Soil Biodiversity Experiment

Suggested Grade Level: 9-12

Time: three to five 50-minute periods

Subject: Science, Environment, Ecosystems, Math, Real Number System, Quantities, English, Writing, Speaking and Listening, Agriculture, Soil Conservation

Overview:
This lesson invites students to explore soil ecosystems and investigate how human activities affect soil biodiversity. Students will investigate soil health by collecting mesofauna from different soil samples using Berlese funnels. Then, they will calculate Simpson's Diversity Index to compare biodiversity and explore how land use affects soil life. The lesson connects soil health to agriculture and conservation, especially in Kansas.

Objectives:
1. Explain how to conserve soil quality.
2. Identify healthy soil compositions.
3. Identify microorganisms in soil.
4. Explain how soil depreciates.
5. Use scientific processes to determine soil quality.
6. Use a Berlese funnel to collect data.
7. Use Simpson's Diversity Formula.
8. Make conclusions based on the data collected.

Background Information
Healthy soil is vital for food production. It affects water quality, biodiversity, wildlife habitat, plant growth, and crop yields. Monitoring and maintaining soil health is essential because unhealthy soil can directly contribute to poor crop quality. An ideal soil contains 25 percent air, 25 percent water, 45 percent mineral material, and 5 percent organic matter. There are three types of soil particles: sand, silt, and clay. Soil with unequal amounts of these three soil particles isn't ideal for growing. On the contrary, near-equal amounts of these are considered loam – the soil type that produces the best yields. Organic matter, one of the most critical factors, makes up only five percent of the ideal soil. Organic matter holds water well and can retain nutrients. It can include mesofauna (microscopic invertebrates) and macrofauna (macroscopic invertebrates), compost, animal manure, and more (Components). Billions of mesofauna and macrofauna can be found in good soil. A single teaspoon of soil can contain more organisms than people on

Earth! Mesofauna, such as bacteria and fungi, decompose organic matter and release key nutrients available for plants in the soil. Macrofauna, such as earthworms and insects, help bind the soil and create airflow in the soil. Healthy soil with high biodiversity helps combat unwanted pests and supports the growth of more nutritious crops. Some organisms in healthy soil can even kill harmful bacteria (Begum).
Soil degrades over time. Weather, temperature, and human activities have decreased its productivity. Unfortunately, intensive farming practices such as deforestation, overgrazing, and intensive cultivation can accelerate the process of soil degradation. A primary reason for the reduction of soil quality is erosion. Erosion is a natural process, but human activities have accelerated it. To solve this issue, the Food Security Act of 1985 included provisions of sodbuster and conservation compliance (Conservation). This act led farmers, ranchers, and agricultural specialists to research ways to maintain and improve soil quality. In part due to their efforts, we now know that there are practical ways to avoid soil erosion. Producers can implement various farming practices, including terrace farming, agroforestry, cover crops, manure application, crop rotation, and no-till farming (Sulaeman).
Simpson's Index of Diversity is a tool used to measure the biodiversity in each soil sample. It measures the number of species per sample and the abundance of the species in a community. A community with more than one or two species is considered less diverse than one in which several species are abundant. The Simpson's Index of Diversity (D) ranges from 0 to 1. In Simpson's Index of Diversity, 1 represents infinite diversity and 0, no diversity (Mesofauna).

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Simpson's Index of Diversity
n = the total number of organisms of a particular species
N = the total number of organisms of all species

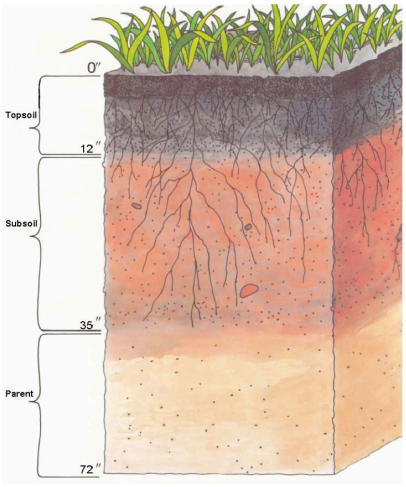
How do I calculate Simpson's diversity index?
Use a Berlese funnel to collect small organisms. First, put a sample in the funnel with a wire or mesh screen. Then, place a bright light above the funnel and a container with alcohol below the funnel. The organisms will migrate downward from the top as the leaf litter dries. They move to the moisture. They will eventually fall into the alcohol, which will preserve them for later observation.

1. Add the individual species populations to get N.
2. Determine N × (N-1).
3. Work out n × (n-1) for each species, where n is the number of individuals in each species.
4. Sum all the values in step 3.
5. Divide the sum obtained in step 4 by the value obtained in step 2.

Or, go to Simpson's Diversity Calculator.

Kansas Industry Information:
Soil is Kansas's most valuable resource. It supports our No. 1 industry, agriculture. Agriculture contributes nearly $8.7 billion each year to the Kansas economy. Kansas' prairie grasslands have developed a unique, rich topsoil over time that we still farm today. This soil, known as Harney Silt Loam, possesses the ideal quality, growing season, and water supply for achieving high crop yields. Harney Silt Loam is richer than many other soils and is typically found in west-central Kansas (The). It sits deep into the earth, drains easily, and is often found on slopes and ridges.
Harney Silt Loam forms from windblown silt, also known as 'loess.' The topsoil is dark, gray-brown, and around 12 inches deep. The next layer is around 23 inches thick and changes from a gray-brown loose clay loam to a brown calcium loose clay loam. The parent material at the bottom is approximately 37 inches thick and yellow-brown in color. This means that Harney Silt Loam's total depth is around 72 inches! Fun fact: Kansas has more acres of prairie soil than any other state! We have almost four million acres of just Harney Silt Loam in west central Kansas, but there are over 300 more soil types throughout the state (Kansas). Soils in every Kansas county have been identified and mapped. You can find soil survey information for all counties on the Kansas NRCS Website:
https://www.nrcs.usda.gov/resources/data-and-reports/soil-series-classification-database-sc

Although Kansas has rich soil, nearly 190 million tons of Kansas topsoil are degraded each year. Under the prairie grasses, it takes around 500 years to create one inch of topsoil. Depending upon conditions, fields in Kansas can lose an inch of topsoil in one or two years due to rain and wind. That is why soil is considered a nonrenewable resource (The).



Harney Silt Loam Profile

Materials:
Day 1: Lesson Introduction
Per class:
1 Liter of the soils below:

- A garden/hardware store or dried soil (control)
- Untilled native soil
- Several fields from which a crop is or has been planted.
- Optional: You or your students can source soils from hayfields and tallgrass prairies. Label the samples and include information about the soil. When collecting soil, include the leaf or crop residue and dig six inches deep or less.

Per student:

- Introduction to Soil Diversity Worksheet (provided)
- Harney | Kansas State Soil booklet by the Soil Science Society of America soils4teachers.org/files/s4t/k12outreach/ks-state-soil-booklet.pdf
- Access to technology
- 2 1-gallon zip-lock bags
- 2 2-L bottles to create a Berlese Funnel

Day 2: Experiment
Per class:

- Mesofauna Biodiversity Investigation Lesson https://www.nourishthefuture.org/media/pages/curriculum/soil-sustainability/hs/mesofauna-biodiversity-investigation/b9a4fc3ab8-1678372101/mesofauna-biodiversity-investigation-student.pdf

Per student:

- Mesofauna Biodiversity Student Instructions (provided)
- 2 2-L bottles to create a Berlese Funnel
- Isopropyl alcohol
- A small jar with a tight-fitting lid
- Wire mesh
- Scissors
- Duct tape
- Soil samples
- A heat lamp
- A ruler/tape measure

Day 3: Collecting Data
Per student:

- Dissecting microscope or magnifying glass
- Jar from Day 2
- Mesofauna Biodiversity Student Instructions (provided)
- Invertebrate Key (provided)
- Invertebrate Calculations (provided)

Instructional Format:

1. Prepare the lesson beforehand.
2. Review background information.
3. Conduct engagement exercise.
4. Lead a class discussion.
5. Complete the activity.
6. Collect the data.
7. Conduct assessment exercise.

Engagement:

To introduce this lesson, provide some background information about soil. Say, “You may not know it, but soil is one of the most important nonrenewable resources on Earth. Without healthy soil, we wouldn’t have agriculture, and without agriculture, we wouldn’t have modern society. But what makes healthy soil? Over the next few days, we’ll dig into what makes soil healthy and discover how its living parts contribute to its productivity.”

Procedures:

Day 1: Lesson Introduction

Prepare:

1. Several weeks before this lesson, collect at least three soil samples described below. (Alternatively, determine where students can collect soil samples or ask students to bring in samples from home.) Also collect several 2-liter bottles. Each sample should fill one quart-sized bag, and there should be one 2-liter bottle per soil sample. Collect background information on the soil samples: till or no-till, crops planted, cover crops planted, grazing, irrigation, fertilizers, and pesticides.

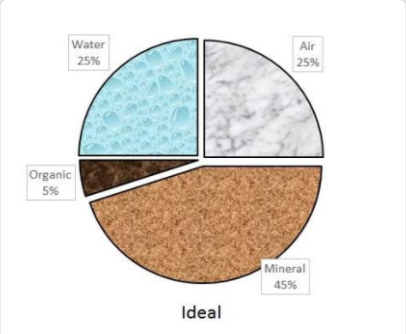
- Dry soil. To dry soil, leave it to air dry or dry it in a drying oven.
- Freshly collected soil from a planted area.
- Freshly collected soil from a non-planted area.

2. Before class, prepare the soil samples. Do not show a label of location or processes of the soil. Either place them on a table for viewing or pass around small cups labeled with soil A, B, C, etc.

Activity:

1. Play this short video: South Carolina NRCS Conservation Videos: The Science of Healthy Soil https://www.youtube.com/watch?v=RvvCwEBXTgY. Additionally, make the Harney | Kansas State Soil booklet by the Soil Science Society of America available to students, either online or printed.
2. Pass out copies of the “Introduction to Soil Diversity” worksheet (provided). Instruct students to come up and view the soils to answer the questions. Students may answer the questions individually, in groups, or as a class.

3. After students are finished with the worksheet, explain that good soils comprise four major components: minerals, water, air, and organic matter. Although organic matter accounts for only 5% of healthy soil, it is vital. A spoonful of soil contains more microorganisms than people on Earth, and many of these microorganisms are key indicators of soil quality.
4. Explain that life forms in soil, such as bacteria, fungi, insects, and earthworms, turn organic matter into rich humus. Soil biodiversity is vital to agriculture, as it can improve soil structure, enhance water movement, increase nutrient availability, and reduce the incidence of pests and diseases.



Day 2: Experiment

Activity

1. Before beginning the experiment, read through the Mesofauna Biodiversity Investigation Lesson listed in materials on your own.
2. Pass out the Mesofauna Biodiversity Student Instructions to each student or group. You could also have them watch the accompanying YouTube video. OSU Extension Professionals: How to Make a Berlese Funnel https://www.youtube.com/watch?v=KnoKvpqeMmA.
3. Pass out the materials listed to each student or group.
4. Instruct students to follow the steps until “Collect data.”

Day 3: Collecting Data

Activity

1. Prepare the materials listed for this activity.
2. Pass out the Invertebrate Key and Invertebrate Calculations Worksheet.
3. Have students retrieve the Student Instructions from Day 2 and continue working on Day 3.

Discussion

1. After students collect the data, open up a classroom discussion about their results. Ask the class about their answers to the conclusion questions and allow students to share anecdotes about their experience.

Vocabulary:

- **Biodiversity**: diversity among and within plant and animal species in an environment.
- **Eutrophication**: excessive nutrient richness in a lake or other body of water, often due to runoff from land, which causes dense plant growth and the death of animal life from lack of oxygen.
- **Exudate**: a substance secreted by a plant or insect.

- **Fertilizer**: any natural or synthetic material applied to soils or plant tissues to supply one or more nutrients essential to plant growth.
- **Leaching**: downward movement of materials in solution through the soil.
- **Macrofauna**: animals large enough to be seen by the naked eye.
- **Mesofauna:** tiny invertebrate animals (such as mites, nematodes, or centipedes) that are usually 0.1mm to 2 mm long.
- **Nitrogen**: a colorless, odorless, unreactive gas that forms about 78% of the Earth's atmosphere
- **Nitrogen fixation**: a biological or chemical process by which elemental nitrogen, from the air, is converted to organic or available nitrogen
- **Relative abundance**: a component of biodiversity referring to how common or rare a species is relative to other species in a defined location or community
- **Simpson's Index of Biodiversity**: a measure of diversity that takes into account the number of species present, as well as the relative abundance of each species
- **Species evenness**: how close in numbers each species in an environment is
- **Species richness**: the number of different species represented in an ecological community, landscape, or region
- **Yield**: measure of grains or seeds generated from a unit of land (agricultural output)

Career Information: Soil Conservationist
Soil conservationists work closely with farmers, ranchers, foresters, and more. They advise and assist with soil conservation, water quality, nutrient management, wetland restoration, and wildlife conservation. Soil conservationists are essential because they help producers reduce their environmental footprint while returning healthy yields. Typically, soil conservationists need a bachelor's degree in soil conservation or a related field.

Assessment: Students can be assessed based on their answers to the worksheet questions.

Kansas Standards:

Next Generation Science Standards:
Ecosystems: Interactions, Energy, and Dynamics
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
Biological Evolution: Unity and Diversity

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Earth and Human Activity
HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Language Arts:
9th-10th Grade
Writing
Research to Build and Present Knowledge
W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Speaking and Listening
Comprehension and Collaboration
SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats, evaluating the credibility and accuracy of each source.

11th-12th Grade
Writing
Research to Build and Present Knowledge
W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Speaking and Listening
Comprehension and Collaboration
SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Math:
The Real Number System

N.RN.1. (9/10) Know and apply the properties of integer exponents to generate equivalent numerical and algebraic expressions.
N.RN.2. (11) Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents.
Quantities
N.Q.1. (all) Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

National Agricultural Literacy Standards:

Agriculture and the Environment

- Describe how wildlife habitats are created and maintained by farmers/ranchers and why these habitats are important (e.g., promoting pollinator habitat, insect refuges, creating buffer zones for nutrient management, etc.) (T1 9-12 a.)
- Describe resource and conservation management practices used in agricultural systems (e.g., riparian management, rotational grazing, no till farming, crop and variety selection, wildlife management, timber harvesting techniques) (T1 9-12 b.)
- Evaluate the potential impacts of climate change on agriculture (T1 9-12 e.)
- Evaluate the various definitions of "sustainable agriculture," considering population growth, carbon footprint, environmental systems, land and water resources, and economics (T1 9-12 f.)
- Understand the natural cycles that govern the flow of nutrients as well as the way various nutrients (organic and inorganic) move through and affect farming and natural systems (T1 9-12 h.)

Plants and Animals for Food, Fiber, and Energy

- Compare similarities and differences between organic and inorganic nutrients (i.e., fertilizer) on plant growth and development; determine how their application affects plant and animal life (T2 9-12 b.)
- Discuss reasons for the government's involvement in agricultural production, processing, and distribution (T2 9-12 c.)
- Evaluate evidence for differing points of view on topics related to agricultural production, processing, and marketing (e.g., grazing; genetic variation and crop production; use of fertilizers and pesticides; open space; farmland preservation; animal welfare practices; world hunger) (T2 9-12 d.)

Science, Technology, Engineering, and Mathematics

- Discuss population growth and the benefits and concerns related to science and technologies applied in agriculture to increase yields and maintain sustainability (T4 9-12 c.)
- Predict the types of careers and skills agricultural scientists will need in the future to support agricultural production and meet the needs of a growing population (T4 9-12 f.)

Culture, Society, Economy, and Geography

- Describe essential agricultural careers related to production, consumption, and regulation (T5 9-12 d.)
- Discuss how agricultural practices have increased agricultural productivity and have impacted (pro and con) the development of the global economy, population, and sustainability (T5 9-12 e.)

- Discuss the relationship between geography (climate and land), politics, and global economies in the distribution of food (T5 9-12 f.)
- Explain the role of government in the production, distribution, and consumption of food (T5 9-12 i.)

Companion Resources

Climate Hubs USDA: No Till: From Science to Practice
https://www.climatehubs.usda.gov/hubs/northern-plains/topic/no-till-science-practice

Cornell AgriTech: Soil Mesofauna: Digging into your farm's soil health:
https://www.youtube.com/watch?v=AHVGFDpRXhQ

Food and Agriculture Organization of the United Nations: Soil Biodiversity Interview with Dr. Diana Wall, a Soil Scientist https://www.youtube.com/watch?v=9Ro-1TiJy2A

Food and Agriculture Organization: Soil biodiversity, the hidden world beneath our feet:
openknowledge.fao.org/server/api/core/bitstreams/8f792132-1515-4ef7-abda-c0bbc641b6ba/content

Food and Agriculture Organization: What can you do to stop soil biodiversity loss?:
openknowledge.fao.org/server/api/core/bitstreams/2bd89544-91b6-4f1e-8271-5f5354a9fd0d/content

Soil Health Institute: Living Soil Film https://www.youtube.com/watch?v=ntJouJhLM48

Author: This lesson was adapted by Amy Benz, retired middle school technology teacher, St. Mary's, KS, from the lesson "Soil and Sustainability" written by Debra Spielmaker, and edited by Marissa Cook, Secondary Education Major at KSU, KFAC intern.

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Introduction to Soil Biodiversity

Student Questions

What is soil biodiversity?

Soil biodiversity is the variety of life that exists within the soil. This includes bacteria, fungi, earthworms, fungi, and termites. They turn organic matter into rich compost. Having soil diversity is vital to agriculture as it can improve soil structure, water movement, and nutrition. Biodiversity can also help diminish pests and diseases. A teaspoon of topsoil typically contains a vast range of different species and up to 6 billion microorganisms.

1. Look at the provided soils. What are the differences?

2. Which soil here do you think is the best? Why?

3. What do you think makes a good soil?

4. Do we have good soil in Kansas? Why or why not?

5. Has the soil in Kansas changed over the years? How? Why?

6. What have we done to help preserve the soil in Kansas?

7. Read the "Harney, Kansas State Soil" booklet provided by your teacher. List five interesting facts about Kansas Soil.

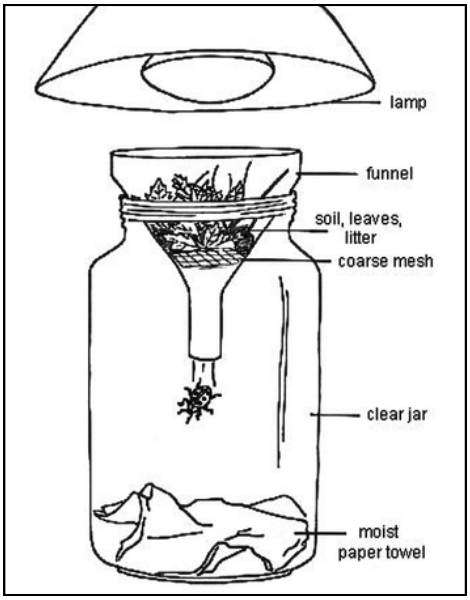
10. In observing the soil samples provided, which do you think has the most diversity? Why?

Mesofauna Biodiversity Instructions

Create a Berlese Funnel Apparatus

For this experiment, you will need:

- 2-liter soda bottle
- Isopropyl alcohol
- A small jar with a tight-fitting lid
- Wire mesh
- Scissors
- Duct tape
- Soil samples
- Heat lamp
- Ruler or tape measure



1. Cut the top of the 2-liter soda bottle off at about one-third of the height. The top part will function as the funnel and will be inverted and inserted into the lower part of the bottle.
2. Pour the isopropyl alcohol into the small jar to a depth of 1.5 centimeters. Place the jar in the bottom of the 2-liter bottle.
3. Invert the top part of the bottle and cut wire mesh large enough to form a basket at the wide end of the funnel. To do this, you might need to fold up the corners of the mesh to make it fit inside the funnel part of the bottle.
4. Tape the edges to the inside of the container. If you are using a small mesh (such as a window screen), create a loose pit in the middle that is deep enough to hold your soil and allow the fauna room to burrow down. Cut numerous slits into the screen first so that larger animals can crawl through.
5. Carefully set the funnel on top of the bottom portion of the 2-liter bottle, making sure it fits tightly in the bottom and does not tip over. The tip of your funnel should be close to the jar with alcohol but should not touch the liquid.
6. Place the leaf litter/soil that you collected into the top of the funnel so that it rests on the mesh.
7. Put a light above your funnel apparatus to help dry out the sample.
8. Repeat this process with a second sample.

Mesofauna Biodiversity Instructions

Collect Data

For this experiment, you will need:

- Jar from previous experiment
- Petri dish
- Dissecting microscope or 10x magnifying lens

1. Gently pour the contents of the alcohol jar into the petri dish for observation. Keep the alcohol jar tightly covered when not in use.
2. Set up a dissecting microscope and place the petri dish under the microscope to identify the species of invertebrates. If you do not have a dissecting microscope, use a 10× magnifying lens.
3. Use the Invertebrate Key to fill out the table and answer the questions. If you cannot determine their identity, count the number and name them species A, B, etc.
4. Collect data following the steps below. You may want to use a blank sheet of paper.

- Determine the species abundance and species diversity of your sample locations. How do these samples compare to the entire ecosystem? If your sample is 1 $ft^2 \times 3$ inches (.2499 ft) deep, then its volume equals .2499ft^3. If the ecosystem is one acre (43,560 ft2), then the ecosystem has a volume of 10,885 ft^3. What is the diversity index of the ecosystem?
- Determine the differences in the Simpson's Diversity Index values from one location to another. Show your work.
- Create a data table to demonstrate the calculated D values from other student groups to determine the mean for each location.
- Graph your data. Be sure to include a scaled interpretation of the volume of the ecosystem that the sample was taken from. Remember, the x-axis is the horizontal axis and always is the independent variable. The y-axis is the vertical axis and is the dependent variable.

Mesofauna Biodiversity Instructions

Conclusion Questions

1. What was your purpose? Did your procedure and findings relate to your original purpose? Does there seem to be a relationship between the sample locations and biodiversity calculated? If so, what is that relationship?

2. What did you hypothesize? Did your experiment support your hypothesis?

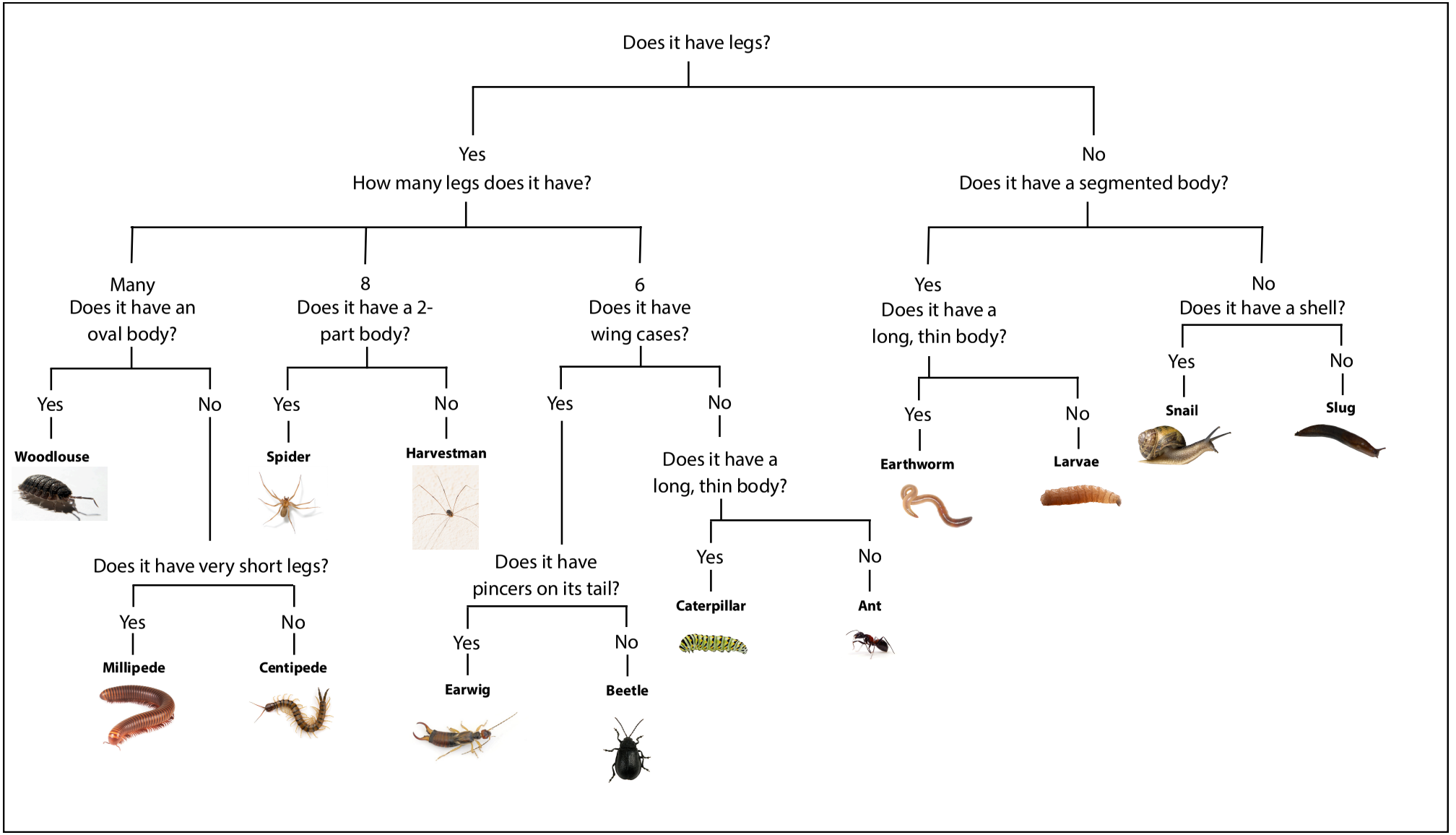
3. Explain your results. Why do you think you got the results you did? (Use your researched resources if necessary, but remember to cite information used.)

4. Identify at least two things that happened during the lab that could have introduced error or affected the results. Not simply human error! Be sure that you explain how/why you feel these caused error in the experiment.

5. Were there any limitations to your experiment? In other words, were there matters that you feel may have affected the accuracy of your results, however were out of your control. If so, describe them.

6. What improvements could be made to the procedures for this lab to reduce the errors and orlimitations identified? Make sure that the improvements are specific and feasible!

Invertebrate Key



Invertebrate Calculations

As you investigate the soil, fill out the data table below.

Organism	Color	Size	# Legs	Antennae?	Wings?	Other features	Guess ID:	Confirmed ID:	# Found
1									
2									
3									
4									
5									
6									
7									
8									Total: ____

Draft the data tables needed to display raw data collection that is measured for each trial. For example:

Species	**Number (n)**	**n(n-1)**	**Observations:**
Total: _____	N = _____	∑ n(n–1) = ____	

How to calculate soil diversity:

1. Add the individual species populations to get N .
2. Determine N × (N - 1) .
3. Calculate n × (n - 1) for each species, where n is the number of individuals in each species.
4. Sum all the values in step 3.
5. Divide the sum obtained in step 4 by the value obtained in step 2.