Smithsonian Environmental
Research Center

EARTHWORMS AND ECOSYSTEMS LESSON PLAN MODULE

Earthworms and Ecosystems: How invasive earthworms affect native ecosystems (Grades 3-8)
Smithsonian Environmental Research Center (SERC), Department of Education

SERC lesson plans are intended as a platform for educators to engage students with topical research from Smithsonian scientists. Activities are designed to provide opportunities for students to interact with science in ways that are applicable to them. For maximum flexibility, lesson plans vary in length and detail, and may be modified depending on class size, ages, and focus.

Based on the following papers by Dr. Katalin Szlavecz from John Hopkins University and SERC scientists Dennis Whigham and Melissa McCormick :

Szlavecz, Katalin., McCormick, Melissa., Xia, Lijun., et. al. 2011. Ecosystem effects of non-native earthworms in Mid-Atlantic Deciduous Forests. *Biological Invasions*. 13: 1165-1182.

Outline (Lessons 3-5 coming soon)

Description of Lesson Plans

Earthworms and Earthworm Invasions
The invasive species that the most attention are the ones that are easily observable, ranging from mammals to fish and plants. In North America there is a major invasion which is invisible, occurring in the soil, with non-native earthworms. It is suspected that nearly 100% of all earthworms in Eastern US backyards are invasive! These invaders have been brought to the US by colonists, plant nurseries, and gardens. Currently Smithsonian researchers, along with scientists from John Hopkins University and Purdue University, are working to understand the effects of non-native earthworms in native forest ecosystems. The potential effects of these invasive worms include interactions with plants through modifying soil conditions, consuming leaf litter and affecting the carbon cycle, digesting and eliminating seeds and changing their viability, and changing the mycorrhizal fungus relationships of soils and plants. In this series of lesson plans students will examine the biology and ecology of earthworms and their potential effects on ecosystems through hands-on laboratory and field exercises.

Lesson Plan 1: Earthworm Anatomy and Groups. In this lesson students will learn the basic anatomy of an earthworm, diagram their parts, and then learn about the three broad categories or groups. They will then conduct a variety of experiments using earthworms on light and dark surfaces as well as in wet and dry conditions.

Lesson Plan 2: Alien Invaders-Worms. This is an introduction to earthworm biology, the three main categories of earthworms, and how to identify them. Students will collect worms using a mustard and water

solution. They will identify, sort, and weigh them. The worms collected may either be released or used in experiments for Lesson Plans 3 & 4.

Lesson Plan 3: Earthworms and Leaf Litter Decomposition. This is a lab designed to test the leaf litter feeding preference of earthworms. It is a longer term study, at least 4 weeks, but can be set up to run continuously in the classroom.

Lesson Plan 4: Earthworms and Seed Germination. In this lab students will work with the idea that digestion of seeds by earthworms may affect their viability and germination. Students will set up an experiment where earthworms digest seeds, which are then collected and germinated.

http://www.fungi.com/mycogrow/index.html

http://www.willisorchards.com/product/Mycorrhizal+Fungi?gclid=COCzveumk60CFcZM4AodzB1iQA

Introduction: Earthworms and Earthworm Invasions

Are invasive earthworms all bad? The answer is yes and no. With moderate numbers of native and/or non-native species of earthworms these invertebrates can have positive effects on ecosystems ranging from mixing the soils to create more evenly distributed soil horizons, creating stable microclimates with their burrows, allowing rain water and carbon dioxide to penetrate lower in the soil column, and the worms themselves may be prey sources for larger vertebrates. Earthworms are also beneficial for gardeners because they help aerate the soil and assist in water filtration to the roots of plants.

The problems arise when nonnative earthworm species outnumber the native, and they begin to dominate soil ecosystems not previously inhabited. This is particularly true in New England states and the upper Midwest which have been free of earthworms since the last glaciation. Large poplations of nonnative worms can have impacts by negatively restructuring soil layers and horizons, over aerating the soil to the point that the fungal communities that plants rely on for nutrients (mycorrhizal fungi) can’t thrive, and increasing competition for food from native earthworms, soil micro organisms (arthropods and other species of fungi), and other macro organisms such as salamanders and larger arthropods.

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Earthworm and Ecosystems
Lesson Plan 1: Earthworm Anatomy & Groups

Based on the following papers by Dr. Katalin Szlavecz from John Hopkins University and SERC scientists Dennis Whigham and Melissa McCormick :

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Lesson Question: What is the anatomy of an earthworm and how does it live in the soil?

Background:

Natural History

- ***Earthworms are Annelids, which means "little rings."*** Their body consists of a muscular series of rings that help them move through the soil. By being ringed the worms increase their surface area. They absorb oxygen through their skin, and increasing the surface area helps increase the area from which they breathe.
- ***Earthworms are bilaterally symmetrical*** if you cut them longitudinally, but they are radially symmetrical if you cut them horizontally.
- ***They have a hydrostatic, or fluid filled, skeleton*** that supports them in lieu of a backbone or chitinous shell like arthropods.
- ***There is a large bump in the middle of mature earthworms called the clitellum*** which houses both male and female reproductive organs, making them hermaphrodites.
- ***They are detritivores*** and consume leaves, debris, and organic matter.
- ***Earthworms consume a great deal of carbon, in the form of detritus, quickly. This causes carbon to be released into the ecosystem quickly because their activities promote decomposition of easily degradable carbon.***
- ***Other roles of earthworms*** include aeration in the soil to allow water and oxygen to reach plant roots, consuming mycorrhizal fungus, mixing soil horizons, and digesting seeds of plant that may or may not assist in germination (also known as scarification).

Digestion

- When food enters their **mouth** it passes past the **ganglia** or brain of the worm, through the **pharynx**, and into the esophagus.
- The **esophagus** is wrapped by 5 pairs of **pseudohearts**.
- These hearts help the earthworm's digestion by contracting and pushing food down the digestive tract. By being close to the esophagus they can also absorb nutrients directly from the digestive tract.
- The food moves from the esophagus to a holding pouch called a **crop**. Much like the crop of birds, the earthworm's crop is a holding area for food.
- The food then passes to the **gizzard** (also like a bird), which has fine grains of sand and pebbles for grinding food into smaller particles.
- The food then passes through the long **intestine** to the **anus**.
- The long digestive tract allows for greater surface area for absorption of food.

- Digestion in earthworms involves taking detritus and digesting the usable nutrients then creating fecal casts that sequester unused carbon into the ground. The sequestration helps plants by increasing the amount of available nitrogen in the soil, in the form of worm casts or fecal pellets.
- Some CO_2 is released into the air via the earthworm's respiration but more importantly increased amounts of CO_2 are released by the bacteria and fungi in the soil when earthworms are active. This is especially true in younger forests, because the earthworms are "unlocking" the carbon and nutrients that feed the bacteria and fungi, releasing CO_2.

Major Groups of Earthworms

- **There are three major groups or types of earthworms:**
    - ***Epigeic(epi-gee-ick)-*** these worms are usually dark red on top and lighter on the bottom and relatively small in size (1-5 cm). The red on their bodies covers at least ¾ of their length. Their darker coloration is like "sunscreen" pigment that keeps them from getting sunburned. They live under the leaves and do not make permanent burrows.

      Epigeic worms consume leaf litter and promote detrital breakdown.

    - ***Endogeic(end-o-gee-ick)-***these worms make burrows in the soil beneath the litter layer. Their burrows are horizontal and relatively shallow, going between the humic and mineral layers (about 30-50 cm deep). They are most often pale white, pink, orangish, or bluish. Some may have lighter bodies but dark red heads. The red head covers less than ½ to ¼ of their body. This is because they come to the surface to grab food, and then retreat back into their burrows with a mouth full of leaves. You can tell these apart from other groups because they come out of the ground, as opposed to the Epigeic that live on the top of the soil, and the anecic are much larger. Endogeic species form networks of permanent burrow systems.

      Endogeic earthworms consume leaf litter, aerate the soil, and mix the humic and mineral layers. They have a significant effect on the fungal and microbial composition the soil based on their burrowing, mixing, and aeration of the soil.

    - ***Anecic (a-knee-sick)-***the anecic earthworms are deep burrowing large worms (7-15 cm). They can burrow up to six feet into the soil, and make straight vertical unbranching tunnels. They are darkly pigmented, and similar to the endogeic coloration of having a dark head and lighter body (though significantly larger). Please note though that it's easy to confuse juvenile anecics with other earthworm types. There is only one worm per burrow and their tunnels are permanent. They come to the surface to grab leaves and then pull them down into the tunnel to feed.

      Anecic earthworms create deep tunnels that permit oxygen and water to penetrate deeply into the soil. They are also large and consume significant volumes of leaf litter.

- **Each group of earthworms has a different effect on its ecosystem.**
    - Epigeic worms consume leaf litter and promote detrital breakdown.
    - Endogeic earthworms consume mostly soil organic matter, aerate the soil, and mix the humic and mineral layers. They have a significant effect on the fungal and microbial composition the soil based on their burrowing, mixing, and aeration of the soil.
    - Anecic earthworms create deep tunnels that permit oxygen and water to penetrate deeply into the soil. They are also large and consume significant volumes of leaf litter.

Brain Storming
Begin by completing the student earthworm anatomy worksheet and information about the three groups of earthworms.

Vocabulary
- **Annelid-**any segmented worm in the phylum annelid.
- **Earthworm-**any annelid worm that burrows in soil and feeds on detrital matter.
- **Bilateral symmetry-**a body plan in which the left and right sides of the organism can be divided into mirror images of each other along the midline.
- **Radial symmetry-**a body plan in which the organisms can be divided into similar segments by passing a plant through the central axis at any angle. Often characteristic of benthic organisms such as starfish and anemones.
- **Coelomate-**an organism with a clearly defined body cavity housing organs.
- **Hydrostatic skeleton-**a water or fluid structured skeleton.
- **Epigeic-**top dwelling, surface of the soil, organisms.
- **Endogeic-** dwelling below the soil surface, in the top 6-12" layers.
- **Anecic-**dwelling below the 12" layer of surface soil.
- **Detritivore-**consumer of detrital matter, debris, and organic materials.
- **Humus-**dark organic materials found in soil, made by the decomposition of organic material either animal or plant.
- **Burrow-**a hole or tunnel in the ground that is made by an animal for refuge, also the act of creating a hole or tunnel in the ground.

Materials
For each group/student:
- Live earthworms [of your choosing/collection, Canadian night crawlers although invasive are readily available at bait stores] (1 per pair of students)
- Black construction paper (1 piece per student)
- White photocopy paper (1 piece per student)
- Wet paper towels (1-2 each student), 2-3 dry (per student)
- Student hand-out (1 per person)
- Pencil

Methods
After completing the handout on earthworm anatomy and general groups have the students break into groups to work with the live earthworms:

Make an Observation about the Earthworms
- Hand out one piece of white and black paper per student and paper towels.
- Have students wet 1-2 paper towels and lay them out flat on their desk side by side.
- Hand out one worm per student onto the wet paper towel.
- Have students observe the external anatomy and identify the head, tail, and clitellum.
- They may gently use one finger to pass it down the earthworm from the head to the tail and then in the opposite direction. Have them describe this, and which direction is rougher. Why? (the earthworm has hair like projections called setae that help them grip the soil, they should feel rougher going from tail to head).

Form a Hypothesis: Have students form a hypothesis about their worm's preferences. Will they prefer wet or dry environments? Light or dark? Why?

Design an Experiment: Using the materials provided have students design a simple experiment about earthworm preferences for wet and dry, light and dark.

Wet or Dry Preference Experiment

1. Have students lay dry paper towels side by side with dry paper towels.
2. Place the earthworm directly in the middle seam between wet and dry.
3. Observe where the worm moves.
4. After 2-3 minutes then place the earthworm back in the middle and replicate this at least 3 more times.
5. Record results on board.

Note: The earthworm prefers the wet because its skin is moist to allow for oxygen absorption. They also have a hydrostatic (water based) skeleton, so drying out dehydrates and kills them.

Dark or Light Preference Experiment

1. Have student lay the black and white paper side by side on the desk.
2. Place the earthworm directly in the middle seam between wet and dry (using the same earthworm).
3. Observes where the worm moves.
4. After 2-3 minutes then place the earthworm back in the middle and replicate this at least 3 more times.
5. Record results on board.

Note: The earthworm prefers the dark paper because it is most like its habitat, which is protected from UV light (sunburn) and from predators. Earthworms do not have eyes and do not need to see but they do sense light.

Analyze the Results: Have students write their results on the board and analyze what they mean. Share with the class.

Make a Conclusion: Did the data support or refute the suggested hypotheses? Why or why not?

Ask Another Question: What questions may arise from these small experiments? What other tests might they conduct?

Variations on the wet and dry experiment can be done with dry-dark, dry-light, wet-dark, wet-light papers and paper towels.

Discussion Points

1. Why are earthworms important for the environment?
2. Based on what you know about the three groups of earthworms, how do you think they affect the soil's composition, chemistry, macro/micro flora and fauna, fungus?
3. Could invasive earthworms (all three groups) have a negative impact on an ecosystem? How?
4. Using what you know how could test or examine the answers from question number 3 above?

MD Teaching Standards: 1.2-1.6 and 3.1, 3.2, 3.5

Name: _____

Date: _____

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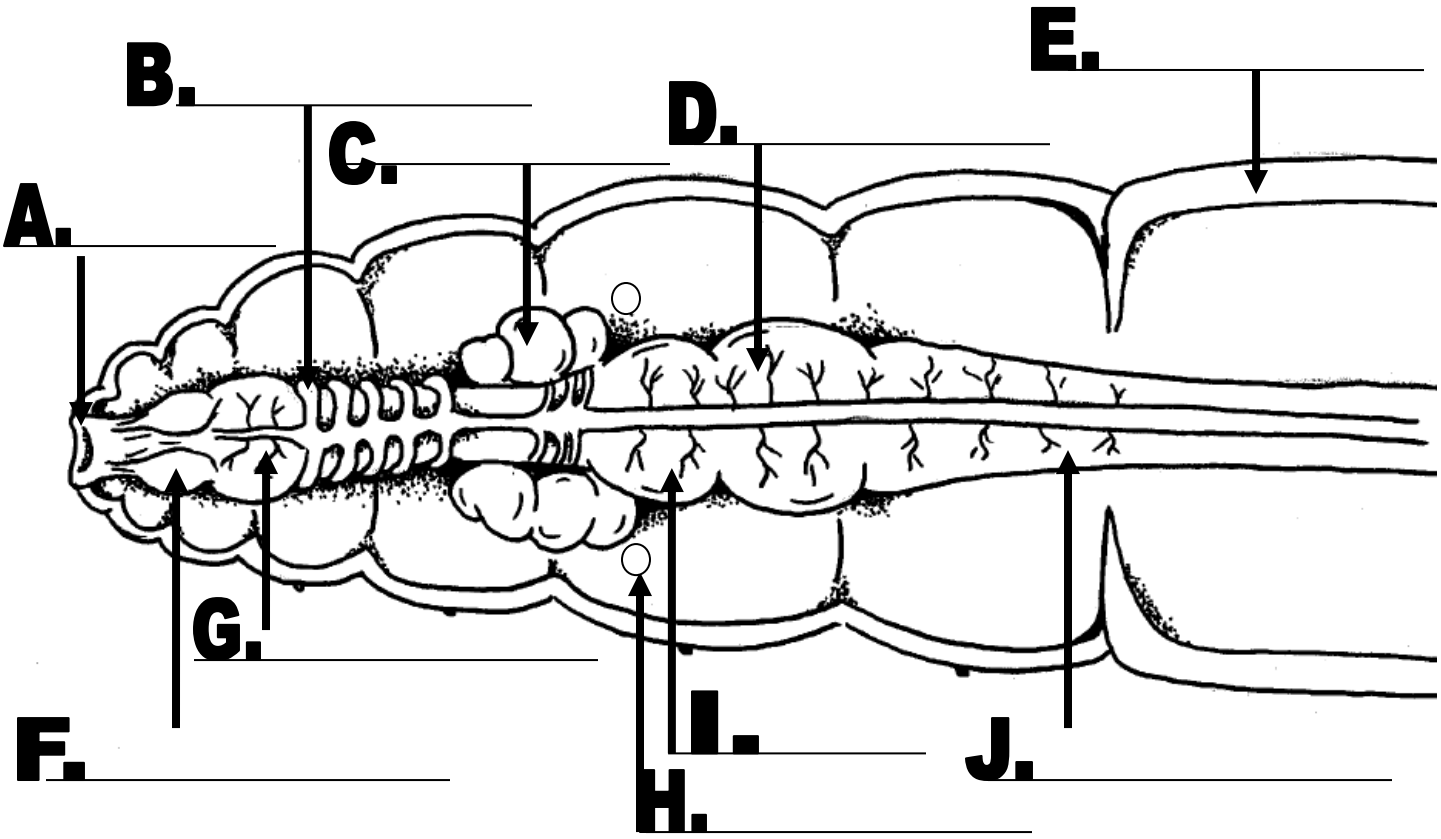
Activity I: Earth Worm Anatomy & Groups Student Worksheet

Label the parts of the earthworm below.



Use the following terms to label the diagram above then describe why each is important in the body of the earthworm:

Crop-_____

Gizzard-_____

Testes-_____

Ovary-_____

Ganglia-_____

Mouth-_____

Pseudohearts-_____

Intestines-_____

Clitellum-_____

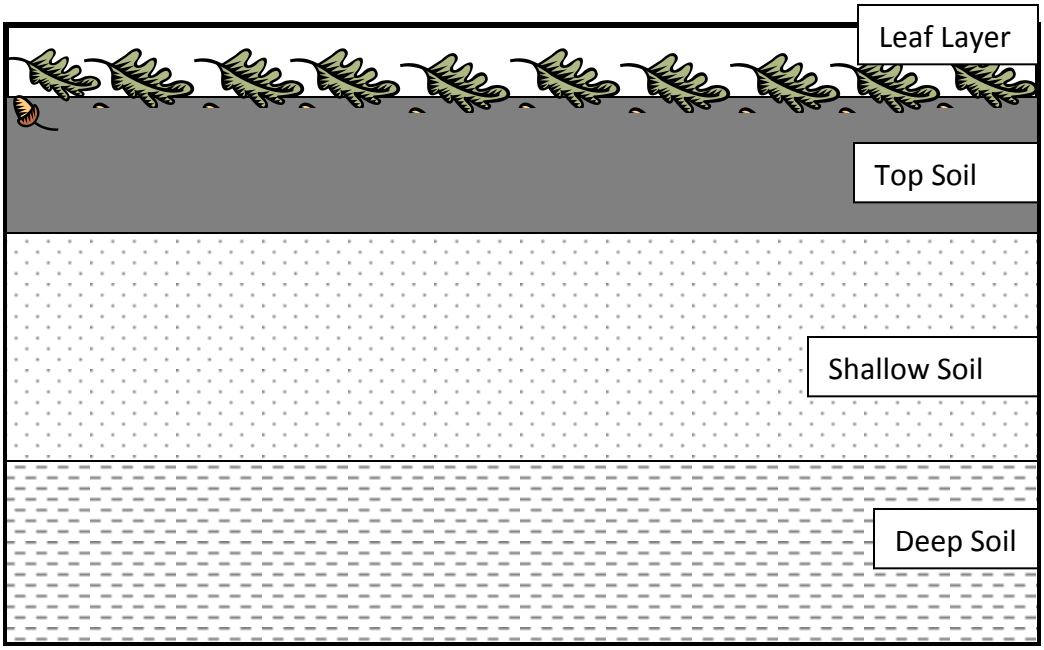
Pharynx-_____

Activity I: Earth Worm Anatomy & Groups Student Worksheet

On the chart below write the characteristics of each of the three broad categories of earthworm and use a crayon to draw a worm with the proper coloration in the last column

	Description	Where is it found?	What type of burrows? (depth/permanent?)	Coloration
Epigeic				
Endogeic				
Anecic				

Using the box to the right draw in where you would find three types of earthworms and the direction/depth of their burrows (horizontal or vertical or both)



Thought Question:

Based on where they are found in the soil how do you think each type of earthworms affect the soil? What about the other micro and macro organisms in the soil?

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Earthworm and Ecosystems
Lesson Plan 2: Alien Invaders- Sampling Earthworms

Based on the following papers by Dr. Katalin Szlavecz from John Hopkins University and SERC scientists Dennis Whigham and Melissa McCormick :

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Earthworm Sampling

Lesson Question: How many earthworms in the three distinct groups are found per square meter of habitat?

Background: Before colonization of the Americas there were native earthworms found in the local soils, with the exceptions of New England and parts of the upper Midwest, where they have been absent since the last glaciation. Ships coming into the new world carried earth and stone ballast, carrying non-native earthworms, as well as settlers bringing agricultural plants potted in soil with non-native worms. While the import of non-native worms sounds harmless, scientists are now finding that it has dramatically altered North America's ecological landscape.

For example in New England, where earthworms were previously absent, introduced earthworms are affecting understory trees. Normally in these forests the leaves and detritus that fall rely solely on the slow decomposition of fungus and small detritivores/microorganisms. This deep leafy layer allows for moisture retention, seedling protection, and prevention of runoff or moisture absorption. After the introduction of non-native worms the loamy layers of leaves were consumed, removing nutrients from the tree roots, exposing seeds to predation and weathering, and allowing erosion to occur. This has promoted the recruitment of invasive plants on bare soil, which respond well to the increased nitrogen and disturbed soils that the earthworms create.

In this activity students will be collecting earthworms from different ecosystems and calculating the number of earthworms per square meter of soil. Knowing that it's estimated that 99-100% of the earthworms in urban and rural soils are invasive, chances are high that the earthworms students collect will be invasive. Because each region is different this is a general guide to collecting and identifying the worms.

As mentioned in Lesson Plan 1 there are three distinct but broad categories of earthworms students will collect:

- ***Epigeic(epi-gee-ick)-*** these worms are usually dark red on top and lighter on the bottom and relatively small in size (1-5 cm). The red on their bodies covers at least ¾ of their length. Their darker coloration is like "sunscreen" pigment that keeps them from getting sunburned. They live under the leaves and do not make permanent burrows.

  Epigeic worms consume leaf litter and promote detrital breakdown.

- ***Endogeic(end-o-gee-ick)-***these worms make burrows in the soil beneath the litter layer. Their burrows are horizontal and relatively shallow, going between the humic and mineral layers (about 30-50 cm deep). They are most often pale white, pink, orangish, or bluish. Some may have lighter bodies but dark red heads. The red head covers less than ½ to ¼ of their body. This is because they come to the surface to

grab food, and then retreat back into their burrows with a mouth full of leaves. You can tell these apart from other groups because they come out of the ground, as opposed to the Epigeic that live on the top of the soil, and the anecic are much larger. Endogeic species form networks of permanent burrow systems.

Endogeic earthworms consume leaf litter, aerate the soil, and mix the humic and mineral layers. They have a significant effect on the fungal and microbial composition the soil based on their burrowing, mixing, and aeration of the soil.

- ***Anecic (a-knee-sick)-***the anecic earthworms are deep burrowing large worms (7-15 cm). They can burrow up to six feet into the soil, and make straight vertical unbranching tunnels. They are darkly pigmented, and similar to the endogeic coloration of having a dark head and lighter body (though significantly larger). Please note though that it's easy to confuse juvenile anecics with other earthworm types. There is only one worm per burrow and their tunnels are permanent. They come to the surface to grab leaves and then pull them down into the tunnel to feed.

  Anecic earthworms create deep tunnels that permit oxygen and water to penetrate deeply into the soil. They are also large and consume significant volumes of leaf litter.

Brain Storming

After reviewing the different types of worms discuss with students how they might go about collecting and identifying the earthworms. Knowing the earthworm's habitat and physiology (from the first lesson plan), have them come up with some ideas of how earthworms might be studied, both invasively (shoveling up the soil) and non-invasively (electroshocking, dry mustard, worm grunting, or waiting for a major rain) and the pros and cons of each.

Vocabulary

- **Annelid**-any segmented worm in the phylum *Annelida*.
- **Epigeic-**categorization of annelids living on top of the soil horizon.
- **Endogeic-**categorization of annelids burrowing and living in the top 6-12" of the soil horizon.
- **Anecic-**categorization of annelids burrowing and living deeper than 12" soil horizon.
- **Loam-**rich dark organic soil containing nearly equal parts of sand and silt as well as some clay.
- **Detritus-**any disintegrated material or debris, organic or inorganic.
- **Soil horizon**-a layer of soil with distinct organic and inorganic characteristics.
- **Burrow**-a hole or tunnel made by an organism.

Materials

For each group/student:

- 1 gallon jug of fresh water.
- 1 gallon jug of mustard solution (3/4 cup per gallon).
  - NOTE: Use dried mustard without any other additives. Liquid mustard from the store contains vinegar and is harmful. You can order bulk dry mustard online or through your local health food store.
  - If you can make the mustard at least 1-2 hours ahead of time it will be stronger and work better for extraction.
- 2 meter sticks
- 3 sorting trays (sandwich sized Tupperware)
- Tweezers (one per student)
- Clipboards and Pencils (one per group)
- Student data and method sheet (one per group)
- Kitchen scale (1 per group)

- Weighing trays (1 per group)
- Moist paper towels (3-4 per group)

Some Hints About Earthworm Extraction using Liquid Mustard:

- ✓ Students should not breathe dry mustard. Wet mustard is relatively benign but make sure students do not have any allergies. Those with allergies may choose to record data.
- ✓ Mustard is an irritant. It irritates the earthworm's skin so that they want to crawl out of their burrows. It does not harm them.
- ✓ If you are using the earthworms for later studies you may want to rinse them in gentle a fresh water bath before placement in study plots.
- ✓ The fresh water jug provided is to rinse the study plot free of mustard and dilute it so that earthworms may resume their burrowing.
- ✓ Liquid extraction does not work well in compact or extremely dry soils.
- ✓ If the soil is overly saturated with rain wait until it dries a bit before sampling. The water may over-dilute the sample.
- ✓ This technique will not work well after it has been very hot and dry or cold the days prior to sampling. The earthworms may still be dormant.
- ✓ If your sample site is in the sun be sure to keep earthworms covered and cool so they don't dehydrate.

NOTE: It's important that students understand that coloration and size isn't always the best way to categorize earthworms (especially with young earthworms). The amount of time it takes for the earthworms to emerge is also critical. You can have students correlate the amount of time it takes the worms to emerge and type of earthworm. ***Students can assume that the worms they collect from the top of the soil are epigeic. Those that are largest are the anecic. Everything in between is endogeic.***

Methods

Make an observation: Students should observe the different ecosystems in the areas that they are being asked to sample. Have them look at the amount of leaf litter, grass, understory plants, light, available water, soil types, plant, and tree types.

Ask a question: Have them ask a question about which ecosystem, or part of an ecosystem, might have more worms or different types of worms from the three groups mentioned.

State a hypothesis: Students should form a hypothesis about their study plot and which of the three types of worms they think will be most common, or how the numbers of worms in their plot will compare to other plots.

Conduct an experiment: Students will conduct a liquid extraction of earthworms using a dry mustard solution. If you want to engage them in scientific design you can provide them with the materials and ask them to design the experiment before giving them the student protocols. Have students follow instructions on the sheet.

Analyze the results: After students collect the earthworms they can bring them back into the classroom for sorting into their respective groups, on wet paper towels. After the worms have been sorted have students weigh them and record their data on the student worksheet provided. Students should then share their information with the entire class. Data should then be calculated and graphed.

Make a conclusion: Did the data support or refute the hypothesis? Why or why not?

Ask the next question

Earthworm and Ecosystems
Lesson Plan 2: Alien Invaders- Sampling Earthworms

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Earthworm Extraction Method: Student Sheet

WARNING: *Be very careful, you will be working with liquid mustard, do not breathe in the dust, touch your eyes or mouth, or ingest the liquid. If you have an allergy to mustard let your instructor know right away.*

1. **Your group will be given an earthworm extraction kit containing**: meter stick, milk jug with fresh water, milk jug with mustard solution, tweezers, sorting pan(s), data sheet, clip board, pencil.
2. **Proceed to your assigned plot** (your instructor will give you the location).
3. **Fill in your data sheet** with student names and your class time/date.
4. **At your plot's designated flag measure a 1 meter x 1 meter square**. If you only have two meter sticks measure the two corners of your square and use sticks to outline the rest of the square.
5. **After marking off your area remove all loose debris from the plot**, be sure to look for earthworms in the leaf litter, under bark, etc. Put these in your collection pan. Remember to keep your collection pan in a shady cool spot. Don't let the earthworms dry out.
6. **Pour a very small amount of water into your worm collection pans**, not a lot, just enough to keep the earthworms moist. You don't want to drown them.
7. **Slowly pour about 1/2 of the mustard solution** across the entire surface of your plot, try to pour evenly and carefully.
8. **As the earthworms come up collect them, using tweezers** (Be careful, don't squeeze them in half). **NOTE: IF AN EARTHWORM ISN'T ALL THE WAY OUT OF ITS BURROW DON'T PULL IT UP. WAIT FOR IT TO COME OUT OF THE BURROW COMPLETELY BEFORE COLLECTING IT!**
9. **If the worms don't come up right away then wait 2-3 minutes** and then pour a bit more mustard solution on the plot.
10. **Continue extraction until the mustard solution is used up.** This should take about 5-10 minutes total.
11. **Pour the fresh water jug's entire contents across your worm plot** and flush out the mustard from the ground.
12. **Bring the collected worms back to the lab, sort them, and then weigh them by group**. Record your data.
13. **Return your worms to the soil near your study plot**, but not in your mustard plot.
14. **On the white-board in the front of the room** write down the total number of individuals in each group in the plot that you studied.
15. **Graph your data** on the graphing paper provided and answer questions.

Earthworm and Ecosystems
Lesson Plan 2: Alien Invaders- Sampling Earthworms

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Earthworm Extraction Student Data Sheet

Class Time and Date: _____

Student Names: _____

Weather Conditions—Temp: _____ **Cloud Cover (%):** _____ **Recent Rain (yes/no):** _____

Plot #	Location	Habitat	# of Epigeic Worms	Weight of Worms (oz)	# of Endogeic Worms	Weight of Worms (oz)	# of Anecic Worms	Weight of Worms (oz)
1								
2								
3								
4								
5								
6								
7								
8								
	TOTALS							
	# per square meter (total/3)							

You can assume that the worms you collect from the top of the soil are epigeic. Those that are large and take longest are anecic, everything in between is endogeic.

EARTHWORM STUDENT IDENTIFICAITON GUIDE

Smithsonian Environmental Research Center

Epigeic(epi-gee-ick)

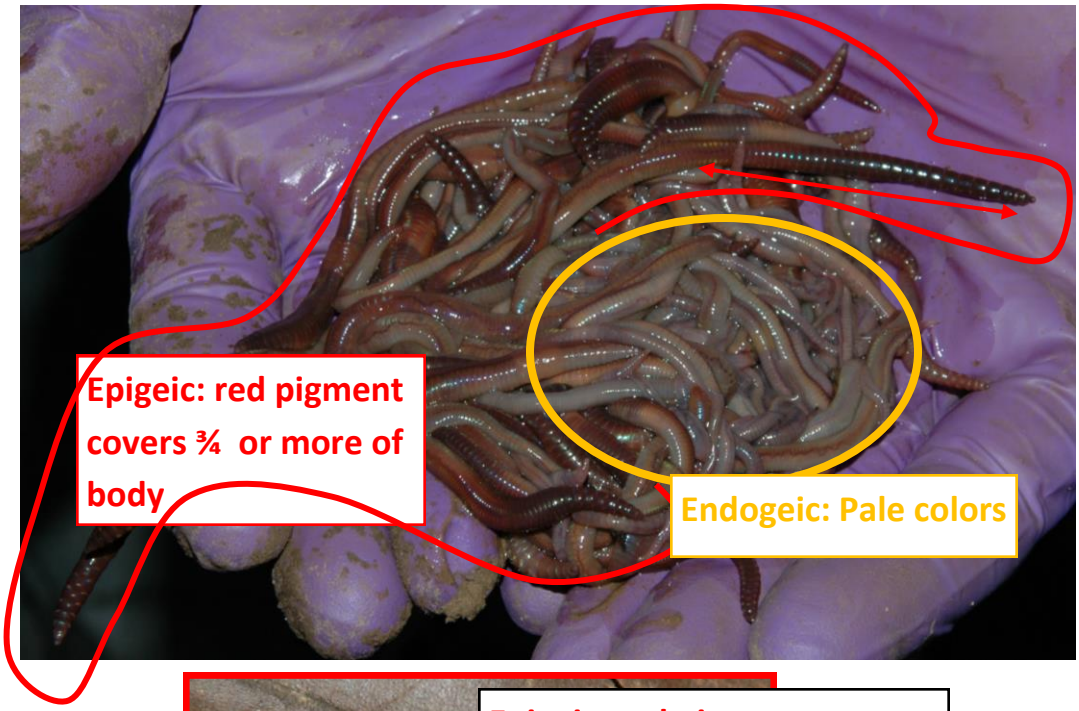
- Found on top of soil, under leaves and debris; they do not make burrows.
- Usually dark red on top and lighter on the bottom.
- The red on their bodies covers at least ¾ of their length.
- Relatively small in size (1-5 cm).

Endogeic(end-o-gee-ick)

- Make burrows in the soil beneath the litter layer, which are horizantal and relatively shallow, going between the humic and mineral layers (about 30-50 cm deep).
- Colors are pale white, pink, orangish, or bluish.
- Some may have lighter bodies but dark red heads. The red head covers less than ½ to ¼ of their body.
- Medium sized worm (2-12 cm long).
- Form networks of permanent horizontal burrow systems.

Anecic (a-knee-sick)

- Deep burrowing large worms (7-15 cm), such as Canadian night crawlers. They can burrow up to six feet into the soil, and make straight vertical unbranching tunnels.
- Darkly pigmented, and similar to the endogeic coloration of having a dark head and lighter body (though significantly larger).
- There is only one worm per burrow and their tunnels are permanent.



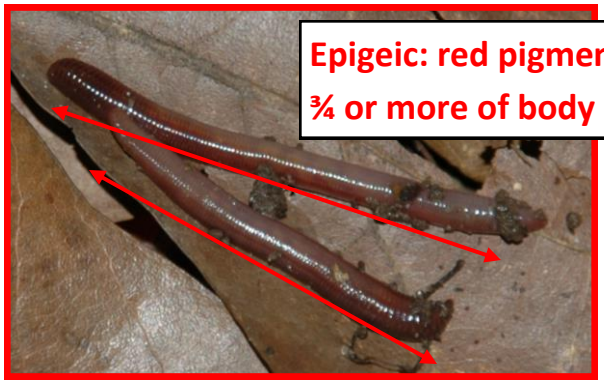
GOOD RULES FOR SORTING:

All Epigeic live on the surface under the leaves.

Endogeic species come up from the soil, and are smaller, usually pale.

Anecic often come up quickly because water fills their straight burrows right away.

The deep burrowing anecic may take the longest to emerge.



How to measure an earthworm for sorting:

Place your earthworm on a wet paper towel. Measure your earthworm, when it is fully extended, end to end. Do not attempt to stretch the earthworm. You can try to gently unroll it to get a measurement.

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Earthworm and Ecosystems
Lesson Plan 3: Earthworms and Leaf Litter

Based on the following papers by Dr. Katalin Szlavecz from John Hopkins University and SERC scientists Dennis Whigham and Melissa McCormick :

Szlavecz, Katalin., McCormick, Melissa., Xia, Lijun., et. al. 2011. Ecosystem effects of non-native earthworms in Mid-Atlantic Deciduous Forests. *Biological Invasions*. 13: 1165-1182.

Lesson Question: Do earthworms have leaf litter feeding preferences?

Note about Lesson Plan Completion Time: this lesson plan is designed to be completed in 4-6 months. Set up time is minimal, but the containers must be allowed to rest for several months before collecting final usable data although observations of change may be made every week by students.

Background: Earthworm invasions by non native species, and their effects on ecosystems, can be directly correlated to the worm's dietary preferences. The differences in dietary preferences by epigeic, endogeic, and anecic worms vary. This is in part due to their burrowing styles and the nutritional qualities of the food consumed. Leaf litter, which the worms consume, protects seedlings; maintains constant moisture levels in the soil keeping a stable soil environment; provides nutrients and food for trees; and prevents erosion and runoff. Changes in leaf litter layers may affect all of these factors in an ecosystem with the potential for altering an ecosystem's flora and fauna composition.

Brain Storming

Begin by having student consider the three different groups of earthworms and their characteristic burrowing patterns. Have them hypothesize about their dietary preferences and how their burrowing styles might influence their feeding (and/or how that may affect your local ecosystems). Next have them discuss how they might research this question or design an experiment to test earthworm feeding preferences.

Vocabulary

- Detritivore
- Burrow
- Humus
- Ecosystem
- Leaf litter
- Forest understory
- Earthworm casts

Materials

For each group/student, suggested 4 groups:

- Four, clear two liter soda bottles (per group)
- One box cutter (for instructor): You will need to prepare the bottles
- Standard potting soil

- Leaf litter, one sandwich bag or about 2 cups per group of the following (up to group leader but here are options):
    - Oak leaves
    - Red maple leaves
    - Tulip poplar leaves
    - Pine needles
    - Dogwood leaves
    - Sassafras leaves
- Ruler (1-2 per group)
- Sand (enough to cover bottom of bottles per group)
- Water bottle (1 per group)
- Student methods and data sheet (1 per student)
- Earthworms (species depends on class preference and hypothesis, should be mature see below)
- Electronic kitchen scales
- Paper towels (damp, enough to weigh worms on)
- Fine window screen mesh (enough to cover 4 bottles and put into bottom of four bottles per group)
- 4 rubber bands, enough to go around soda bottles.
- Measuring Cup (1-2 per group)
- Permanent marker (1+ per group)
- Masking tape (roll)
- Duct tape (2-3 pieces per group)
- Soil pH kit (1 per group: inexpensive versions available online through Carolina Biological supply and through and through local garden supply stores)
- Lid or plastic container to set experiment in (1 per group)

Some Hints About Choosing Earthworms and Preparing Materials For the Lab:

- ✓ For this study the types of leaf litter you need will depend on the students' hypotheses. Leaf litter should be monoculture, and as "clean" as possible, with only one species.
- ✓ You may wish to wash and dry the leaf littler if you have time, to eliminate pesticides, other insects, or organisms.
- ✓ Leaf litter should be dry when initially weighed and then added to containers. It should also be dried before final weighing.
- ✓ Worms and soil must be kept damp using a spray bottle. Be sure to use non-chlorinated water.
- ✓ The types of earthworms you choose for this experiment will vary based on hypothesis.
- ✓ Regardless of species the earthworms should be mature, with a clear clitellum present, indicating that they are sexually mature. This is the light colored band, or lump, that goes around their body near the head. See previous lesson plans for earthworm anatomy.
- ✓ To weigh earthworms it is suggested that they are rinsed in fresh non-clorinated water to prevent dirt from being weighed.
- ✓ For optimal weighing results you may wish to keep the worms a container with wet paper towels, and no food, overnight to allow them to clear their digestive tracts.
- ✓ You will need to prepare the two liter soda bottle ahead of time by rinsing them, removing the labels, and then cutting the bottles where their necks begin to turn inward, so that you're left with a clear cylinder. Flat bottom bottles work best if available.
- ✓ You will also need to punch holes in the bottoms of each bottle to provide drainage of water or leaching of water. We suggest using a drill with a 1/32" bit or smaller. If using containers with cloverleaf pattern be sure to drill at least one hole in each section.

Methods

Make an observation:

- Students should make some observations, based on previous lessons and what they know about native and invasive earthworms.
- These observations should pertain to how the different groups of earthworms feed and how this might affect their dietary and feeding preferences.
- Additionally students should consider such things as the acidity of specific types of leaves such as oaks and pines versus trees like maples and dogwoods and how earthworms might affect the pH or acidity of the soil.

Ask a question: Have students ask a question about dietary preference in earthworms using their observations. Lead them to the specific types of leaves you have already collected and the worms available in your area and thoughts about pH.

State a hypothesis: Next have students create a testable hypothesis about earthworms and their dietary preferences.

Conduct an experiment: Provide students with a list of material and have them brain storm about experimental design. Be sure to include a control. Guide them towards the methods provided on the student method sheet. Set up experiment as directed.

Analyze the results: The experiment is designed to run for 4-6 weeks, depending on time available, more may also be required during colder months. Have students use the student data sheet to collect information.

Make a conclusion: After collecting the data have students graph their information and share this information with the class. As a class hypothesize about the experiment and what happened to the leaf litter and earthworms.

Ask the next question: After the data is analyzed have students come up with more questions and further extensions and possible experiments.

EXAMPLE OF POSSIBLE LAB SET UPS:

EXAMPLE 1

Group 1
Worm Type: 10 Red Wigglers (endogeic)

- **Container 1:** Control
- **Container 1:** Oak leaf litter
- **Container 3:** Maple leaf litter
- **Container 4:** Pine needle leaf litter

Group 2
Worm Type: 10 Night Crawlers (Anecic)

- **Container 1:** Control
- **Container 1:** Oak leaf litter
- **Container 3:** Maple leaf litter
- **Container 4:** Pine needle leaf litter

Group 3
Worm Type: 10 Epigeic Worms (collected around school see previous earthworm collection protocols)

- **Container 1:** Control
- **Container 1:** Oak leaf litter
- **Container 3:** Maple leaf litter
- **Container 4:** Pine needle leaf litter

EXAMPLE 2:

Group 1
Worm Type: 5 Red Wigglers (endogeic)
All Containers: Oak leaf litter

Group 2
Worm Type: 10 Red Wigglers
All Containers: Oak leaf litter

Group 3
Worm Type: 15 Red Wigglers
All Containers: Oak leaf litter

Group 4
Worm Type: 20 Red Wigglers
All Containers: Oak leaf litter

Earthworm and Ecosystems
Lesson Plan 3: Earthworms and Leaf Litter

Smithsonian Environmental Research Center

Earthworms and Leaf Litter Student Data and Set Up Method Sheet

Put a check beside each of the following items to make sure that you have what you need:

- ☐ Four, clear two liter soda bottles with top cut off (per group)
- ☐ Standard potting soil (enough to fill 4 bottles)
- ☐ Leaf litter (your instructor will guide you as to as to what species or types you need based on your hypothesis and experimental design). You should have about one sandwich bag or 2 cups of leaf litter per bottle.
- ☐ Ruler (1-2 per group)
- ☐ Sand (enough to cover bottom of bottles per group)
- ☐ Water bottle filled with non-chlorinated water (1 per group)
- ☐ Student methods and data sheet (one per student)
- ☐ Earthworms (your instructor will guide to as to what species or types you need based on your hypothesis and experimental design).Electronic kitchen scales
- ☐ Paper towels (damp, enough to weigh worms on)
- ☐ Fine window screen mesh (enough to cover 4 bottles and enough to fill in bottom of each bottle)
- ☐ 4 rubber bands, enough to go around soda bottles.
- ☐ Measuring Cup (1-2 per group)
- ☐ Permanent marker and masking tape
- ☐ Duct tape (2-3 pieces)
- ☐ Soil pH kit
- ☐ Lid or plastic container to set experiment in.

Experimental Set Up Steps

Step 1: Make sure your soda bottles are clean and dry and then add screen mesh into the bottom of the bottle to make sure the holes in the bottom are covered. You may want to add a couple of pieces of duct tape to hold this in place.

Step 2: Place masking tape on each bottle and label it 1-4 and assign one to be the control and the rest to be your treatments.

Step 3: Add 1 cup of clean sand to the bottom of each bottle. Gently tap bottles on counter top to settle the sand.

Step 4: Using the kit provided measure the pH of your soil and then add 6 cups of potting soil to each bottle and again gently tap the bottle on the counter top to settle the soil.

Step 5: Depending on your hypothesis, and the experimental design of your group, you may have one species of leaf litter or several. Make sure your leaf litter is dry and then weigh it on the scale provided. Leaf litter weight should be the same for each container. Be sure to tare your scale. Record the leaf litter weights on the sheet data sheet. This should be done for each bottle and not collectively

Step 6: Choose a set number of earthworms for your experiment; this will vary based on your hypothesis and experimental design. It is suggested that you use no more than one species per bottle, and no more than 10 individuals per bottle.

Step 7: Once you have chosen how many earthworms you will use then select the desired number of mature adults. This means that they should have a clear clitellum.

Step 8: Weigh your earthworms and record their weight on your data sheet. This weight should be per each bottle. Your instructor may have you starve the earthworms for 24 hours before weighing, this will

depend on the amount of class time available. Starving them sounds mean but it actually allows them to clear their digestive tracts so that you're not weighing their feces and undigested food.

Step 9: Place the earthworms and leaf litter in their assigned bottles and be sure to label them with the treatment, number and types of worms.

Step 10: Cover the soil with leaf litter and then using the water provided in your water bottle gently pour water through the soil until it leeches through the soil and out the bottom. This should not be a gushing torrent of water, but just enough to trickle through.

Step 11: Cover each bottle with the screen provided and then rubber band securely. Place all of the containers in or on a container that is waterproof. A dark quiet area is idea.

Step 12: Observe your experiment every week and be sure to keep soil moist.

Student Data Sheet

Name of Group Members: _____

Date of Initial Set Up: _____ Group Number: _____

Question:

Hypothesis:

Dependant Variable *(this is the thing that is changed or modified in your experiment):*

Independent Variables *(remember these are stand alone and don't change):*

SET UP INFORMATION Date: _____

Treatment Number	Control	1	2	3
Leaf Litter Type	**(if applicable)**			
Leaf Litter Weight	**(if applicable)**			
Soil pH				
Worm Species	**None**			
Total Worm Weight	**None**			

Earthworm and Ecosystems
Lesson Plan 3: Earthworms and Leaf Litter

Group Number/Name: _____

OBSERVATION DATA

Date: _____

Observation of leaf litter

Observation of soil

Observation of leeching when water is poured through (this will be qualitative and not quantative)

pH of water that leeched through soil

Date: _____

Observation of leaf litter

Observation of soil

Observation of leeching when water is poured through (this will be qualitative and not quantative)

pH of water that leeched through soil

Date: _____

Observation of leaf litter

Observation of soil

Observation of leeching when water is poured through (this will be qualitative and not quantative)

pH of water that leeched through soil

Final Observation Data Sheet

Treatment Number	Control	1	2	3
Leaf Litter Type	**(if applicable)**			
Leaf Litter Weight	**(if applicable)**			
Soil pH				
Worm Species	**None**			
Total Worm Weight	**None**			

Compare the final data to the initial data that was collected regarding leaf type, worm type/weight, and soil pH. What does your data suggest?

Does this data support or not support your hypothesis? Why or why not?

What other questions arise after doing this experiment? What other types of experiments might you conduct?

Discussion Points

- Discuss with students how earthworms affect leaf litter, and how leaf litter acts like the 'skin' of the forest protecting seedlings, preventing erosion, holding in moisture, helping soil chemistry, and slowly releasing nutrients.
- Ask students how earthworms alter the chemistry of the soil based on their presence (numbers) and dietary preferences.
- You may want to offer them ideas such as how too many earthworms can over-till and aerate the soil, or too rapidly consume leaf litter.
- Based on your experimental findings you may also want to discuss how earthworm preference of certain leaf types may lead to changes in soil chemistry and what is sequestered underground in their castings or poop.
- Finally discuss what we can do to monitor earthworms and control invasives and their movement into native forests and areas where they previously have been excluded.

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Earthworms and Ecosystems
Lesson Plan 4: Earthworms and Seeds

Based on the following papers by Dr. Katalin Szlavecz from John Hopkins University and SERC scientists Dennis Whigham and Melissa McCormick :

Szlavecz, Katalin., McCormick, Melissa., Xia, Lijun., et. al. 2011. Ecosystem effects of non-native earthworms in Mid-Atlantic Deciduous Forests. *Biological Invasions*. 13: 1165-1182.

McCormick, Melissa., Parker, Kenneth., Szlavecz, Katalin., Whigham, Dennis. Pending Publication. Effects of Earthworms on Orchid Seeds. SERC.

Lesson Question: Does earthworm digestion affect the germination of seeds?

Background: Earthworms are thought of as the "tillers" of the earth. They effectively till and aerate the soil; however their ecological role is much larger, including their effects on seeds and seedlings in forest ecosystems. This is especially true of invasions of large numbers of earthworms into ecosystems not previously inhabited or with minimal earthworm presence. Through their digest processes earthworms convert carbon and nutrients that is locked up in detritus into a more readily available form. They then distribute these nutrients into the soil, through burrowing, sometimes horizontally or vertically in the soil horizon depending on their preferred habitat. In this digestive process earthworms often consume the seeds of plants, which as several consequences. As the seeds pass through the earthworms' digestive tract they are exposed to sand and grit, which scarifies them. Some seed species need this scarification to germinate, while it may be detrimental to others. In this process earthworms may also transport the seeds in the soil column and bury them. This may be beneficial for some types of seeds and not for others.

NOTE: This lesson plan may stand alone or be used in conjunction with previous materials in the rest of the *Earthworms and Ecosystems* lesson modules. At a minimum it is suggested that students have a working concept of earthworm anatomy and digestion for this activity.

Brain Storming: Have students brainstorm about how they think earthworms might affect the seeds of plants. Then have them discuss how the digestive process of the worm might affect the seeds' coat and its germination. Based the brainstorming have them come up with some questions the might like to test regarding this process, and generate ideas about how they might design an experiment.

Vocabulary

- **Seed-**an embryonic plant that is enclosed in a covering or seed coat, with or without stored food or endosperm.
- **Seed coat-**the covering of a seed.
- **Germination-**the process by which a plant emerges from a seed.
- **Digestion-**the breakdown of food, through mechanical or chemical processes, into smaller parts that are more easily absorbed into the blood stream.
- **Gizzard-**an organ found in the digestive tract of animals, that holds grit or fine stones, used for grinding food before moving on to the stomach. It is often muscular and thick walled.
- **Scarification**-scratching or roughing the seed coat of a seed. This process may aid in the germination of the seed.

- **Viability**-the capability of a seed to germinate and produce a new plant.

Materials

For each group/student:

- 10 plastic 8 oz jars (available online, though cosmetic suppliers, e-bay, or Carolina Biological Supply Co.).
- Earthworms (one per jar, you may choose night crawlers, red wigglers, or local earthworms. Be sure that if you choose red wigglers that you don't release them into the wild, they are an invasive species!).
- White clover seeds (other possible seeds would include basil, lettuce, or grass seeds, etc.), you will need enough for at least 40 per group, available at farm stores or online.
- Plaster of paris (1 box should be enough for entire class)
- Mixing bowl, spoon, and measuring cup for water (1 for class)
- Tweezers (at least 1 set per group)
- Paper towels, enough for each group
- Bowl of water (one per group, can be soup bowl sized)
- Leaf litter (preferred maple, tulip poplar, or sweet gum work well, must be dried and weighed, need about 1-2 oz per container for a total of about 40 oz)
- Tray or pan to hold containers of earthworms (one per group)
- Permanent marker (one per group)
- Masking tape role (one per group)
- Fine mesh window screen (1 roll per class should be enough)
- Scissors (2-3 pairs per group)
- Rubber bands (1 bag for class)
- Newspaper for tables or benches
- Potting soil (1-2 bags per class)
- Plant rearing trays (2 set per group, enough to hold 10-20 seeds each)
- Popsicle sticks (10-12 per group)

Methods

Make an observation:

- Have students make some general observations about how earthworms move and digest food. You may wish to distribute real earthworms for this observation (as an earthworm moves longitudinally it pushes food through its long digestive tract, starting at the mouth and moving through the crop, gizzard, and intestines. The earthworm has a long digestive tract for more surface area to absorb nutrients and it's "rings" allow for peristalsis of food through the gut. Earthworm movement in the soil may also bury seeds and/or provide them with fertilizer in the form of castings).
- Next have them observe how this type of digestion and movement might affect the seeds of plants (by passing through the gut of earthworm's seeds are often scarified, which in some speices helps with germination. Seeds may also be buried or provided with fertilizer, which may also help with germination).

Ask a question: Have students as a question about earthworm digestion and seeds. For example, "If seeds pass through the gut of an earthworm do they germinate more than those that don't?" or "Do certain species of seeds germinate more successfully than others when passed through an earthworm's gut?"

State a hypothesis: Based on the question have students create a working hypothesis.

Conduct an experiment: You may want to give students a list of materials and have them brain-storm about they would test earthworm digestion on seed viability. After brain storming provide them with the set up for your experiment:

NOTE: Before conducting experiment be sure that you have enough adult worms of the particular species you are using. You may use night crawlers, red wigglers, or earthworms collected in your local region. Adults have a clear clitellum or bump right behind the head. For best results keep them in a bowl or jar with a wet paper towel, and no food, for twenty four hours. Rinse them before use in class to remove waste.

Step 1: Distribute materials to each group of students and have them lay down newspaper in their work area.
Step 2: Place clean jars on newspaper and fill each with at least ½" of plaster of paris. While plaster is drying have students cut out screen mesh to cover top of jar, with enough mesh left to rubber band closed.
Step 3: For each jar place one or two strips of masking tape on the side and write the following: jar number, worm species, leaf litter type (abbreviation ok, seed type (abbreviation is ok), and date.
Step 4: Select at least one adult earthworm for each jar and place in jar. To select a mature adult be sure they have a clear clitellum or enlarged lump just behind their head.
Step 5: Weigh approximately 1 oz of leaf litter for each jar. Crush up dried leaf litter until it is in small pieces. Make sure leaf litter is damp, but not dripping.
Step 6: Count out 10-20 seeds for each jar (instructor will give you exact number).
Step 7: Add seeds to each 1 oz of wet leaf litter and then place in each jar on top of earthworm. Be sure to write seed type or abbreviation on top of jar.
Step 8: Place square of mesh over jar and rubber band in place. Put all jars on tray with group's name, class, and date. Allow to sit for 48 hours.
Step 9: After 48 hours remove earthworms from jars and rinse each worm gently in a bowl of non-chlorinated water.
Step 10: Remove the leaf litter from the jars and collect undigested seeds from remaining leaf litter. This may be easier with a hand-lens or microscope. Count the number of seeds and place them on a damp paper towel. Rinse empty jars lightly with non-chlorinated water and return to tray.
Step 11: Place worms, one per jar, back into jars (cover) and allow them to rest for 72 hours.
Step 12: Set up plant rearing trays with potting soil and plant undigested seeds, one per section. Write date, plant species, that the seeds are undigested, and the group name/number on popsicle sticks and place in the soil of the trays. Optionally place trays under grow light or where they will receive optimal sunlight in your classroom. Avoid drafty windows.
Step 13: After 72 hours collect earthworm feces from jars. Count and sort out seeds. Follow the same procedures for step 12.
Step 14: Record information about seed germination for those seeds that passed through the earthworm gut and those that did not.

Analyze the results: Have students share their results with the class and discuss their collective experiment. Analyze the results of each experiment. Did the data support or refute the hypotheses presented? Why or why not?

Make a conclusion: Have students draw a conclusion based on the results, and suggest why this conclusion is supported.

Ask the next question: Finish the exercise by having students ask what questions arose from their experiment, and/or experimental design. Have them ask another question or series of questions that could be a follow up to this experiment.

Discussion Points

- Which seeds germinated best? Those that passed through the earthworm's guts? Those that didn't?
- Why would passing through an earthworm's gut benefit or hard different types of seeds?
- What would large numbers of invasive worms mean for the seeds of forest plants?

EARTHWORMS AND ECOSYSTEMS STUDENT DATA SHEET

Name: _____

Group Name/Members: _____

_____ **Date:** _____

Question:

Hypothesis:

Jar Number	Number of Seeds at Start of Experiment	Leaf Litter Species (1 oz per jar)	Worm Species (1 adult per jar)	Number of Seeds Recovered in Leaf Litter After 48 hrs.	Number of Seeds Recovered in Worm Castings

How many seeds that were not digested germinated? _____

How many seeds that were digested germinated? _____

Does this data support or refute your hypothesis? Why or why not?