could you improve upon the design of your original experiment?

Food Preferences of Slugs:

The Next Chapter

or

Slugs II!!

Objectives

In this lab you will:

- formulate a hypothesis about slug feeding behavior.
- design and carry out a biological experiment to determine if your hypothesis is correct.
- make observations of slug feeding behavior.
- accurately record observations and organize data.
- draw conclusions and make deductions based on data.
- discuss findings with other class members.

Introduction

One of the most exciting things about science is that scientists never run out of questions! As a result of your last experiment with slugs, you may have discovered some of the foods that slugs seem to like, and some that they don't like. But is that the whole story? Of course not! Why do slugs "like" the foods they do and what experiments could you do to find out? If a slug liked (or disliked) a food when you tested it, does the slug always feel the same way about that food? Or do certain conditions make the slug "pickier"? What experiments could you do to answer these questions? You can probably think of many more questions about slug food preferences and you should have some good ideas about how to design experiments to answer these questions.

Your task for today's lab is to think of a specific question concerning the feeding behavior of slugs, write a hypothesis about slug feeding preference, and then design and carry out an experiment that attempts to test your hypothesis.

Materials

- slug
- plastic container to serve as slug home
- slug food such as lettuce or other leaves
- graph grids transferred to transparency film
- assorted other materials depending on design of experiment
- metric ruler
- scissors
- hand lens
- dissecting microscope (optional)

Safety Precautions

- Treat the slug humanely. It is a living organism!
- Never consume laboratory specimens.
- Be careful when using scissors

Procedure

1. Write a question about the feeding behavior of slugs. Express your question in the form of a hypothesis. Make sure your hypothesis is testable with the materials and amount of time available. Check with your teacher to be sure it is appropriate. Have your teacher initial here that your question is acceptable to test:

   ____

   initials/date

2. Determine what type(s) of plant material are necessary for your experiment, and obtain samples of each material needed.

3. Follow the same basic procedure as in the previous lab, modifying it as necessary to test your hypothesis. You may need to make special modifications depending on what your hypothesis states.

4. **Upon completion, of the experiment, write up your lab using the following format:**

I. Introduction

a. State your hypothesis.

II. Materials and Methods:

a. Briefly outline the procedure you followed and how you collected your data.

II. Results:

a. Present your data in a neat, organized and labeled table.

III. Discussion:

a. State a conclusion, if you were able to make one.

b. Describe any problems you encountered.

c. List any modifications you would make if you were to repeat this experiment.