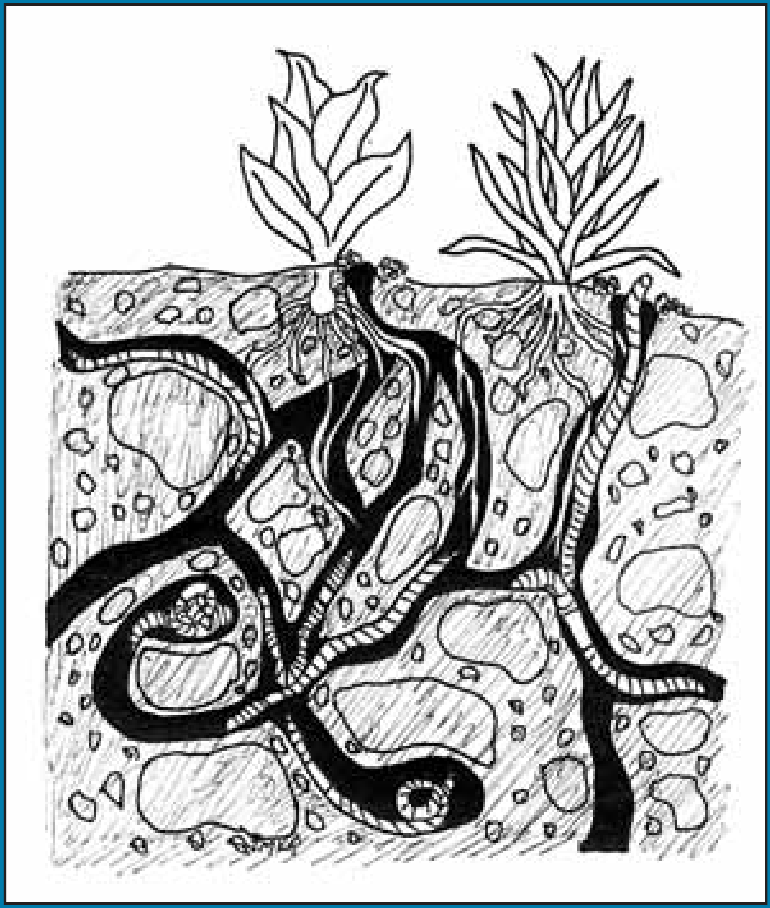
WORMOLOGY 101

A Vermicomposting Curriculum for Middle and High School Teachers



Ted Miller & Bruce Shotland

WORMOLOGY 101:
A Vermicomposting Geographic Curriculum for Middle and High School Teachers

Ted Miller
Bruce Shotland

with
Ray Jobin
Al Rydant
Cindy Sterling

Under the auspices of
the NH Geographic Alliance,
Keene State College, Keene, NH 03435-2001

Made possible in part by a grant from:
The United States Environmental Protection Agency Environmental Education Grant Program
(Grant Number NE-97104501-1)

Although the information in this document has been funded by the U.S. Environmental Protection Agency under assistance agreement NE-97104501-1 to Keene State College, it may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

Graphic Design by Salwen Studios, Keene, NH 03431
Illustrations by Jenna M. Konesko, Wardsboro, VT 05355
(Illustrations to be used only for vermicomposting related subjects used in *Wormology 101.)*

Impact Earth
7 Main Street
Suite 9
Keene, NH 03431
603-358-0486

ACKNOWLEDGEMENTS

Wormology 101 is the product of many contributors
who were kind enough to share their knowledge with us,
and patient enough to edit the many draft versions.

Our special thanks go to all the people who made this project possible.

Our appreciation goes to the educators who pilot tested this
program in their classrooms:

Cliff Learner, High School Science Teacher,
Keene High School, Keene, NH
and
Linda Carson, Seventh Grade Science Teacher,
Hillborough-Deering School, Hillsborough, NH

The support of the school administrators,
and the comments and questions of all students from
seventh grade to twelfth, is also appreciated.

TABLE OF CONTENTS

PREFACE

This curriculum is an extension of our successful *Feed It To The Worms: A Vermicomposting Geographic Curriculum Guide* for the elementary grades (available at www.nhga.net). It represents a long-term commitment to develop sound resource management educational programs by the New Hampshire Geographic Alliance, Impact Earth, and the Environmental Protection Agency.

The five lessons in each grade set (7-8 and 9-12) have been pilot tested in schools at each level and aligned with the National Geography Standards and National Science Standards. Further, lessons are formulated to merge into today's NCLB milieu, as well as to minimize costs associated with program adoption.

The curriculum affords an excellent year-long project to instill the concepts of effective resource management and responsible citizenship. It can easily be extended for both extra credit and science fair projects and, indeed, has strong community-wide applications. We encourage you to create an active and real-world learning environment where students can take the curriculum into their community.

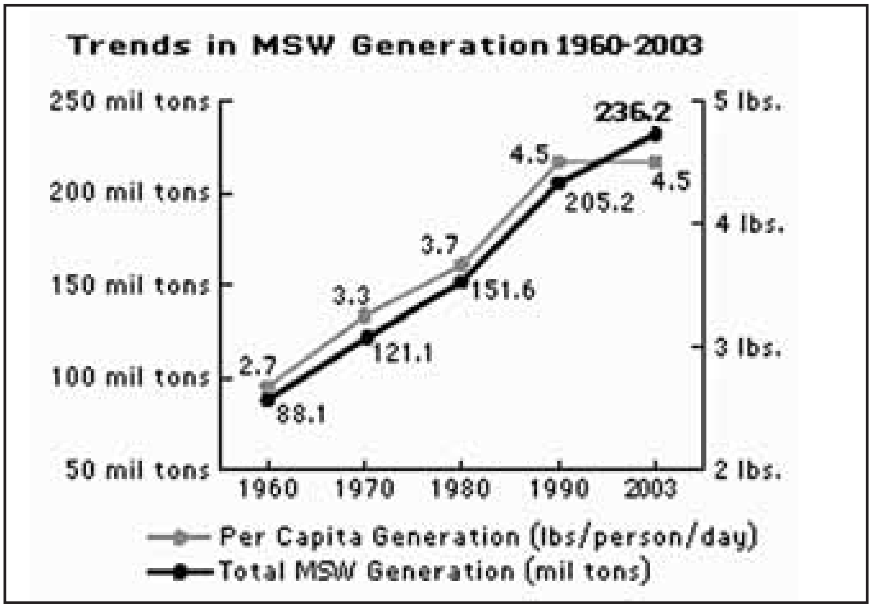
As with all curricula, this is an on-going process and we encourage you to both modify the lessons and share your experiences with us at the New Hampshire Geographic Alliance and Impact Earth.

INTRODUCTION

WASTE MANAGEMENT AND VERMICOMPOSTING

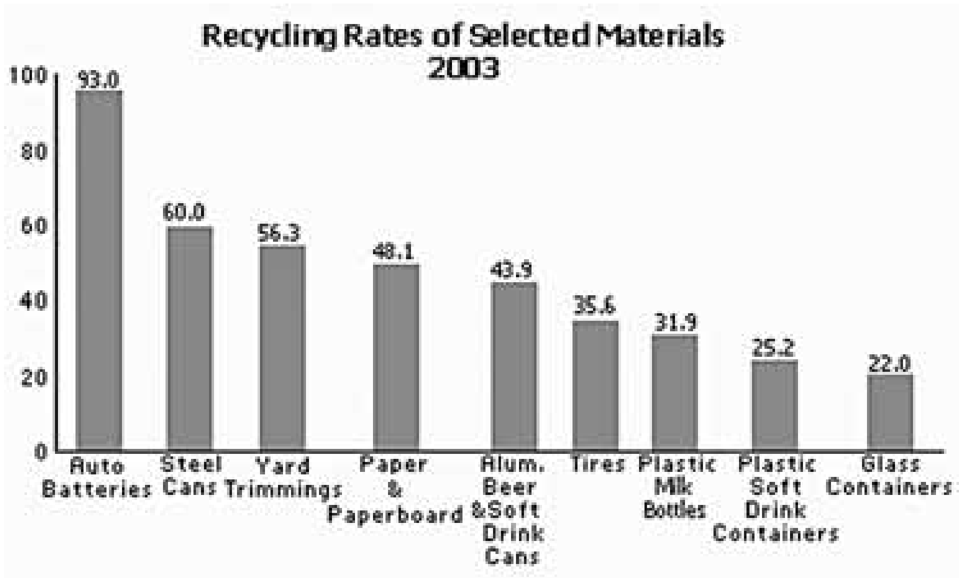
Trash and garbage, commonly referred to as municipal solid waste (MSW), consists of normal household items such as paper, yard trimmings, plastics, food scraps, glass, and clothing, to name but a few items. Nationally, US residents produce almost 240 million tons of MSW annually, a number which has been rising consistently over the last 50 years. This means the average American disposes of approximately 4.5 pounds of trash per day (Figure 1 – USEPA, Municipal Solid Waste, 2005).

Figure 1
(Source: USEPA 2005)



The most environmentally sound strategies for reducing MSW are ranked as source reduction, recycling and composting, and disposal via incineration or landfilling. Recycling and composting divert some 72 million tons of material each year from the MSW stream. Recycling rates of selected materials are shown in Figure 2. Automotive batteries are recycled at a rate of 93%, paper and paperboard at 48%, and yard trimmings at 56%. Together, yard trimmings and food residuals account for some 23% of MSW and clearly represent an area where composting can reduce the burden on a dwindling supply of landfill space (Marsh and Grossa 2005; USEPA. Composting 2005).

Figure 2
(Source: USEPA 2005)



Early in the 20th Century Barrett promoted the concept of using composted materials, aided by the natural decomposer processes of earthworms. He determined that fruits and vegetables became healthier and plants more productive when fertilized with worm castings (Rodale 1992). Soon thereafter, Howard found that worms provided fertile castings, with the added benefit of soil aeration (see: Rodale 1992; Jenness, Rushlow, and Mendolia 1996). Zaller and Arnone (1999) demonstrated, in an examination of climate change, a unique relationship between plant growth and earthworm castings under different levels of $CO2$.

Today continuing research demonstrates that Eisenia fetida (redworms) are the most effective "composters" due to their ability to digest large amounts of waste and to produce nutrient-rich castings. This process, known as vermicomposting, can be implemented in both urban and rural settings, requires minimal space, and represents an inexpensive, low-maintenance form of waste management. Indeed, Bhattacharrya and Chattopadhyay (2002, 2005) have employed redworms to even enhance fly ash waste from coal burning plants, demonstrating that vermicomposting results in increased bioavailability of nitrogen and phosphate, both key elements in plant growth.

Vermicomposting produces a more nutrient-rich soil additive than traditional composting and can easily be used for household plants and gardens. The controlled environment of a vermicomposting bin reduces both the risk of soil contamination from from leachates, other pollutants and the amount of time taken for food to decompose. This is simply because the worms eat the food scraps, thus quickening the process of decomposition. In Lagunitas, California it has been determined that worms "will digest about 100 pounds of garbage in [just] three to four weeks" (Logsdon 1994,65).

Nationally, vermicomposting has been demonstrated to be an effective waste management strategy. Although it is similar to composting this form of solid waste management is becoming a new and popular way to help control biodegradable forms of waste. As the public becomes more aware of the positive effect that vermicomposting has on the environment it may well become an integrated tool in our nation's efforts to more effectively manage our waste stream. Composting has a number of benefits, including the creation of a useful product from organic waste, soil remediation and enhancement, promoting higher yields of crops, reducing the need for chemical fertilizers, and removing solids from the waste stream and runoff (USEPA. Composting 2005).

A STANDARDS-BASED CURRICULUM

This middle and high school curriculum guide was developed as a corollary to a similar program developed for the elementary grades (Sterling, Rydant, and Jobin 2001). The lessons are constructed around the national standards for geography, mathematics, and science (Geography for Life 1994; Principles and Standards for School Mathematics 2000; The National Committee on Science, 1996).

Each lesson has been developed to address several specific standards and conforms to the national model developed by the National Geographic Society, the National Council for Geographic Education, the Association of American Geographers, and the American Geographical Society. Further, each module focuses on both organizational and content standards from the spatial and ecological perspectives, as a means of enriching student's understandings of people, places, and environments.

The following lessons are organized around two grade sets, 7-8 and 9-12. Lessons may obviously be adapted to local needs; extension activities are included and may be used to enhance the program. Material requirements are minimized to reduce implementation costs. Terms highlighted in bold text appear in the glossary.

BIBLIOGRAPHY

Bhattacharya, S.S. and G.N. Chattopadhyay. 2002. Increasing Bioavailability of Phosphorus from Fly Ash through Vermicomposting. *Journal of Environmental Quality* 31: 2116-2119.

Bhattacharya, S.S. and G.N. Chattopadhyay. 2005. Transformation of Nitrogen During Vermicomposting of Fly Ash. *Waste Management & Research* September: 488-491.

Cutter, S. and W. Renwick. 2004. *Exploration, Conservation, Preservation* (4th Ed.). NY: Wiley.

Geography for Life; National Geography Standards 1994. Geography Education Standards Project, National Geographic Research and Exploration. Washington, DC: National Geographic Society.

Jenness, L., R. Rushlow, and D. Mendolia. 1996. *The Wide World of Worms*. Geography Department, Keene State College, Keene, NH.

Logsdon, G. 1994. Worldwide Progress in Vermicomposting. *BioCycle* 35: 63-65.

Marsh, W. and J. Grossa. 2005. *Environmental Geography* (3rd Ed.). Wiley: Hoboken, NJ.

Principles and Standards for School Mathematics 2000. Standards 2000 Project. Reston: VA: National Council of Teachers of Mathematics.

Rodale, J. 1992. *The Complete Book of Composting*. Emmaus, PA: Rodale Books.

Sterling, C., A. Rydant, and R. Jobin. 2001. *Feed it to the Worms: A Geographic Vermicomposting Curriculum Guide*, Keene, NH: Impact Earth

The National Committee on Science Education Standards and Assessment 1996. *National Science Education Standards*. Washington, DC: National Academy Press.

US Environmental Protection Agency. 2005. *Composting*. http://www.epa.gov/epaoswer/non-hw/composting/index.htm (last accessed 5/23/05).

US Environmental Protection Agency. 2005. *Municipal Solid Waste: Basic Facts*. http://www.epa.gov/msw/facts.htm (last accessed 5/23/05).

Zaller, J. and J. Arnone III. 1999. Interactions Between Plant Species and Earthworms Casts in a Calcareous Grassland Under Elevated CO2. *Ecology* 80 (3) April: 873-881.

FUN FACTS ABOUT WORMS

The scientific name for the redworm is Eisenia fetida (i see' nee a/fet' ida).

Worms have no eyes but are sensitive to light, especially at their front end. They move away from light, and will become paralyzed if exposed to light for too long (approximately one hour).

Worms have no teeth, but do have a mouth, located in the first anterior segment. The mouth has a small sensitive pad of flesh, called the prostomium, that protrudes above its mouth and stretches out to sense suitable food particles.

Worms do not have a nose, but are able to absorb oxygen from the air through their skin. The skin needs to be moist in order to absorb oxygen. If a worm's skin dries out, it will die.

Most worms live less than a year in the wild. In a worm culture an individual redworm has been kept alive for four and a half years.

Redworms can eat half their weight in food per day.

Worms are hermaphrodites; each worm has both male and female organs.

Egg capsules (cocoons) are lemon-shaped and about the size of a match head. After three weeks baby worms hatch from the cocoon. One to five baby worms emerge from each egg. In 60-90 days, the young worms are mature.

Adult redworms can each produce 1500 offspring within six months.

Contrary to popular belief, worms cannot reproduce by being cut into small pieces. However, they do have amazing healing powers. If you cut a worm in half, both sides will continue wiggling. The portion with the head may grow a new tail if the cut is after the segments that contain vital organs. The tail portion will continue to wiggle until the nerve cells die. The tail end will not grow a new head.

Two thousand redworms in a worm bin can produce 7 pounds of castings in one month.

In addition to making soil, worms are natural soil tillers. They mix layers of soil while producing tunnels in the soil to help air and water to reach plant roots. Tiny feeler-like bristles, called setae, on the bottom of worms help worms to move through the soil.

Chemical fertilizers are harmful to worms.

There are over 3000 species of earthworms in the world. Redworms (Eisenia fetida) are best for a worm bin because they are natural surface feeders that do not burrow as nightcrawlers do. Thus, living in a worm bin is not as confining to redworms as it would be to nightcrawlers.

The largest earthworm ever found was in South Africa and measured 22 feet from its nose to the tip of its tail.

NATIONAL GEOGRAPHY STANDARDS

Physical and human phenomena are spatially distributed over Earth's surface. The national geography standards are designed to produce a geographically informed person (1) who sees meaning in the arrangement of things in space; (2) who sees relations between people, place, and environments; (3) who uses geographic skills; and (4) who applies spatial and ecological perspectives to life situations.

To accomplish these perspectives geography is divided into six essential elements and 18 standards. Each element and its corresponding standard are described below.

The World in Spatial Terms

Geography studies the relationships between people, places, and environments by mapping information about them into a spatial context.

The geographically informed person knows and understands:

1. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
2. How to use mental maps to organize information about people, places, and environments in a spatial context.
3. How to analyze the spatial organization of people, places, and environments on Earth's surface.

Places and Regions

The identities and lives of individuals and peoples are rooted in particular places and in those human constructs called regions.

The geographically informed person knows and understands:

4. The physical and human characteristics of places.
5. That people create regions to interpret Earth's complexity.
6. How culture and experience influence people's perceptions of places and regions.

Physical Systems

Physical processes shape Earth's surface and interact with plant and animal life to create, sustain, and modify ecosystems.

The geographically informed person knows and understands:

7. The physical processes that shape the patterns of Earth's surface.
8. The characteristics and spatial distribution of ecosystems on Earth's surface.

Human Systems

People are central to geography in that human activities help shape Earth's surface, human settlements and structures are part of Earth's surface, and humans compete for control of Earth's surface.

The geographically informed person knows and understands:

9. The characteristics, distribution, and migration of human populations on Earth's surface.
10. The characteristics, distribution, and complexity of Earth's cultural mosaics.
11. The patterns and networks of economic interdependence on Earth's surface.
12. The processes, patterns, and functions of human settlement.
13. How the forces of cooperation and conflict among people influence the division and control of Earth's surface.

Environment and Society

The physical environment is modified by human activities, largely as a consequence of the ways in which human societies value and use Earth's natural resources, and human activities are also influenced by Earth's physical features and processes.

The geographically informed person knows and understands:

14. How human actions modify the physical environment.
15. How physical systems affect human systems.
16. The changes that occur in the meaning, use, distribution, and importance of resources.

The Uses of Geography

Knowledge of geography enables people to develop an understanding of the relationships between people, places, and environments over time - that is, of Earth as it was, is, and might be.

The geographically informed person knows and understands:

17. How to apply geography and interpret the past.
18. How to apply geography to interpret the present and plan for the future.

Source: *Geography for Life: National Geography Standards. 1994*. Geography Education Standards Project. Washington, D.C.: National Geographic Research and Exploration.

NATIONAL SCIENCE STANDARDS

Following is a listing of the the eight categories under which the Science Standards are classified.

Unifying Concepts and Processes in Science

Science as Inquiry

Physical Science

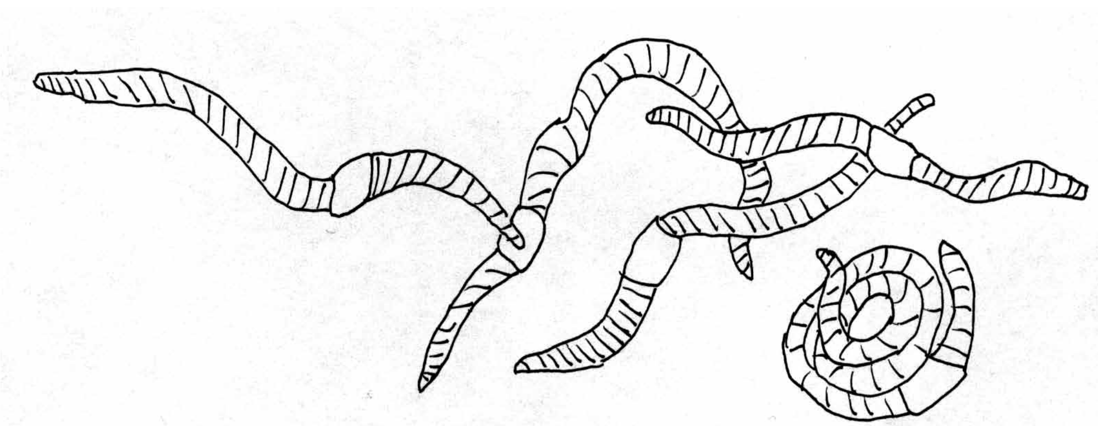
Life Science

Earth and Space Science

Science and Technology

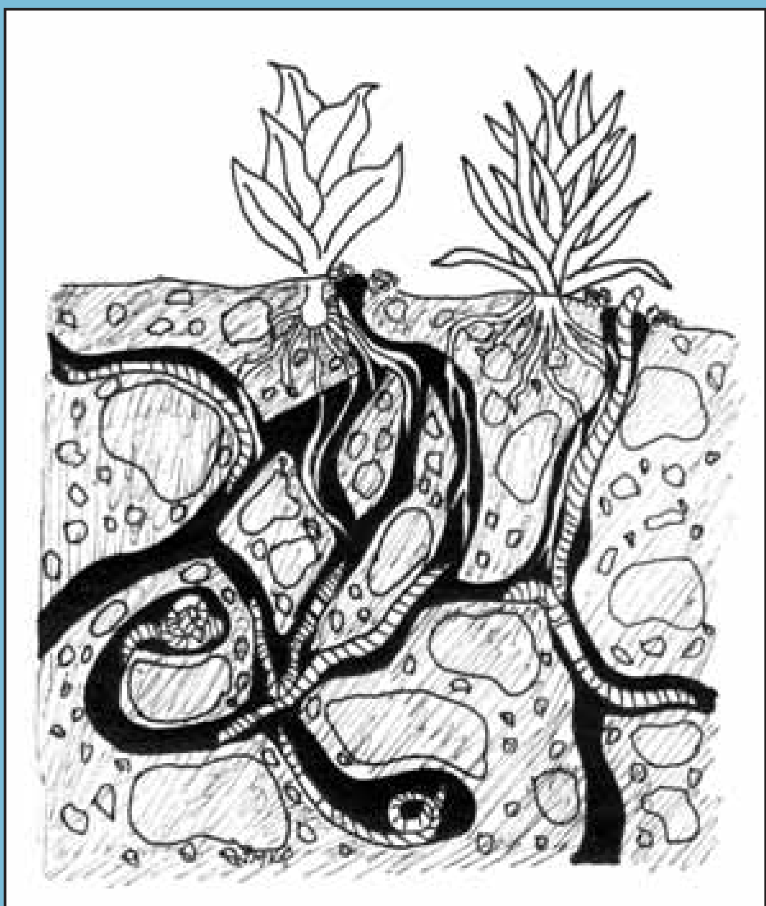
Science in Personal and Social Perspective

History and Nature of Science



Section 1

Grades 7/8
Lessons 1 – 5



Grades 7/8

Lesson 1: Geological Time Moves at a Worm's Pace

STANDARDS

Geography Content Standard 7:
The student knows and understands the physical processes that shape the patterns of Earth's surface.

Science Standards (grades 5-8), Content Standard A:
The student will develop and understand scientific inquiry.

Content Standard D:
The student will develop an understanding of Earth's history.

Essential Questions:
- How can we understand how old the earth is?
- How do we understand the evolution of earthworms and other forms of life on the earth?

Outcomes:
After doing this lesson students will:
- Have a better understanding of geologic time.
- Develop a better understanding of geologic soil development and the evolution of life on the planet.
- Quantify large numbers and see how math helps to solve problems for better understanding.

Materials:
Several large bags of popcorn; paper towels; a clock or timer; paper; pencils or pens; a calculator; a timeline with important organic events (page 18); important organic events sheet (page 19); lab journal.

Time Needed:
3-5 class periods

Teacher Content Background:

The "Geologic Time Moves at a Worm's Pace" lesson is designed to begin the story of the worm and its earthly home. The earth building process has been estimated to be 4.5 billion years!! This immense amount of time is hard to comprehend. The study of an important component of physical geography is **geomorphology,** or the study of landforms. The worm story begins here.

The lithosphere or solid crust at the earth's surface owes its development to internal forces called **tectonic processes** and external leveling processes known as **gradational processes.**

The tectonic processes include **plate tectonics, diastrophism, and volcanism**. The theory of plate tectonics began with Alfred Wegener's belief that the earth was once one large landmass that divided into the continents we know today. His belief became known as **Continental Drift**. Today it is believed that there are as many as 20 plates moving across the lithosphere. These plates move and collide in several ways creating the landforms we look at every day.

The movement of the plates has created forces such as **volcanism** or the movement of magma to the earth's surface. This liquid hardens and creates the rock and **parent material** that forms the basis of soils. In fact, it is one of the first steps in the soil building process. Internal pressures also shape the earth through **folding** and **faulting** or **diastrophism**. This process helps to create the mountains, hills and valleys that each contribute to the development of our soils. **Topography** and slope also contribute to the development of our soils.

Just as important to the development of the earth's surface are the gradational processes. Gradation includes the fragmentation and chemical breakdown or **weathering** of earth materials. This process allows the materials to move. **Mass wasting** is the movement of materials downslope due to gravity. **Erosion** can move and remove material all together. Material can be transported by **water (fluvial), wind (aeolian)**, and **ice (glaciation)** and are important ingredients in the development of soil. Eventually, materials can be deposited at lower levels and developed into soil and a home for worms.

LESSON PROCEDURES AND ACTIVITIES

1. Teacher should provide content background to his or her students on the earth building processes and their role in the development of soil. Explain that a lab journal should be used for all activities.

2. Divide class into groups of four students. Each student is assigned a job: an eater, a counter, a timer, and a score keeper.

3. Distribute paper towels and two handfuls of popcorn to each of the groups.

4. Explain each person's job:
   a. Eater can only eat one piece of popcorn at a time. Kernel must be chewed and swallowed before the next kernel is put into mouth.
   b. Counter calls out each eaten kernel.
   c. Recorder records each kernel eaten on a group sheet of paper.
   d. Timer keeps track of time (5:00 minutes), lets group know amount of time remaining, and also lets teacher know if more popcorn is needed.

5. Once all groups understand the activity and their roles, teacher starts the timer and initiates activity.

6. After five minutes, stop all eaters and have recorders total the final number of kernels eaten by the eater in each group.

7. Record each group's final number on board and add up number of kernels eaten by all groups in class in the five minute period.

8. Ask the class to figure out how many pieces of popcorn would be eaten in an hour (if eaten at the same rate – i.e. the groups' total was 535 pieces in 5 minutes, in a day, and in a year). Students should have calculators to do this.

9. Explain to the class the earth is 4,500,000,000 years old. This is a large number and a class discussion is helpful so that the class understands the length of time.

10. After you have had this discussion, ask each group to figure out how long it would take to eat 4.5 billion pieces of popcorn at the same rate they ate in five minutes.

Example:	5 minutes =	38 pieces	(x12)
	1 hour =	1656 pieces	(x24)
	1 day =	39,744 pieces	(x365)
	1 year =	14,506,560 pieces	

Then ask the class, “How long would it take you to eat 4,500,000,000 pieces of popcorn?” (In this example, the answer would be 310.2 years of eating popcorn at the rate of 38 pieces every 5 minutes). This can be a homework assignment.

11. The next class period, review the math and check to see if all students were able to do the computations. After any corrections, begin a classroom discussion about geologic time.

12. Draw a solid line across the entire board and divide it into 5 equal areas. This will represent the 4.5 billion years of earth history (evolution). Have students come to the board and put a mark on the line where they believe major life forms evolved on the earth. Some of the life forms suggested might be: when life began, plants, animals without backbones (invertebrates), animals with backbones (vertebrates), coral reefs, amphibians, reptiles, mammals, birds, fish, modern humans, and earthworms.

13. Have each student research earthworms and find out when they evolved on the earth. Remind students that earthworms are invertebrates.

Final Exhibition:

1. Assign students into six groups. Each group will be given an Era on the geologic timeline to research and report back in class. Each era should include dates in million of years, important physical events, major periods and epochs, and important organic events. Use the chart (page 19), for students to record information on the Eras.

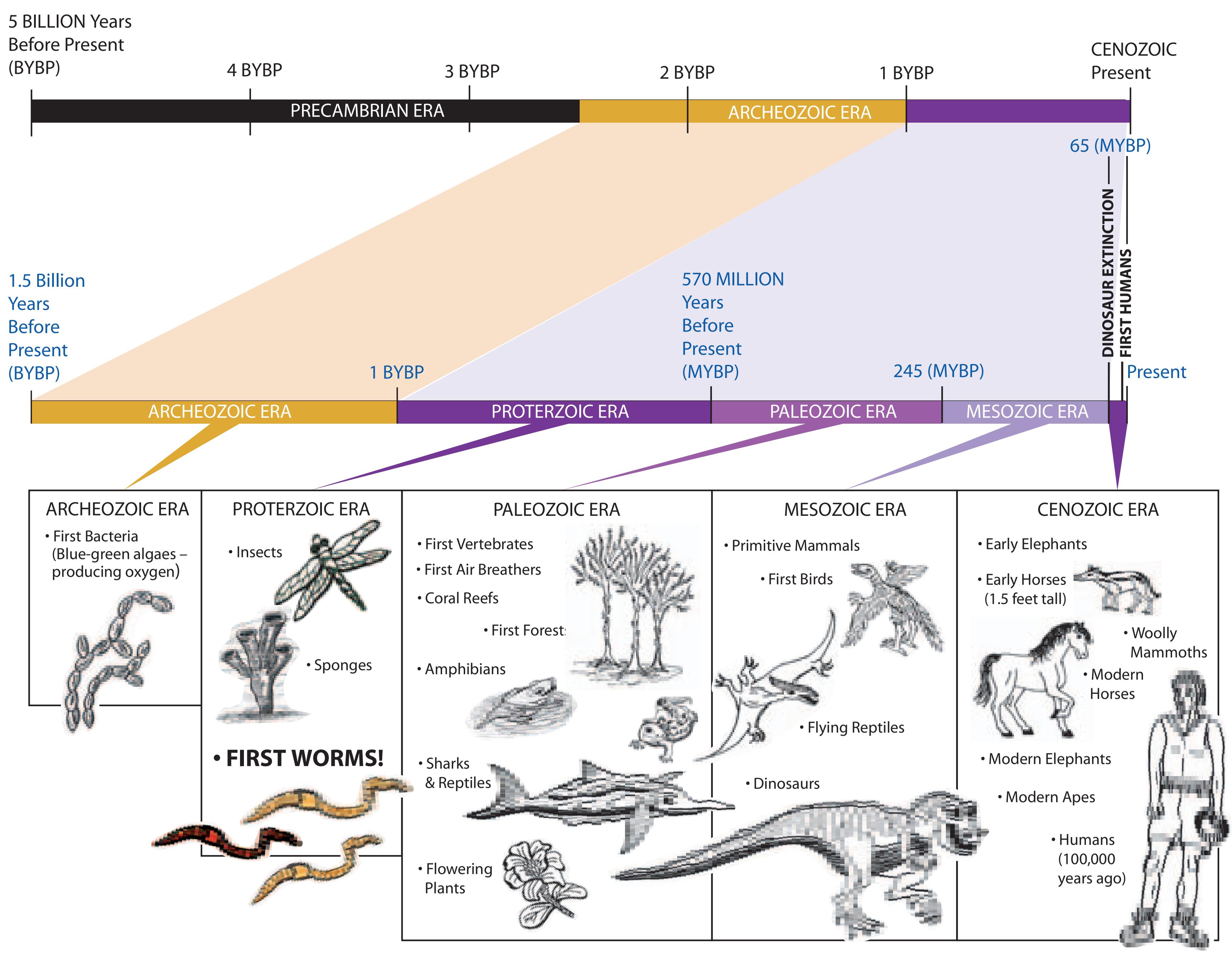
2. A classroom timeline should be displayed in the room for all to see. Student information can be added to the display.

Extension Activity (Discussion):

Ask students:

- Where on the timeline do you think soils developed?
- How long in time do you think it takes to develop soils?
- Do you think soil is a valuable resource? Why might it be important to protect this resource?
- Allow students to speculate at this stage. This will help transition into Lesson Two.

TIMELINE WITH IMPORTANT ORGANIC EVENTS



	IMPORTANT ORGANIC EVENTS
Cenozoic	
Mesozoic	
Paleozoic	
Proterzoic	
Archeozoic	

Grades 7/8

Lesson 2: It's More Than Just Dirt!

STANDARDS

Geography Content Standard 8:
The student knows and understands the characteristics and spatial distribution of ecosystems on the Earth's surface.

Science Standards (Grades 5-8), Content Standard A:
The student will develop and understand scientific inquiry.

Content Standard C:
The student will develop an understanding of populations, ecosystems, and diversity of organisms.

Content Standard D:
The student will develop an understanding of Earth's history.

Essential Questions:
- What do we know about the soils in our area?
- How do we find information on soils?
- What are some of the major characteristics of soils?
- Where do we find the major soil types in the United States?

Outcomes:
After doing this lesson, students will know:
- The major soil types where worms live.
- The physical properties of soils including color, texture, and structure.
- About soil profiles and their significance to the local ecosystem.
- Soil types.
- The basics of classifying soils using the national soil classification system.
- Types of soils worms prefer.
- The general regions of America's major soil types.
- To become an accurate observer in the natural world.

Materials:
Small clear glass jars for soil collection (the teacher may have to provide a number of these); shovels; dissecting scopes; hand lenses; examples of various soil types from scientific warehouses (sandy soil, dark organic soil, red clay soil); earthworms collected by students; map of your town, region, or neighborhood; a copy of the national soil classification system (page 28); soil profile (page 24); Atlas of the United States.

Websites for content research:
http://soils.ag.uidaho.edu/soilorders/index.htm

Time Needed:
7-10 class periods

Teacher Content Background:
The development of soil is dependent on five major factors. First, we learn that soils are all derived from fragments of rock material that can be weathered directly beneath the surface. This is called **residual parent material**. Regions of volcanic activity can provide rich **volcanic soils** like those in parts of California and Andean South America. The geologic process of diastrophism can push ancient sea beds to the earth's surface providing us with the **limestone** rich

soils found on the Florida Peninsula. Sometimes the rock fragments are transported by water, wind, or ice. This is called **transported parent material**. Parent materials influence the chemicals and nutrients as well as the size of soil particles in our soils. Transportation of soils can give us a hint as to the fertility of soil. Rich soils along our rivers and streams are called **alluvium**. This explains the location and early development of civilization. Wind can deposit large quantities of rich soils called **loess**. Regions in the American Midwest and parts of China have large loess areas.

Second, **organic activity** influences the development of soils. Plants and animals contribute in many ways. Vegetation cover affects the erosion rate in our soils. Vegetation also contributes to the organic content of our soils. Decaying grassland vegetation produces some of our richest soils. With the help of bacteria in the soils, the process of decay produces a jellylike mass called **humus**. Humus content is important to fertility. The humus helps to hold moisture content and provide food for microorganisms. The **microorganisms**, like the earthworm, help to mix the soil and provide additional soil through their digestive process.

Third, **climate** has a huge impact on the development of soils. Temperature is important to the vegetation growth, the rate of decay in soils, and the rate of chemical reactions that provide nutrients to soil.

Fourth, **land configuration** is an important factor in soil development. The slope of the land and the direction it faces affect soils directly and indirectly. Steep slopes can influence moisture retention, vegetation cover, and erosion rate. Valley floors are often poorly drained. This can move salt and alkaline substances to the soil surface through capillary action, thus hurting soil fertility. The direction of a slope can affect the microclimate. North facing slopes are colder and wetter than south facing surfaces.

Last, we have the **time factor**. In the evolution of soil, it is important to understand that when a soil reaches a state of equilibrium with its environment, it is **mature**. Although there is no fixed time that it takes for soils to reach maturity, it generally takes hundreds to thousands of years. Soils begin to develop when rocks or deposits of loose material are colonized by simple animal and plant life. Once this begins to happen, differences begin to take place from the surface to the parent material below. A vertical zonation into distinct layers or horizons happens as soils mature. They become more pronounced with maturity. The vertical zonation from the surface to the parent material is called the **soil profile** (page 24).

Soils are classified by their color, fertility, texture, moisture content, and chemical content. A national **soil classification system** places soils in eight major types (page 28).

LESSON PROCEDURES AND ACTIVITIES

1. Teacher should introduce the five factors that influence the development of soils. Terminology and concepts should be reviewed.

2. Teacher brings in samples of three soil types into the classroom- sandy, dark organic, red clay.

3. Using dissecting scopes, have students view and draw in their notebooks what the samples look like (eg. texture, size of particles).

4. Allow students to feel and describe the soil. Students should write their descriptions by their drawings.

5. Questions and discussion (you will get a variety of answers).
- a. Ask students if they could find soils like these around their homes.
- b. Ask what some of the major differences are between the soils.
- c. Ask why it is important to know about soils, and how we can benefit from learning more about soils.

6. Review how soil is a valuable natural resource and how it is very important to conserve our natural resources.

7. Review soil horizons (page 25) with class.

8. Take students outside and dig a test pit which demonstrates to students a soil profile. Discuss soil horizons O, A, and B.

9. For homework, have students find an area near their home where they can dig an open pit to develop a soil profile of their area. Before digging, have them describe the area in detail in their science log (plant growth, hillside, near river, plains or valley, etc.). Have students diagram their soil profile for a comparison to classmates' profiles. Their pits should be 2-3 feet deep and 2-3 feet wide. As they are digging, have them record the number of earthworms they find in the soil and their soil horizon location. After collecting soil samples, students should fill their soil test pit holes.

10. Have students bring soil samples into class from their profile area. These should be from assorted areas near where students live (lakeside, hillside, open fields, marsh, bog, forest, backyard, next to a river). Students should label jars as to location. They should bring in samples from soil horizons O, A, and B. Each horizon should be labeled in a separate jar.

11. Back in class, have students go over the descriptions they recorded in their science log of their areas. Discuss how one of a scientist's and geographer's jobs is to be an accurate observer of the natural world.

12. Have each student set up jars of soil horizons one on top of the other with horizon O on top of A, which is then on top of B. Each horizon should have a description of the area it was found, and the number of worms found in each horizon. Set the jars and student descriptions around the room. Students can place a marker on a neighborhood, town or regional map as to the location of their samples. Divide the class into two groups, one group remaining by their soil samples while the other group makes rounds of the room, making comparisons of the various groupings of soils and noting where each of the horizons came from, as well as the number of worms found. When they have completed this task, have students repeat this by changing roles. Have students develop a data chart using this information.

13. Have a class discussion of the observations noted and have students ask questions of each other as they go around the room. Have students fill in their charts and decide which soil samples had the most worms. Have class try to figure out why some soil samples had more worms than others. You might start the conversations with, "Why does Sarah's soil have more worms than Joe's?" and "What was Sarah's soil like and how was it different from yours?"

Final Exhibition:

1. Using the classroom town map, the soil classification system, and the information gathered from the location markers, students will construct a "soil map" of their town, region, or neighborhood.

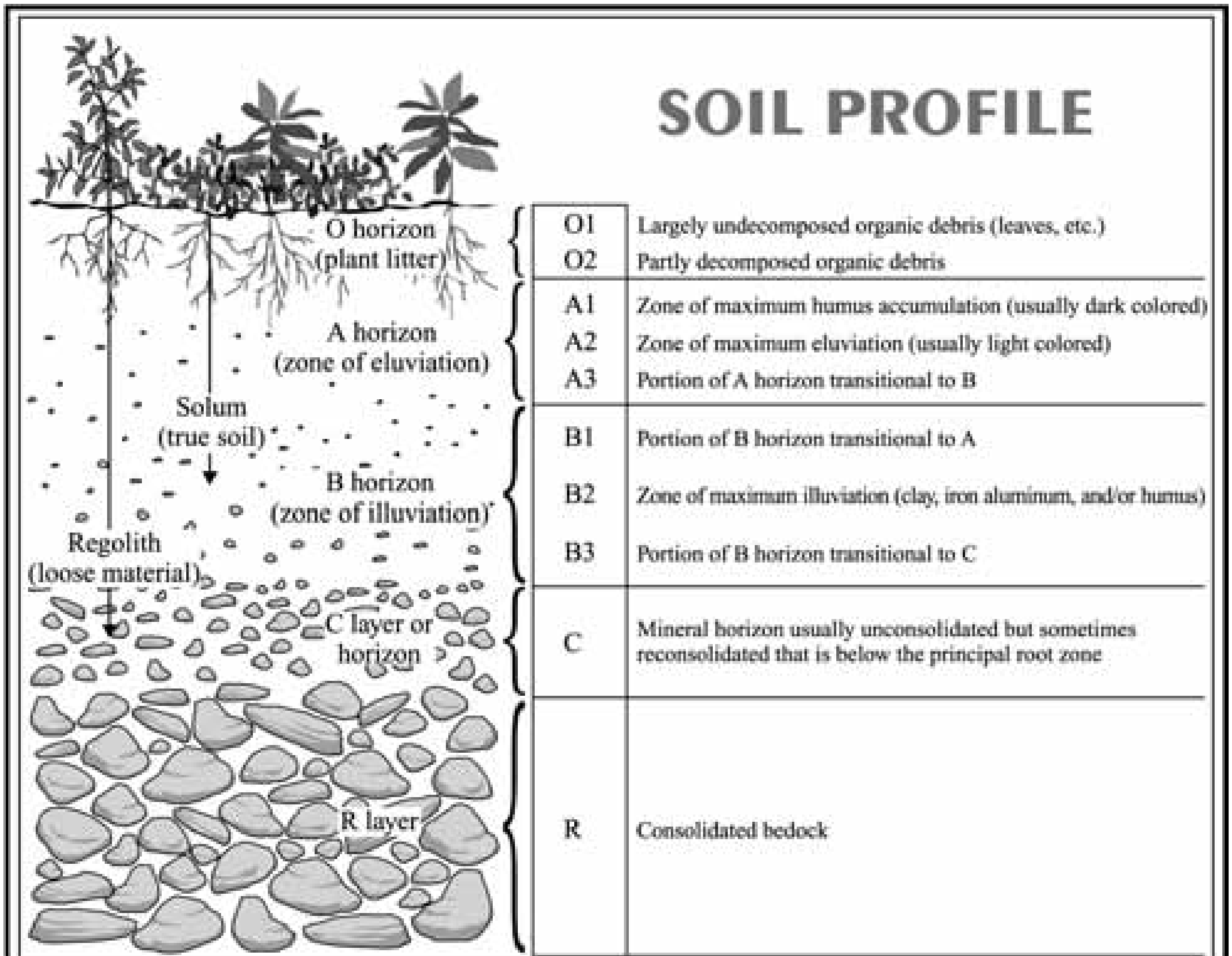
2. Using a soil classification system and a blank map of their state, students will produce a map of the major soil regions in their state. Using the above information students should now be able to develop a hypothesis as to what types of soils and areas of their state are best suited for the study of worms. After their hypothesis is developed, a classroom discussion should ensue with reasons for students' hypotheses stated and defended. Ask students, "What information would you need to prove your hypothesis?"

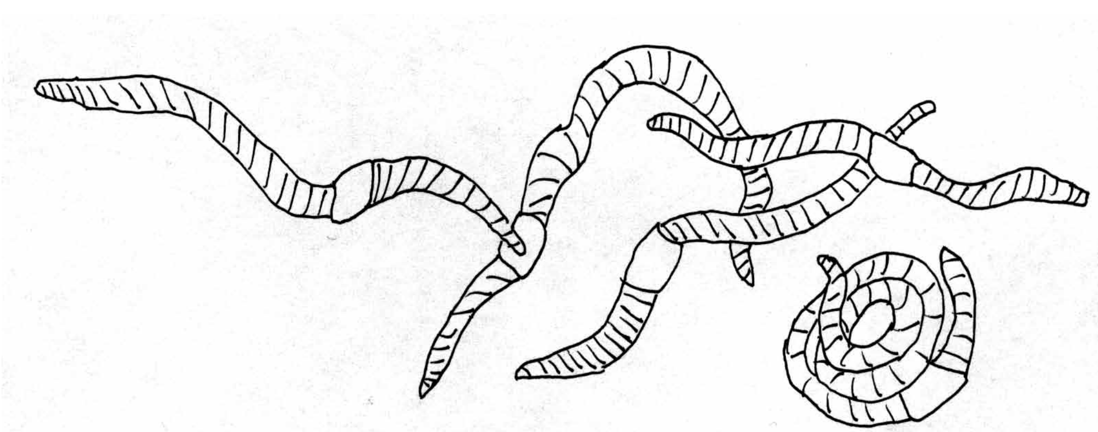
Extension Activity (Use this extension to transition into Lesson 3):

1. Discussion – "How do earthworms contribute to the development of soil?" "How might worms be put to use in soil conservation projects?"

2. Use the "National Soil Classification System" sheet, page 28, to have students respond to the following questions:

- "What soil patterns do you see?"
- "What regions of the continental United States would be best for the study of microorganisms like worms?"
- "What regions would benefit from improved soil conservation?"
- "What might explain the differences in soil fertility between the different regions in the United States?" (Guide your students back to the five factors on soil development.)
- "What are some ways soils are transported (water, wind, ice)?"

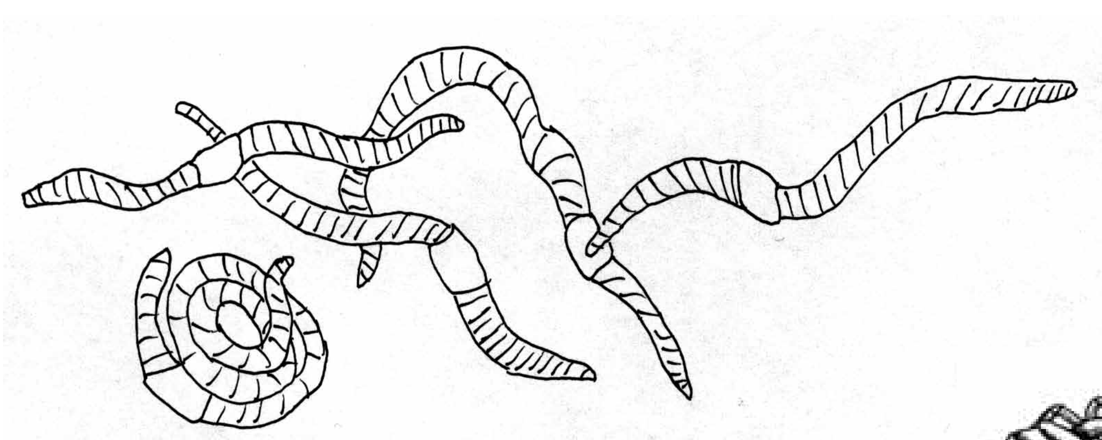

SOIL PROFILE
O horizon
(plant litter)
A horizon
(zone of eluviation)
Solum
(true soil)
B horizon
(zone of illuviation)
Regolith
(loose material)
C layer or
horizon
R layer
O1 Largely undecomposed organic debris (leaves, etc.)
O2 Partly decomposed organic debris
A1 Zone of maximum humus accumulation (usually dark colored)
A2 Zone of maximum eluviation (usually light colored)
A3 Portion of A horizon transitional to B
B1 Portion of B horizon transitional to A
B2 Zone of maximum illuviation (clay, iron aluminum, and/or humus)
B3 Portion of B horizon transitional to C
C Mineral horizon usually unconsolidated but sometimes reconsolidated that is below the principal root zone
R Consolidated bedock



SOIL HORIZONS

HORIZON	BASIC PROPERTIES
O	Layers dominated by organic matter
A	Mineral layers at the surface or below the O horizon. Contains accumulated decomposed materials.
E	Area of leached silicate clays, iron, or aluminum. Contains resistant sand and silt particles.
B	Below O, A, and E horizons. Zone of accumulated materials from above. Area of broken down parent material.
C	Parent material, excluding bedrock, little affected by soil formation processes.
R	Hard bedrock, such as granite or sandstone.

(Adapted from: Singer, M. and D. Munns. 1999. *Soils: An Introduction*. 4th Edition. Upper Saddle River, NJ: Prentice Hall ISBN 0-13-679242-1)



THE PROPERTIES OF GOOD SOILS

Soils play five key roles in our ecosystem. First, they provide a medium for plant roots and supply nutrients to plants. Second, soils control the fate of water in the hydrologic cycle. Third, they act as recyclers, processing waste products and dead bodies of plants and animals. Fourth, soils provide a habitat for a host of living organisms, from mammals to reptiles to microscopic organisms. Fifth, soils play an important role in human engineering activities, such as road construction and building materials.

Defining what makes a good soil is somewhat difficult because it depends on the needs of the particular user. In general, good soils emanate from the five major use categories above.

- A good soil will provide sufficient mass to ensure physical support for plants, anchoring the root system to keep the plant from toppling.
- A good soil will provide proper ventilation for root respiration.
- A good soil will absorb rainwater and retain it where plants can use it. Good water retention capability is essential for plant growth during dry periods.
- A good soil will act as an insulator, protecting plant roots from excessive heat.
- A good soil will protect plants from toxic substances produced naturally or by humans. This is accomplished by ventilating gasses, by decomposing or absorbing organic toxins, or by suppressing toxin-producing organisms.
- A good soil will provide a continuing supply of dissolved mineral nutrients appropriate for plant growth.
- A good soil will act to filter, purify, and cleanse water as it travels through the soil or over its surface.
- A good soil recycles organic waste, turning it into beneficial humus and converting mineral nutrients into forms plants can use.
- A good soil provides a habitat for organisms. Soils are an integral component of our ecosystem and are home to millions of life forms.
- A good soil provides sufficient building material properties: shear strength, compressability, or stability for such things as road beds, building foundations, or building materials such as concrete or bricks.

Adapted from: Brady, N. and R. Weil. 1999. *The Nature and Properties of Soils*. 12th Edition. Chapter 1. Upper Saddle River, NJ: Prentice Hall.

SOIL FACTS

Soils are complex biological, geological, and chemical materials on which plants grow. They are dynamic ecological systems that provide plants with water, support, nutrients, and air. Soils are the host for an enormous number of microorganisms that recycle the materials of life. They support all terrestrial ecosystems, humans, and provide the base for food, fiber, water, building materials, construction sites, and places for waste disposal.

Soil is generally described as the unconsolidated, thin, variable layer of materials (both mineral and organic) that covers most of the earth's surface. It is usually biologically active. Soil is often described as the loose surface material in which plants grow. More accurately it is an ecosystem itself. It is part of the landscape and has characteristic layers with specific properties such as color, mineral and organic content, hardness, and thickness.

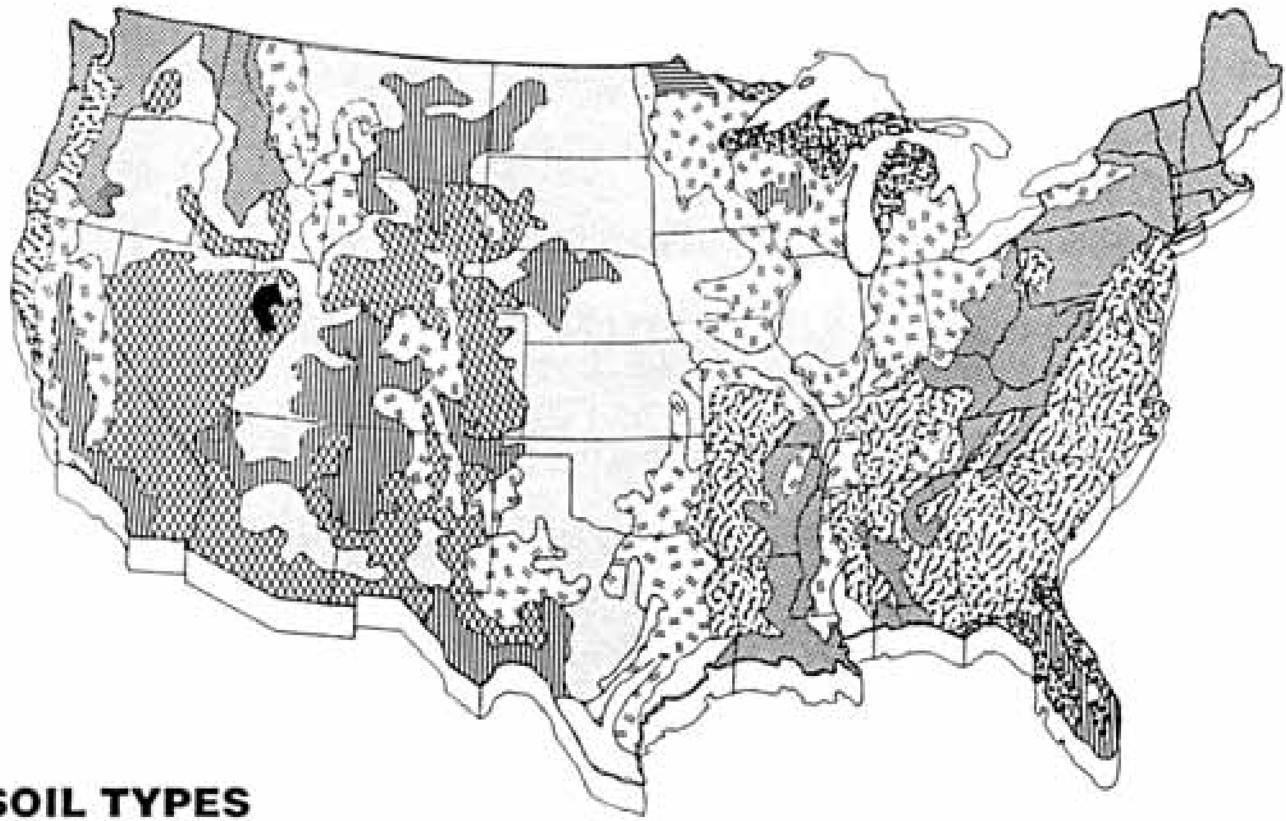
Soil formation is the result of many factors. It develops from parent material (minerals, rocks) by weathering processes. The rate of soil formation depends on climate, especially the amount of precipitation and temperature. Vegetation, topography, and time also influence the rate of soil formation.

During the process of soil formation plants, bacteria, algae, and small animals, from protozoa to worms, insects, and mammals all play a role. During the decay of plant material large molecules form that remain in the soil. This material is called humus and is responsible for the brown and black colors in the top layers of some soils. Humus is very important because it retains water and nutrients and acts to hold soil together.

Soils are three dimensional ecosystems. With depth soil layers are called horizons. Organic matter from decomposed materials tends to accumulate in the uppermost horizon, giving this area a darker color. This is known as the O Horizon. Immediately below the humus layer is the A Horizon, an area of high biologic activity containing accumulated decomposed organic matter. Together these top two layers are often referred to as topsoil. Below this is the E Horizon which represents the layer from which minerals (silicate clay, iron, or aluminum) have been leached. Further down is the B Horizon which is characterized by the presence of all the materials that may have been leached out of the A, O, and E horizons. Here parent materials are also being broken down. Finally, the C Horizon represents the bottom-most layers where rock or parent material is being broken down and which are little affected by soil formation processes. The C Horizon is the least weathered part of the soil profile.

Soils are composed of solids surrounding spaces or pores, which may be filled with gas (air) and/or water. While these solids are primarily minerals, they may also include living organisms and dead organic matter. Soil particles, and therefore soils, are comprised of some combination of sand, clay, and silt. Individual particles are held together by clay and organic matter and give a soil its characteristic structure and texture.

NATIONAL SOIL CLASSIFICATION SYSTEM (CONTIGUOUS 48 STATES)



SOIL TYPES

- ALFISOLS—middle-aged, relatively fertile, medium brown soils
- ARIDISOLS—middle-aged desert soils, low in organic matter
- ENTISOLS—very young under-developed solid, pale yellow to reddish brown
- HISTOSOLS—very young organic peats and mucks, dark brown to black
- MOLLISOLS—middle-aged to young, very fertile, dark brown
- SPODOSOLS—young, nutrient-poor soils, mostly sandy, pale ash color
- ULTISOLS—very old, nutrient-poor, distinct horizons, yellow to red
- VERTISOLS—middle-aged clayey soils, crack when dry, dull colors

Grades 7/8

Lesson 3: The Worm's Home – An Icy Start?

STANDARDS

Geography Content Standard 7:
The student knows and understands the physical processes that shape the patterns of Earth's surface.

Science Standards (Grades 5-8), Content Standard A:
The student will develop and understand scientific inquiry.

Content Standard D:
The student will develop an understanding of Earth's history.

Essential Questions:

- When did the glaciers move through North America and how did they help to create some of our soils and landforms?
- What parts of our nation have been affected by continental glaciation?

Outcomes:

After doing this lesson students will:

- Gain an understanding of how and when glaciers moved over North America.
- Understand what types of landforms and soils are created from glacial movements.

Materials:

Access to a freezer; water; paper cups or pie tins; dirt; plastic tub or sink; plaster of paris; images of glaciers and landforms created by glaciers; maps of North America and the United States; a stream table (optional); topographic map of New Hampshire; plastic snow sled for use as a stream table; 60 watt lamp; a brick; a ruler; a plastic milk jug; and a bucket.

Time Needed:

5 class periods

Teacher Content Background:

Students should now understand that there are numerous combinations of factors that contribute to the development of landforms and soils on Earth. Nevertheless, a study of soils reveals that there are a limited number of general types of soil. These soils resulted from a different combination of factors. The differences between these soil regimes resulted mostly from climatic differences and indirectly the differences in plant cover.

First, we find the soil forming process in humid tropical and subtropical climates with high temperatures and abundant precipitation is called **laterization**. This process breaks down base materials quickly and a decomposition of most minerals results. When vegetation is removed, the soils are leached of their nutrients, and crusts of aluminum and iron compounds are formed (**laterites**).

Second, the cool moist climates of the high middle latitudes with a coniferous forest cover are important in the **podzolization** process. Low temperatures reduce microorganism activity and allow humus to accumulate but little mixing of the humus below the surface takes place. Leaching by strong acidic solutions removes nutrients leaving silica, causing a gray ashy soil called **podzol** (Russian).

Third, we have the process called **calcification**. This process requires the evaporation rate to exceed precipitation. It allows minerals to accumulate in the soil. The most important mineral is calcium carbonate. In the dry desert regions of the American west, salt often forms at the surface. However, in our Midwest, grasses use calcium and deposit it back into the soil when they die and decompose. The thick root systems and abundant animal life produce rich humus. The mid-latitude grasslands of the United States are rich in both bases and humus, making it one of the world's most productive agricultural soils.

The differences in climate help to give the United States a great variety of vegetation biomes, animal life, landforms, and soils. Some regions of our country were influenced by **continental ice sheets** starting 2 million years ago in the **Pleistocene Epoch**. There were believed to have been four major advances and retreats of ice in this period. As these ice sheets advanced and retreated, they eroded, deposited, and reshaped parts of our country.

In some areas of the United States, erosion gouged out valleys, scoured out rock basins, smoothed out hills, removed soil, and exposed rocks below. Ice-scoured plains were left with many lakes, marshes, and **muskeg** (poorly drained soils with grown over vegetation).

In other areas, ice-deposition gave regions large features such **terminal moraines** and **recessional moraines**. Martha's Vineyard and Nantucket Island are terminal moraines in Massachusetts, while Cape Cod is a recessional moraine. In some areas, massive accumulations of unsorted **glacial till** were deposited to a depth of 100 feet. In places like Illinois and Iowa, the plains of rich, dark grassland soils developed on till. As the glaciers melted, they formed **outwash plains** that are smooth, with sorted deposits of soil and rock. Water-filled pits called **kettle holes** were created when blocks of ice melted and formed holes that became lakes in our landscape. Deposition formed streamlined hills called **drumlins**, and narrow winding ridges called **eskers**. Eskers are a source of prime gravel and sand in regions of past glaciation.

A diagram, on page 32, for making a stream table is included for the purpose of visualizing the movement and impact of a moving glacier.

LESSON PROCEDURES AND ACTIVITIES

1. Review the major concepts involved in the relationships between soil development, climate, and the Pleistocene Glaciation Epoch in the Teacher Background sections.

2. Have students build a glacier and observe the effects of glacial movement. To begin this, create a miniature glacier by freezing water, gravel, sand, or small rocks in a pie tin, paper cup, or rectangular gallon container (cut off the top of a plastic milk container).

3. Have students place their "glaciers" in the freezer overnight. The next day students should take the frozen glacier out of its mold and use it to simulate a glacier's movement over dirt, wood or other material in the classroom.

4. If you have access to a stream table with sand, start the glacier at one end by pushing it onto the sand. Set up a 60 watt lamp at the "south" end to simulate a melting glacier. As the day goes by check the melting glacier. River systems, moraines, and glacial lakes should all develop.

5. Students should draw before and after diagrams in their journal of what takes place.

6. Have students check for movement in the soil material (sand) and where it ends up. Record results on the Stream Table Data Sheet, page 33. Vary height of stream table and record any changes that occur.

Final Exhibition:

1. Have students build plaster models of the various landforms created by glaciers.

2. Have students search for websites about New Hampshire glacial landforms and glaciation in North America. Assign class to research the various landforms they have learned about.

3. Have students label a New Hampshire map with glacial landforms and complete a map of North America showing the extent of the last Pleistocene glaciation.

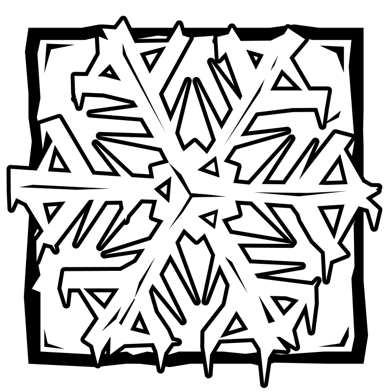
4. Use the map of the United States to have students label the states whose soils were impacted by the Pleistocene glaciers.

Extension Activity (Use this extension to transition into Lesson 4):

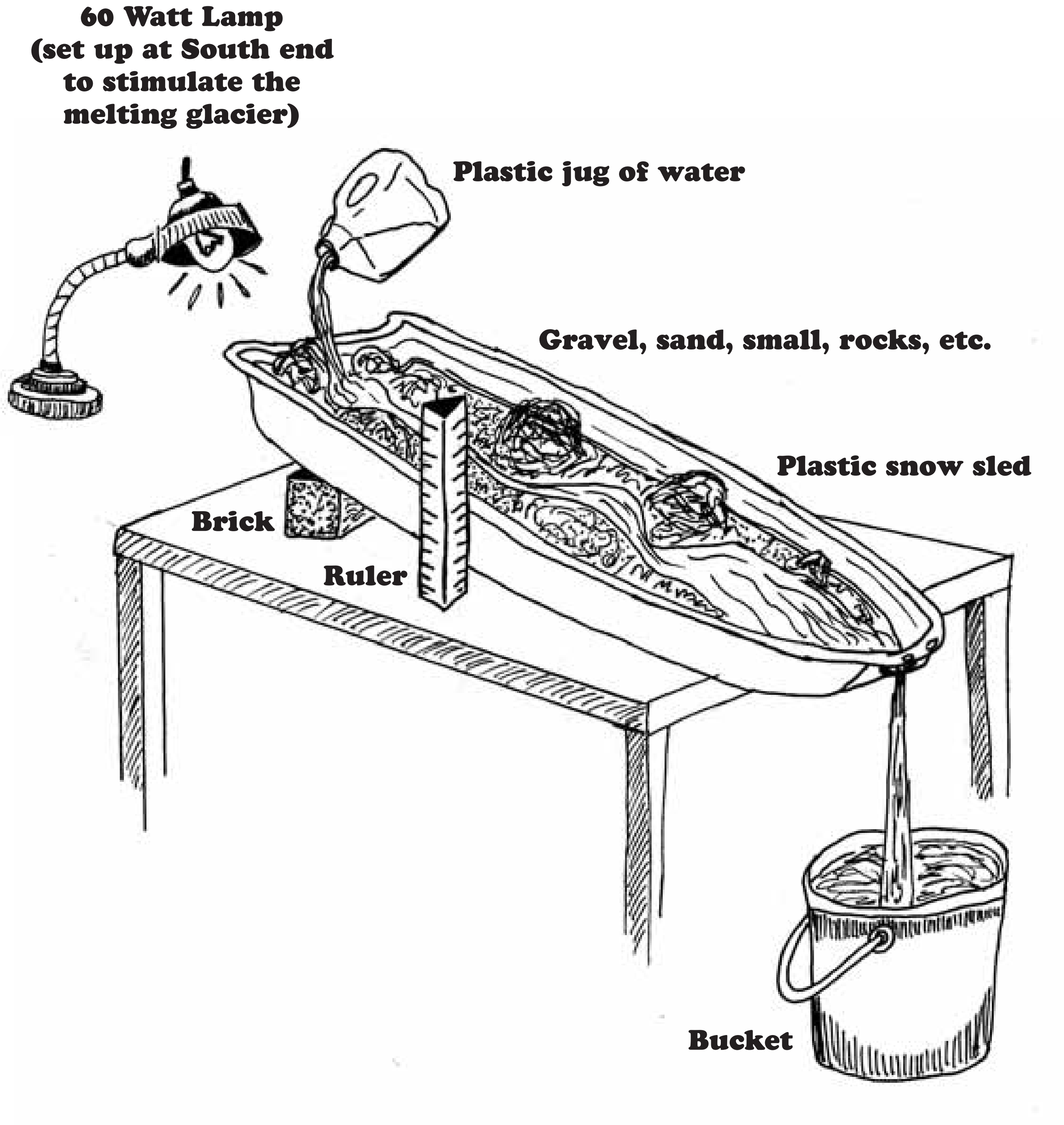
1. Have student invert his or her “glacier” so that the side with sand and gravel is facing up. Place soil on the top of the “glacier”. Pour water slowly over the soil and record what happens.

2. Have students discuss the following:
    - How does a glacier form?
    - When did glaciers develop in North America?
    - How does a glacier move?
    - What happened to the material your “glacier” passed over?
    - What happened to the material carried by your glacier?
    - Summarize the effect of erosion by ice on the land.
    - Describe the path of the water as it flows off your “glacier”?
    - Where does the soil collect?
    - Does all the soil move? Explain your answer.

3. Have students use their map of the United States (see #4 in Final Exhibition section) to compare to the soil types in the National Soil Classification System map in Lesson 2, page 28, and answer the following questions:
    - In the states covered by the glaciers, are there any similarities in types of soils?
    - From what you have learned, what might explain the differences you find?
    - In what states impacted by glaciation would you find organisms like worms naturally doing best?
    - What states would benefit most from creating artificial compost to raise worms?



HOW TO MAKE A STREAM TABLE



STREAM TABLE DATA SHEET

MATERIAL	HEIGHT OF STREAM TABLE	SPEED OF MOVEMENT
Sand (Top) Clay (Bottom)		
Sand (Top) Clay (Bottom)		
Pebbles (Top) Clay (Bottom)		

Grades 7/8

Lesson 4: What Lives in the Soil?

STANDARDS

Geography Content Standard 8:
The student knows and understands the characteristics and spatial distribution of ecosystems on the Earth's surface.

Science Standards (Grades 5-8), Content Standard A:
The student will develop and understand scientific inquiry.

Content Standard C:
The student will develop an understanding of populations, ecosystems, and diversity of organisms.

Essential Questions:
- What else lives in the soil in addition to worms?
- How do we find other living things in soil?
- What are invertebrates?
- What invertebrates can be found in different types of soil?

Outcomes:
After doing this lesson students will learn:
- Other types of living organisms that help keep soil healthy.
- Techniques for collecting living things.
- About the ecology of soil.
- About invertebrates and other unfamiliar life forms.
- How to use topographic maps.

Materials:
One-gallon plastic milk container (empty); an empty jelly jar (or other small jar with a tight fitting lid); a stick-about 25 cm long; 15 x 15 cm 1/4" mesh hardware cloth or aluminum window screen; a pair of scissors or tin snips for aluminum screen; masking tape or duct tape; rubbing alcohol (ethyl); a gooseneck lamp with a 40 watt bulb; a soil invertebrate identification key; shallow plastic or glass dishes; dissecting scope; topographic quadrangle of your area; Data Collection Chart (page 38). Use the following websites for content research:

http://www.jmath.freesurf.fr/invert_links.htm
http://www.ento.csiro.au/Ecowatch/Invertebrates.htm
http://www.geocities.com/CapeCanaveral/Lab/1300/index.html
http://soils.ag.uidaho.edu/soilorders/index.htm

Superintendent of Documents
PO Box 371954
Pittsburgh, PA 15250-7954
Phone: 202.512.1800
Fax: 202.512.2250
http://minerals.usgs.gov/minerals or www.access.gpo.gov/su_docs/sale/prf.html

Time Needed:
1-2 class periods for set up of apparatus. After 4-5 days you can carefully remove the glass jar and screw on its lid. Once this is completed 2-3 more class periods to draw and identify the organisms you have collected and compile data collected on the chart.

Teacher Content Background:

Arthropods is the name for a large group of invertebrates having jointed legs. In soil they can be very small or up to several inches in length. They can include insects such as ants, springtails, beetles, and other organisms related to insects, such as mites, spiders, and centipedes, millipedes, and pseudo-scorpions.

Arthropods are important in soil because they help in breaking down organic matter, and help to improve soil by adding their own organic matter to it. They help to create a good environment for plants to grow by aiding in soil aeration, stopping erosion, and helping to allow water to flow freely.

LESSON PROCEDURES AND ACTIVITIES

1. Cut the bottom off the milk jug (Figure A, page 36) and turn it upside down over the jar to make a funnel.

2. Tape the stick to the handle of the milk jug (Figure B) so it is just long enough to reach the outside bottom of the jar.

3. Bend down the corners of the hardware cloth or screening so it fits snugly inside the wide end of the funnel (milk jug). If using window screen, cut and pinch numerous slits so larger animals can crawl through (Figure C).

4. Students should collect several handfuls of topsoil, humus, and leaf litter from around your home, school, or community and record what type of ecosystem from which they have collected each (riverine, forest, open field, etc.) in their lab journal or notebook. It would also be a good idea to have students record time of day sample was collected, weather, and cloud cover. Bring these samples into class (Figure D).

5. On a local topographic quadrangle map mark where your soil samples were collected.

6. Pour alcohol into the jar to a depth of 2-3 cm (Figure E).

7. Carefully set the funnel on top of the jar and tape the stick to the jar so it won't be disturbed (Figure F).

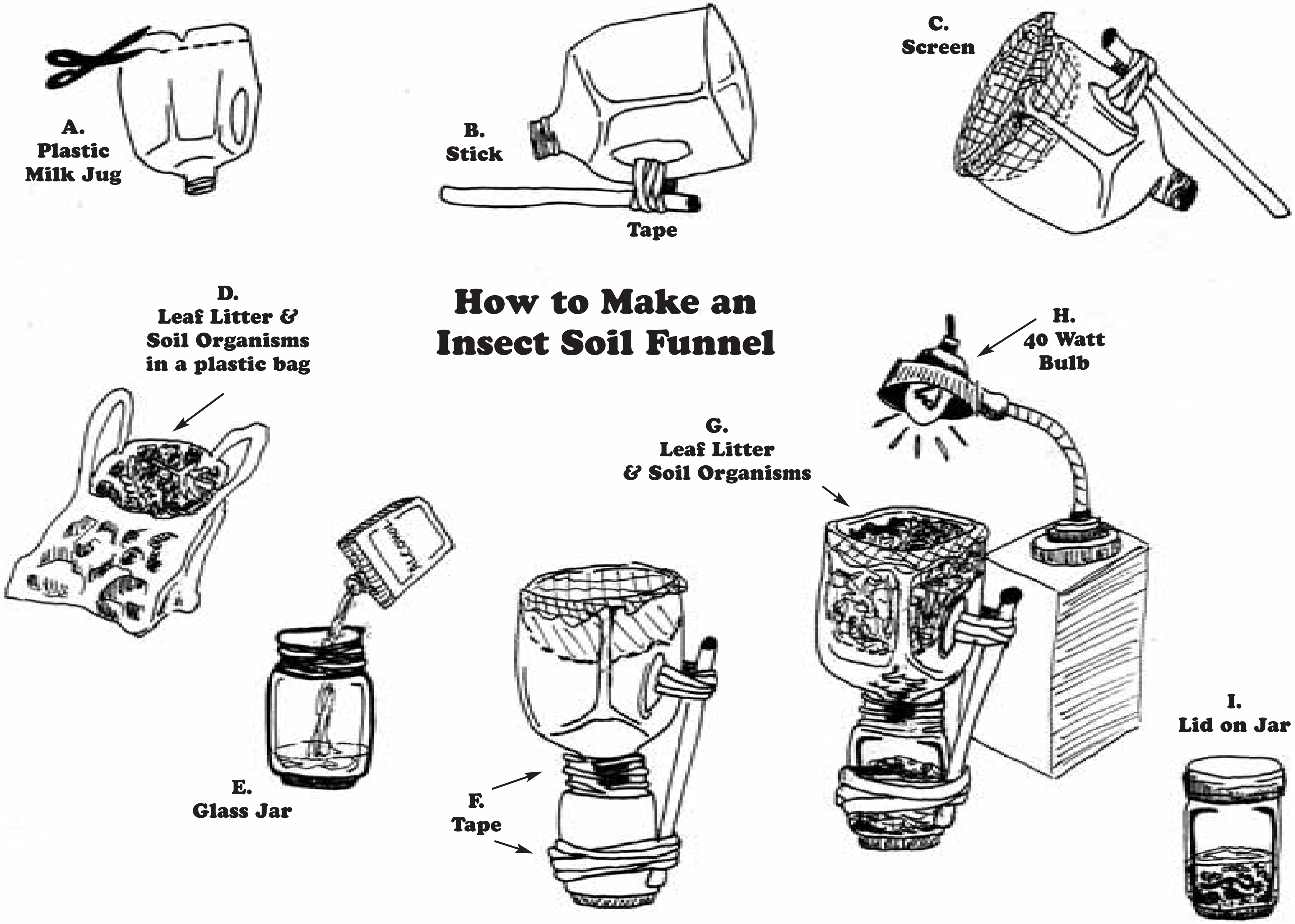
8. Pour the soil samples from the bag onto the screen of the funnel (Figure G).

9. Leave the funnel/jar unit in a warm, quiet place where it won't be disturbed.

10. Set a lamp over the funnel to speed drying. Keep the 40 watt bulb at least 10 cm away from the funnel for 4-5 days (Figure H).

11. As the sample dries out, the animals will move downward and fall into the alcohol. After 4 or 5 days you can carefully remove the funnel from the jar and screw the lid onto the jar. The alcohol will preserve the sample you have collected indefinitely (Figure I).

How to Make an Insect Soil Funnel



12. Now that your students have their samples, have them carefully transfer several of the organisms at a time to a shallow glass or plastic dish and view them under a binocular dissecting scope.

13. Your students can now begin drawing the various invertebrates that live in the soil and leaf litter, along with the worms. Have students draw several different types of organisms found in their samples. These drawings should be completed in their notebooks or lab journals.

14. Once drawings have been completed, students can use a soil invertebrate key to identify the organisms they have collected. This is a good time to lead a discussion on the characteristics of common invertebrate species of soils in your area.

15. You can have students do research on some of the various species found to report back to the class. What do these organisms do to help or hurt soils? What role might each organism play in the soil environment? Why do we find more arthropods in some places than others? What is their place in the ecology of the area? How do they help or hurt the development of worms in the soil? Where can these invertebrates be found in the community?

16. Have students draw conclusions about the environment from the organisms found. Have them compare with other students in class the various types of invertebrates found in the different types of ecosystems. Have students develop hypotheses using the topographic maps and areas where soils were collected.

17. At the end of this lesson the student notebook or lab journal should be collected to assess the work your students have accomplished. In their journals students should have maps of collection sites, the various soil types that are found there, and any other information you asked the student to collect.

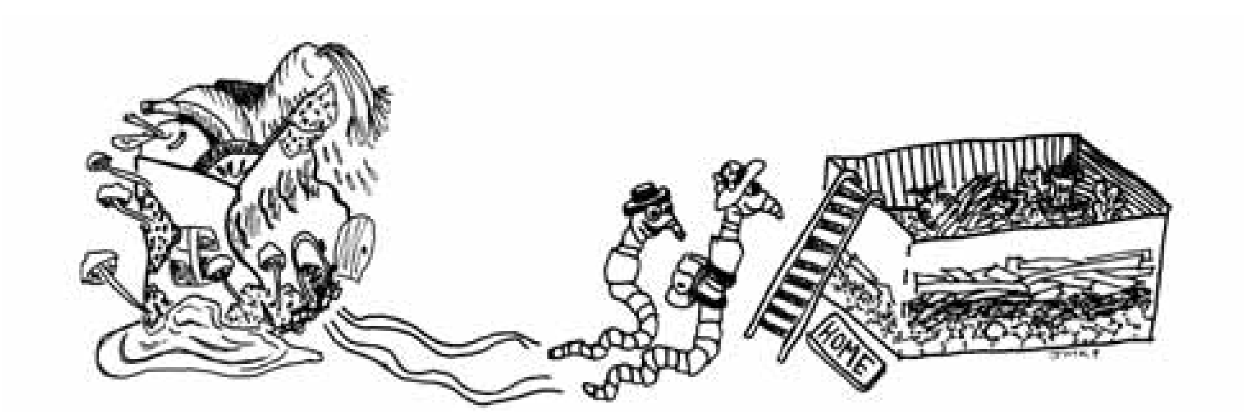
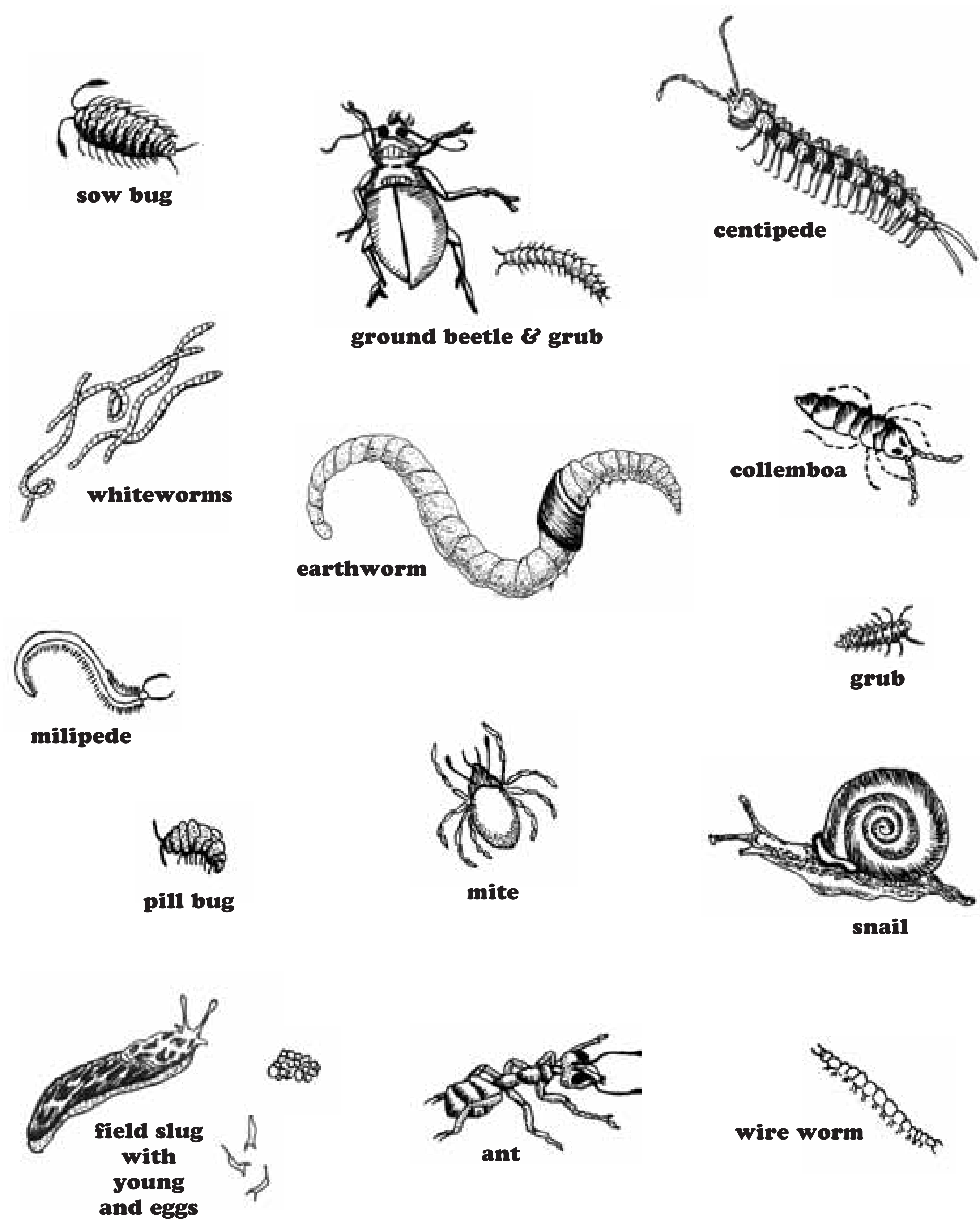


CHART FOR COLLECTION OF DATA

Type & Name of Organism Found	Type of Ecosystem Sample	Type of Soil	Miscellaneous Information About Organism

SOIL ORGANISMS



Grades 7/8

Lesson 5:
Worms Are Garbage Mouths

STANDARDS

Science Standards (Grades 5-8), Content Standard A:
The student will develop and understand scientific inquiry.

Content Standard C:
The student will develop an understanding of populations, ecosystems, and diversity of organisms.

Essential Questions:
- What is vermicomposting?
- How can we compost with worms (vermiculture) in the classroom?
- How can we help to make more enriched soil?
- How do we build a worm composter?
- Where else in the world is vermicomposting being used?

Outcomes:
After doing this lesson students will learn:
- How to build a worm composting bin.
- About the materials needed for a worm composter.
- How to care for and what to feed their worms.
- How to harvest a worm composting bin.

Materials:
Several 2 foot x 3 foot plastic bins with tight fitting lids; newspaper soaked in water; 2 inch wood blocks and a tray that will keep the plastic bin off the ground and catch any moisture that may leak out; redworms (Eisenia fetida) work best (these are available from various stores and catalogs that sell garden or fishing supplies); food scraps (almost any fruit, grain, or vegetable matter, other than oil, is good for worm composting- watermelon, banana peels, tortilla chips, tomato: ***absolutely no meat, poultry, fish or dairy products, or anything with colored inks***; a kitchen scale; soil or fine sand to provide grit; leaves and other yard trimmings; colored pencils or crayons; glue gun; screening material; drawing paper; plastic gloves.

Websites for content research:

http://www.wormsway.com/articles/10_04_wormbins.asp
http://www.challenge.state.la.us/edres/lessons/middle/lesson4.htm
http://www.earth911.org/master.asp?s=organics/composting/wormcompost.asp
http://www.gnb.ca/0009/o372/0003/0013-e.html
http://www.tandjenterprises.com/andj lawnworms buildsoils.htm
http://www.anr.state.vt.us/dec/wastediv/compost/pubs/dr_inghams_article.htm
http://www.anr.state.vt.us/dec/wastediv/compost/vermicompost.htm
http://www.nasaexplores.com/show_912_teacher_st.php?id=030307125651

Time Needed:
2 - 3 class periods to set up the vermicomposting bin, then one half-hour of time per week for upkeep of bins (this may be done during lunch period or after school as extra credit). This becomes an excellent ongoing science experiment your students will truly enjoy and get excited about.

LESSON PROCEDURES AND ACTIVITIES

1. Teacher provides lecture about worms and an explanation of red wigglers, touching on reproduction, explaining briefly worm composting and worm castings.

2. 1/8” holes need to be punched or drilled into the sides and bottom of the plastic bins. Teacher explains these are for ventilation and drainage so the material inside can drain and obtain needed air for the worms and the ecosystem being constructed. Use the glue gun to glue small pieces of screening material over the holes on the inside of the plastic bins. This is to block off exits so the worms can not escape.

3. Newspaper needs to be shredded into long, thin strips about 1/2 inch to 1 inch wide. This paper serves as a “bedding” in which the worms will live. The worms will also consume it along with the other materials. Once torn into strips the paper is soaked in water and set aside to drain.

4. The moist paper (bedding) is then added to the bottom of the bin until the bin is 1/3 full. Keep the bedding damp, but don’t let it become soaking wet. Add dry paper as needed to soak up excess water. Keep your bin in a sheltered location where the bedding can stay below 30°C.

5. Set your bin up on the wood blocks and place the tray underneath it to catch any drainage that might occur.

6. Mix in several handfuls of soil or fine sand to the bedding. Well crushed egg shells can be added every several months to act as grit for the worms.

7. Your bins need to be only 30 – 40 cm deep, since compost worms are surface feeders. The rule of thumb for bin size is two square feet of surface area per two pounds of food waste per week.

8. Weigh the amount of food scraps you will be supplying to your worms keeping in mind that .5 kilogram of worms can consume about .25 kilogram of kitchen scraps daily.

9. Start your bins off with .5 kilograms of worms for each .25 kilograms of food scraps you plan to compost each week. Unless you start composting more food scraps, you should never need to add any more worms. Add food scraps in small amounts, especially at first, or your bin may get smelly or heat up.

10. Each time you add food, gently stir the bedding to loosen it and keep it from becoming packed down. It is important to keep the air circulating to allow the process of decomposition. (Plastic gloves should be made available.)

11. When you add food, spread it out into a shallow layer and cover it with about another 5 cm of damp bedding. On top of this add 3 to 5 cm of dry bedding to keep other insects out of your bin.

12. Never let the bedding dry out. You may need to add water from time to time, in addition to food. Fruit juice or water from cooking vegetables are excellent additions because they provide added nutrients and minerals.

13. The process is slow and makes for a wonderful year-long science project. You won’t see much change from day to day. The worms will grow if you provide them with the basics: moist environment, food, bedding to allow air circulation, stable temperature between 18° and 22° C inside the bin.

14. About every three months, your worm castings will be ready to harvest. To do this, simply separate worms from the vermicompost to be harvested, offer fresh bedding and food scraps and watch the cycle begin again. This worm composted soil is excellent to use in gardens or with houseplants. If you have enough from your classes it can be sold to parents to support this project or others.

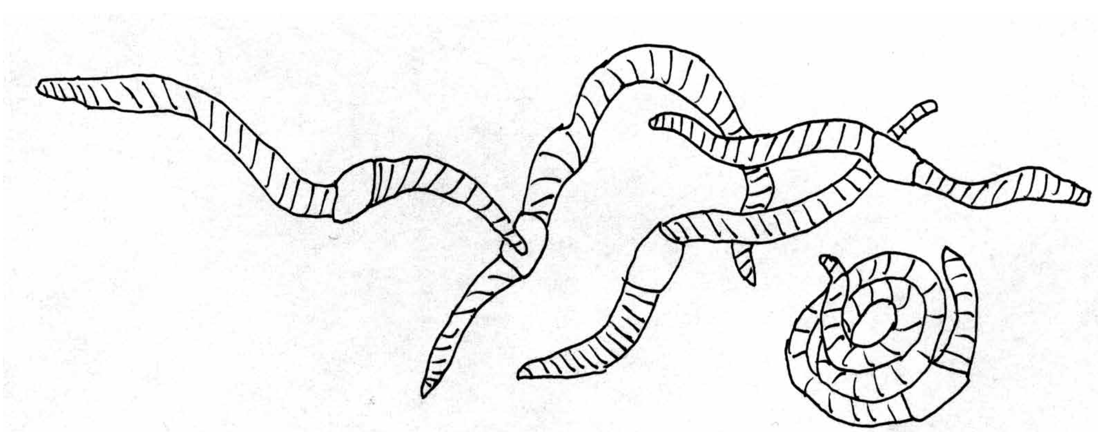
Extension Activity:

1. Have students keep a detailed journal of the process of vermiculture. Keep data on the mass of food fed to worms, how often they were fed, what they were fed, how many worms you started with, and how many were there after every three months. This can all be detailed with hand drawn diagrams, video, or photography. This can make an excellent science fair project.

2. Have students set up a business selling the worm compost. They can keep a detailed list of costs and amount of sales as the year progresses.

3. Have students do reports on:

a. Worms and other types of invertebrates.
b. What are different types of worms and how are they classified by science?
c. How do worms breathe?
d. Why are worms slimy?
e. Can worms see, feel, hear or smell?
f. How long have red worms been around? Other types of worms?
g. Where in the world is vermicomposting being used? Do a report using maps showing other countries and how they are using worms to compost and develop better soils.
h. Make a map for your classroom showing other locations around the world where vermicomposting is currently being used (See Grades 9-12: Lesson 2, following).



ORDERING YOUR WORMS

You'll need one pound of worms for a 19" x 16" x 12" worm bin.

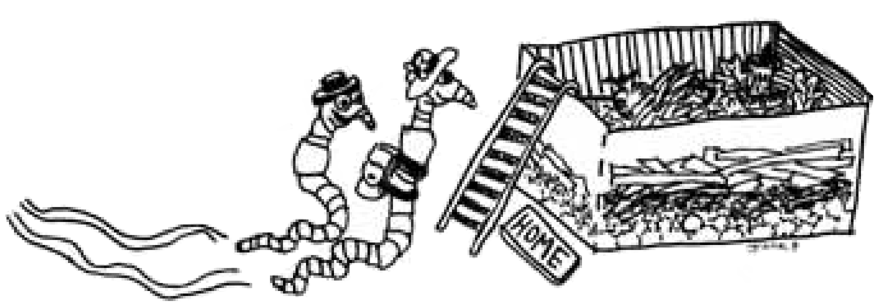
Flowerfield Enterprise
10332 Shaver Road
Kalamazoo, MI 49002
(616) 327-0108 Sells worms, worm bins, and worm bin guides.

Gardener's Supply Company
128 Intervale Road
Burlington, VT 05401
(802) 863-1700 Sells worms, worm bins and worm bin guides.

Real Goods
966 Mazzoni Street
Ukiah, CA 95482-3471
1-800-762-7325
Sells worms, worm bins and worm bin guides.

Seventh Generation
49 Hercules Drive
Colchester, VT 05446-1672
1-800-456-1177
Sells worms, worm bins and worm bin guides.

Smith and Hawken
2 Arbor Lane, Box 6900
Florence, KY 41022
1-800-776-3336 Sells worm bins and related supplies, including worm bin guides. No worms for sale. Offers classes on worm bin composting.



POTENTIAL PROBLEMS & CURES

Fruit Flies

Though fruit flies do not pose any health hazards, these little creatures can be a nuisance in the classroom. To help prevent these potentially prolific pests, do the following:

1. Avoid putting rotting or rotten food in your worm bin. Fly larvae are more likely to be present on rotten food.

2. Cut food scraps into small pieces. Worms will be able to eat smaller pieces more quickly, thereby limiting the possibility of fruit flies thriving on decomposing food.

3. Don't overfeed worms. Ripe food that sits around in the bin attracts (and may contain) flies.

4. Bury food. Burying the food will help keep unwanted pests and pets from intruding on your bin.

5. Keep bedding material moist, but not too wet. Overly wet conditions encourage the proliferation of fruit flies. Wet conditions might also cause an odor problem, as anaerobic bacteria thrive when it is too wet.

6. Feed worms a varied diet. If citrus foods dominate the bin, the bin may become too acidic, which may attract fruit flies.

7. Loosely place a piece of plastic or a sheet of newspaper inside the bin on top of the worm bin contents. This plastic or newspaper cover will create another barrier to help prevent flies from getting in (or out) of the bin.

8. Limit citrus fruits.

To help control an existing fruit fly problem, try the following:

1. Remove rotten food from the bin when fruit flies are present. Fruit flies often lay their eggs on decomposing food.

2. Tape or staple flypaper strips on the inside of the bin lid, and/or hang a strip near the bin. Flypaper strips can be purchased inexpensively at most hardware stores.

3. Create a fly trap to put in the bin. A bowl of apple cider vinegar with a drop of dish detergent, placed near the bin, will attract and kill flies. Change liquid regularly to keep fly trap potent.

4. Place a whole sheet of newspaper on top of bin contents. Change this sheet regularly as flies tend to congregate on the newspaper.

5. Sprinkle lime in the bin to neutralize excessively acidic conditions.

6. For temporary relief, take bin outside and leave uncovered for up to four hours to air out the bin (out of direct sunlight).

If the problem cannot be controlled, have your class analyze the problem, and speculate about what is causing it. The best solution may be to harvest the worms and start a new bin from scratch, using what you have learned from your past experience to create a better bin.

Odors

If your worm bin has an unpleasant odor, one of the following may be the culprit:

1. Bin is too wet. Solve the problem by not adding any water or foods with a high percentage of water (e.g., melons) and by adding more dry bedding.

2. Bin does not get enough air. Anaerobic bacteria (bacteria which thrive without air) is smelly. To aerate, add fresh bedding and mix bin contents daily.

3. The food in bin is naturally smelly. For instance, we have found that onions and broccoli do not smell very pleasant when they decompose in the worm bin. Simply remove any food source that smells bad from the bin.

4. Bin contains non-compostables. Meat, bones, dairy and oily products should not be fed to the worms because these items become rancid when decomposing.

Dying Worms

If you notice the worm population dwindling, or worms crawling all over the bin trying to escape, check for the following:

1. Bin is too wet and worms are drowning.

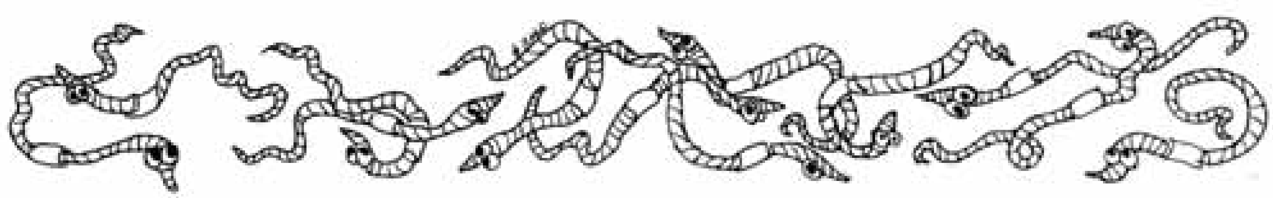
2. Bin is too dry and worms dry out.

3. Bin does not get enough air and worms suffocate.

4. Worms do not get enough food. Once the worms devour all of their food and newspaper bedding, they will start to eat their own castings which are poisonous to them. TIME TO HARVEST.

5. The bin is exposed to extreme temperatures. The worms thrive in temperatures from 55° to 77°F.

NOTE: Dead worms decompose rather quickly. If you do not monitor the above conditions you can have a box of dead worms before you even realize it.



BINS & BEDDING

Once you have worms and a bin, follow these six easy steps to set up a worm bin. Soon worms will be recycling food scraps into a healthy, nutrient-rich soil amendment called compost.

1. Acquire a bin.

Reuse an old dresser drawer or fish tank, build a box out of wood or find/buy a plastic bin. The approximate size is 16" x 24" x 8" or 10 gallons. Make sure the bin is clean by rinsing it with tap water to remove any residues which may be harmful to the worms. For wooden bins, line the bottom and sides with plastic (an old shower curtain or plastic garbage bag works well).

2. Prepare the bedding.

Instead of soil, composting redworms live in moist newspaper bedding. Like soil, newspaper strips provide air, water, and food for the worms.
a. Using about 50 pages, tear newspaper into 1/2" to 1" strips. Avoid using colored print, which may be toxic to the worms.
b. Place newspaper strips into a large plastic garbage bag or container. Add water until bedding feels like a damp sponge, moist but not dripping. Add dry strips if it gets too wet.
c. Add the strips to the bin, making sure bedding is fluffy (not packed down) to provide air for the worms. Bin should be 3/4 full of wet newspaper strips.
d. Sprinkle 2-4 cups of soil in bin, which introduces beneficial microorganisms. Gritty soil particles also aids the worms' digestive process. Potting soil, or soil from outdoors, is fine.

3. Add the worms.

Before adding the worms, find out how many worms you are starting with. The easiest method is to weigh the worms. If you do not have access to a scale, determine the worms' volume. The amount of worms is important for knowing how much food to feed them and for record keeping.

4. Bury food scraps under bedding.

Feed the worms fruit and vegetable scraps that would normally be thrown away, such as peels, rinds, cores, etc. Limit the amount of citrus fruits that you place in the bin. NO MEATS, BONES, OILS, OR DAIRY PRODUCTS.
a. Cut or break food scraps into small pieces--the smaller, the better.
b. Measure the amount of food. Feed worms approximately 3 times their weight per week. Monitor the bin every week to see if the worms are or are not eating the food. Adjust feeding levels accordingly. (If you start with one pound of worms, add 3 pounds of food per week.)
c. Bury food scraps in the bin. Lift up bedding, add food scraps, then cover food with bedding.

5. Place a full sheet of dry newspaper on top of the bedding.

This will help maintain the moisture balance, keep any possible odors in the bin, and help prevent fruit flies from making a home in the bin. Replace this sheet frequently if fruit flies are present, or if bin gets too wet.

6. Cover and choose a spot for the bin.
Cover the bin with a lid made of plastic, plywood or cloth, but leave the lid ajar so the bin receives some air. If desired, you may drill holes into the bin. Place the bin away from windows and heaters.

FEED, WATER and FLUFF!!! To keep worms happy, feed them about once a week. If bedding dries up, spray with water. (If bedding gets too wet, add dry newspaper strips.) Fluff up bedding once a week so the worms get enough air.

HOW TO BUILD A WOODEN BIN

Contact the Cornell Cooperative Extension for a complete diagram
http://www.cfe.cornell.edu/compost

Materials:
1 - 4 foot x 8 foot x 1/2" sheet exterior plywood
1 - 14 foot construction grade 2" x 4"
1 - 16 foot construction grade 2" x 4"
1 - lb 4d galvanized nails
1/4 lb. 16d galvanized nails
2 - 3" door hinges

Tools:
Tape measure; skill saw or rip hand saw; hammer; saw horses; long straight edge or chalk snap line; screwdriver; chisel; wood glue; drill with 1/2" bit. Use eye and ear protection.

Construction Details:
Measure and cut plywood as follows.

To make base, cut the 14 foot 2" x 4" into five pieces: two 48" and three 20" long. The remaining 12" piece will be used in making the sides as described below. Nail the 2" x 4"s together on edge with two 16d nails at each joint. Nail the plywood piece onto the 2"x 4" frame using the 4d nails.

To build the box, cut three 12" pieces from the 16 foot 2" x 4". Place a 12" 2" x 4" under the end of each side panel so that the 2" x 4" is flush with the top and side edges of the plywood, and nail the boards into place. Nail the side pieces onto the base frame.

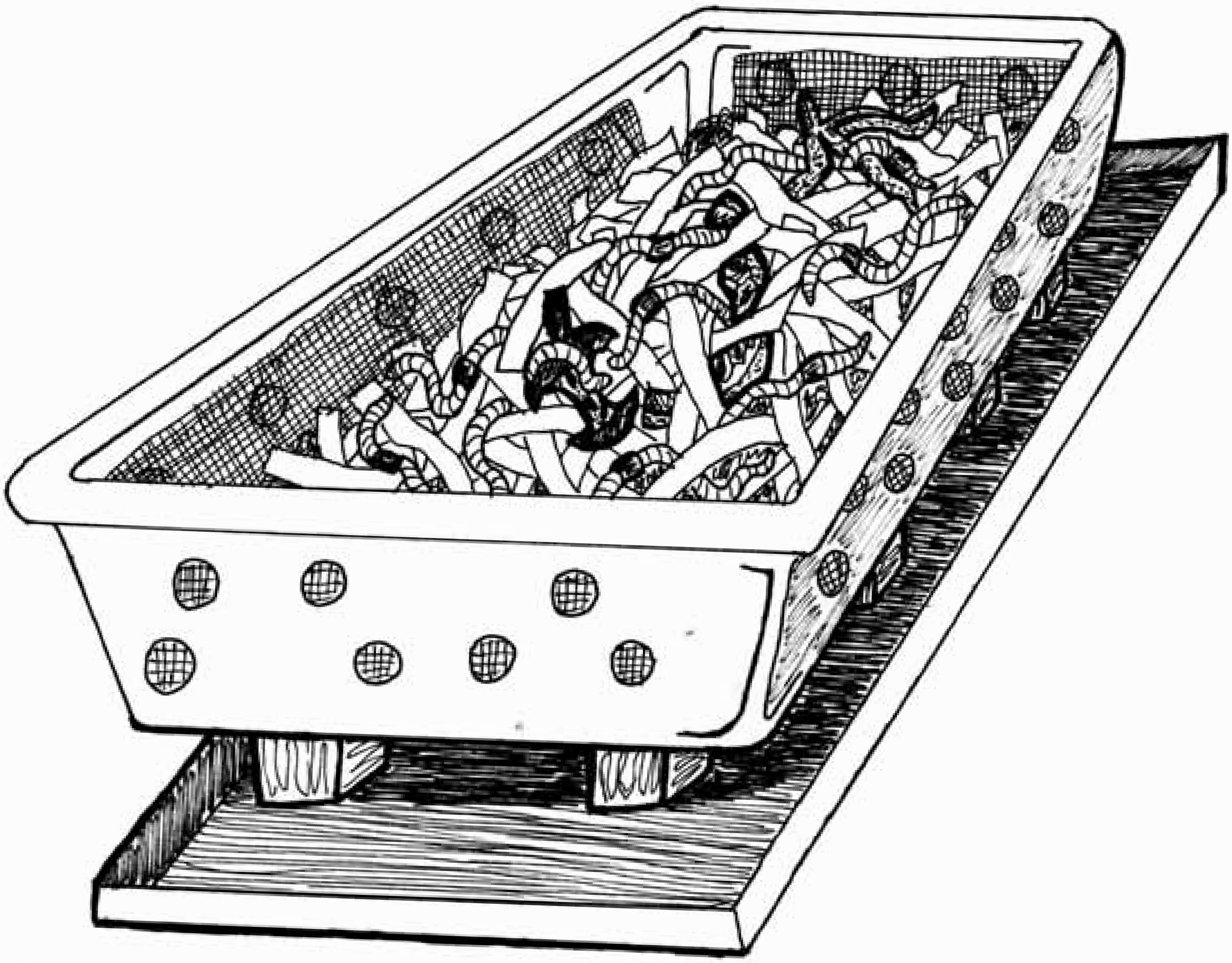
To complete the box, nail the ends onto the base and sides.

To reinforce the box, place a nail at least every 3 inches wherever plywood and 2" x 4"s meet. Drill twelve 1/2" holes through the bottom of the box for drainage.

To build the lid, cut the remainder of the 16 foot 2" x 4" into two 51" lengths and two 27" pieces. Cut lap joints in the corners, then glue and nail the frame together. Center the plywood onto the 2" x 4" frame and nail with 4d nails. Lay top on ground with plywood surface touching the ground. Attach hinges to the top and back. Position hinges so the screws go through plywood and 2" x 4"s.

FOODS FOR WORMS

Apples	Coffee Grounds	Molasses	Pizza Crust
Beans	Corn	Oatmeal	Potatoes
Bread	Cream of Wheat	Onion	Rice
Cabbage	Cucumber	Orange	Tea Leaves
Carrot	Egg Shells	Pancakes	Tomatoes
Cauliflower	Grapefruit	Pasta	Turnip
Celery	Grits	Peas	Waffles
Cereal	Lettuce	Pineapple	Watermelon



GLOSSARY

actinomycetes
Microorganisms that have the characteristics of both fungi and bacteria. They create cobweb-like growths throughout the compost and give compost an earthy aroma.

aortic arches
The five "hearts" of the earthworm circulatory system.

aerobic
Pertaining to presence of free oxygen. Organisms that utilize oxygen to carry out life functions.

aeolian
Deposited or eroded by wind.

aeolian erosion
The process of wind removing and helping to move rock material.

A-horizon
Upper soil layer in which humus and other organic materials are mixed with mineral particles.

alluvium
Any stream-deposited sedimentary material.

anaerobic
Pertaining to the presence of free oxygen. Organisms that can grow without oxygen.

anterior
Toward the front.

anus
The posterior opening of the alimentary canal.

arthropods
Animals with segmented bodies, exoskeletons, and jointed appendages.

bacteria
A one-celled organism that comes in many shapes that can only be seen with a microscope. They can cause decay and disease but most are beneficial because they help recycle nutrients.

barrier
A geographic zone such as an ocean, desert, or glacier which would prevent the migration of animals or worms.

bedding
Moisture-retaining medium which provides a suitable environment for worms.

B-horizon
Mineral soil layer below the A-horizon.

biodegradable
Capable of being broken down into simple parts by living organisms.

biome
A large recognizable assemblage of plants and animals in functioning interaction with its environment.

biosolid
The solid residue from a wastewater treatment system.

calcification
Soil- forming process of subhumid and semi-arid climates. The soil is in the mollisol order and is characterized by little leaching or eluviation. Humus accumulates along with minerals, especially calcium carbonates.

carbon
An element that is abundant in wood chips, sawdust, straw, and leaves. Carbon provides energy for living things.

castings
Worm manure.

chemical weathering
The decomposition of rock by an alteration of rock-forming minerals.

C-horizon
Lower soil layer composed of weathered parent material that has not been significantly affected by translocation or leaching.

climate
The average weather conditions of a place over a period of years.

clitellum
A swollen region containing gland cells which secrete the cocoon material. This is sometimes present on sexually mature worms and called bands or girdles.

cocoon
Structure formed by the clitellum which protects the embryonic worms until they hatch.

compost
A rich soil-like mixture that is produced when organic matter breaks down.

continental drift
The hypothesis that an original single landmass (Pangaea) broke and that the continents have moved very slowly over the asthenosphere to their present locations.

continental glacier
Vast blankets of ice that covered large parts of the earth during times of extreme cold. They completely inundate the underlying terrain to depths of hundreds or thousands of feet.

continental ice sheet
Mass of glacial ice thousands of feet thick that is of continental proportions and covers all but the highest points of land. The sheet usually flows from one or more areas of accumulation outward in all directions.

crop
In earthworms, part of the digestive system in which food can be stored.

crust
The outermost solid layer of the earth.

decompose
To decay or rot; To break down into simpler substances.

decomposer
An organism that breaks down cells of dead plants and animals into simpler substances.

decomposition
The process of breaking down complex materials into simpler substances.

diastrophism
The deformation of the earth's crust. Folding and faulting are examples.

digestive tract
The long tube where food is broken down into forms which animals can use. It begins at the mouth and ends with the anus.

dorsal
The top surface of an earthworm.

drumlin
Streamlined, elongated hill composed of glacial drift.

ecosystem
Collection of all the organisms that live in a particular place, together with their nonliving environment.

Eisenia Fetida
Scientific name for one of several redworm species used for vermicomposting. Color varies from purple, red, dark red to brownish red, often with alternating bands in between segments. Found in manure, compost heaps, and decaying vegetation where moisture levels are high.

enchytraeids
Small, white, segmented worms common in vermicomposting systems. They are also called pot worms and as decomposers, they do not harm earthworms.

environment
Surroundings, habitat.

erosion
Detachment and removal of rock material.

esker
A narrow winding ridge composed of glacial gravels formed by meltwater.

esophagus
Part of the food tube in earthworms that connects between the pharynx and the crop.

excrete
To secrete and discharge waste.

faulting
The movement of adjacent crustal blocks along joints, or fracture planes, in bedrock.

female genital pores
The female sexual organs of the earthworm.

fluvial erosion
The action of water removing and helping to move rock material.

folding
The movement of the earth's crust created by internal pressures.

ganglia (singular: ganglion)
Groups of nerve cells.

genital pores
Sexual organs.

geomorphic processes
Various movements that have taken place within the earth's crust creating landforms.

geomorphology
The scientific study of landform origins, characteristics, and evolutions and their processes.

glacial drift
Sediment transported by glaciers and deposited in water bodies.

glacial lake
A large water remnant of a receding glacier.

glacial till
The deposits of rocks, silt, and sand after glacier has receded.

glaciation
To cover with a glacier.

gland
A specialized type of tissue which produces secretion. In worm's skin, it is mucus.

gizzard
Structure in the anterior portion of the digestive tract whose muscular contractions help grind food in the presence of grit.

gradational processes
Processes that derive their energy indirectly from the sun and directly from earth gravitation and serve to wear down, fill in, and level off the earth's surface.

harvest
To gather-in or process.

hatchlings
Worms as they emerge from a cocoon.

heart
Muscular thickening of blood vessels whose valves control the direction of blood flow. Earthworms have several, commonly five pairs, of these vessels which connect the dorsal to the ventral blood vessels.

hermaphrodite
An animal or plant with both male and female reproductive organs.

humus
A dark, stable organic material found on top or in soil.

immigrate
To move into a region.

inorganic
Being or composed of matter other than plant or animal; like a mineral.

intestine
The tubular part of the alimentary canal that extends from the stomach to the anus.

kettle hole
Water-filled pit formed by the melting of a remnant ice block left buried in drift after the retreat of a glacier.

kettle lake
Formed in a kettle hole with glacial water from receding ice.

Koppen classification
Climatic classification system.

land configuration
The terrain or shape of the land.

laterites
Iron, aluminum, and manganese rich layer in the subsoil (B horizon) that can be the end product of laterization in the wet-dry tropics.

laterization
A soil-forming process of hot,wet climates. The soil type is often an oxisol with little or no humus and a heavy accumulation of iron or aluminum compounds.

leachates
Inorganic soil components from the surface layer of the soil. They are removed by gravitational water.

limestone
A type of rock created by the calcification process which has a high concentration of calcium carbonate.

loess
Wind deposited soil.

macroorganism
Organism large enough to see by the naked eye.

manure
Animal excreta. Worm castings.

mass wasting
The collective movement of surface materials downslope as a result of earth gravitation.

mature
Having completed natural growth and development.

mechanical weathering
The physical disintegration of rock material without any changes in chemical composition.

male genital pores
The male sexual organs of the earthworm.

microclimate
Climate associated with a small area at or near the earth's surface.

microorganism
Organism requiring magnification for observation.

moist skin
Outer layer of skin that is wet.

moraine
The largest and most conspicuous landform feature produced by glacial deposition.

mucus
A watery secretion, often thick and slippery, produced by gland cells. One function is to keep membranes moist.

muskeg
A thick deposit of partially decayed vegetable matter of wet boreal regions. A bog.

nephridia
The excretory of an annelid that filters fluid in the coelom.

nerve collar
Part of the nervous system that circles the pharynx in the earthworm.

nutrient cycle
Cycling of nutrients in the ecosystem or environment.

O-horizon
The immediate surface layer of a soil profile, consisting mostly of organic material.

organic activity
Processes promoted by living organisms like plants and animals.

organic matter
Material which comes from something once alive.

overload
To deposit more garbage in a worm bin than can be processed aerobically.

outwash plain
An extensive, relatively smooth plain covered with sorted deposits carried forward by the meltwater from an ice sheet.

ovaries
A pair of female reproductive organs.

oxidation
The chemical union of oxygen atoms with various mineral elements to produce new products. It often creates products more easily eroded.

parent material
The source of weathered fragments of rock from which soil is made.

permeability
Soil characteristic in which there are interconnected pore spaces through which water can move.

pharynx
The tubular passage of the vertebrates digestive and respiratory tracts extending from the back of the nasal cavity and mouth to the esophagus. In invertebrates, it is part of the alimentary canal.

phylum annelida
Phylum that contains segmented worms.

plate tectonics
The theory that the lithosphere is composed of segments or plates that move over the earth's surface.

Pleistocene Epoch
An ice age that began 2 million years ago and ended 10,000 years ago. It is believed to have had four major ice advances that helped to form the current surface of earth.

podzol
Acidic, gray, ashy soil often found in cool moist climate regions.

podzolization
A soil-forming process of humid climates with long, cold winter seasons. Spodosols are the typical type of soil, characterized by the surface accumulation of raw humus, strong acidity, and the leaching or eluviation of soluble bases and iron and aluminum compounds.

pollute
To make foul or unclean, to contaminate.

population
The total number of individuals of a single species in a defined area.

population density
Number of specific organisms per unit area.

posterior
Toward the rear, back or tail.

prostomium
Fleshy lobe protruding above the mouth of an earthworm.

recessional moraine
An end moraine deposited behind a terminal moraine, marking pauses in the retreat of a valley glacier or ice sheet.

redworms
A common name for Eisenia Fetida. A common worm used for composting.

residual parent material
Weathered fragments of rock material that accumulate beneath the soil.

segments
Numerous disc-shaped portions of an earthworm's body bounded anteriorly and posteriorly by membranes. People identify earthworm species by counting the number of segments anterior to the position of structures such as the clitellium, ovaries, or testes. Segmentation is a characteristic of all annelids.

septa
The internal wall between the segments of an annelid's body.

setae
Bristles on each segment used in locomotion.

sexually mature
Possessing a clitellium and capable of reproducing.

slime
Mucus secretion of earthworms which helps to keep skin moist so that gas exchange can take place.

slope
The inclination of the earth's surface.

soil
A varying mixture of weathered mineral particles, decaying organic matter, living organisms, gasses, and liquid solutions. Soil is part of the outer skin of the earth.

soil classification system
Developed by soil scientists of the USDA over a long period of time. Many changes have given us a system that identifies six levels or classes in descending categories, beginning with 10 soil orders, 47 suborders, 185 great groups, and ever-increasing numbers of subgroups, families, and series.

soil profile
The vertical cross-section of soil from it's surface to the parent material from which it is formed.

soil horizon
A separate soil layer.

subsoil
Mineral-bearing soil beneath humus-containing topsoil.

tectonic processes
Processes that derive their energy from within earth's crust and serve to create landforms by disrupting, elevating, and shaping the earth's surface.

terminal moraines
A glacial deposit that builds up at the outermost advance of ice advance.

testes
A pair of male sexual reproductive organs.

till
Rock debris that is deposited directly by moving or melting ice.

time factor
The length of time it takes for soil to reach a state of dynamic equilibrium with its environment. It varies with conditions but usually takes hundreds to thousands of years.

top dressing
Nutrient-containing materials placed on the soil surface around the base of plants.

topography
Surface configuration of the earth.

transported parent material
Rock fragments carried by water, wind, or ice to help form new deposits for developing soil surface.

ventral
Term for the underside of a worm.

vermicomposting
Mixture of partially decomposed organic waste, bedding, worm castings, cocoons, and worms.

vermiculture
The raising of earthworms under controlled conditions.

volcanic soils
Soils created from the breakdown of parent materials whose origin came from volcanic, tectonic processes.

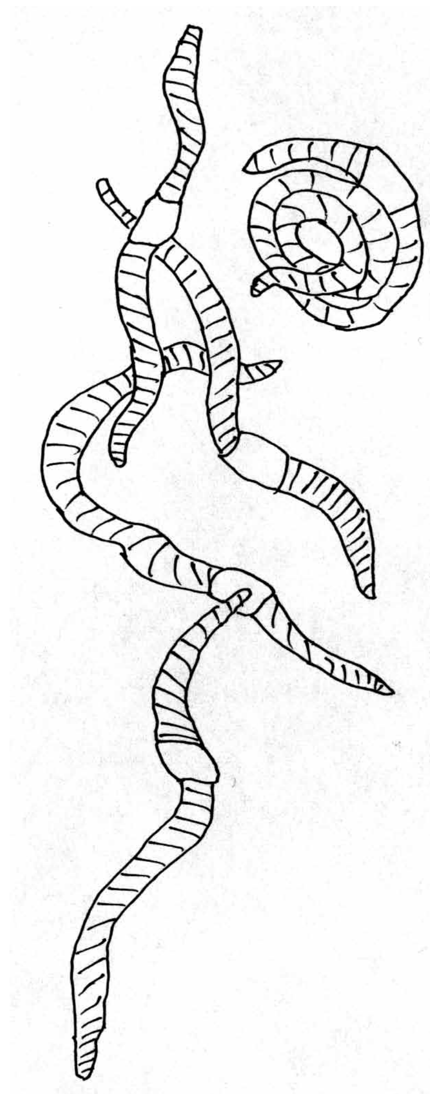
volcanism
The upward movement of molten material (magma) to the earth's surface where it is cooled. Cooled rock forms the parent material for the production of soil.

weathering
The physical and chemical disintegration of rock that is exposed to the weather.

worm bedding
The medium, usually cellulose-based, in which worms are raised in culture, such as shredded, corrugated cartons, newspaper, or leaf mold.

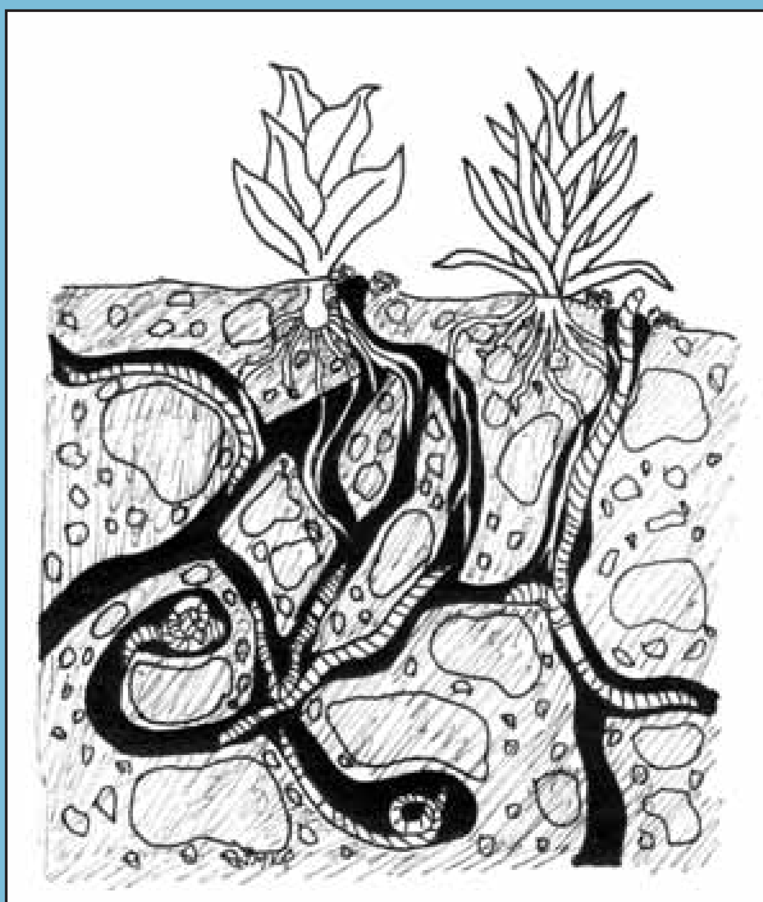
worm bin
Container designed to accommodate a vermicomposting system.

worm casting
Undigested material, soil bacteria deposited through the anus. Worm manure.



Section 2

Grades 9 – 12
Lessons 1 – 5



Grades 9 – 12

Lesson 1: What Is Vermicomposting Anyway?

STANDARDS

Geography Content Standard 18:
The student will know and understand how to apply geography to interpret the present and plan for the future.

Science Standards (Grades 9-12), Content Standard A:
The student will develop abilities necessary to do scientific inquiry.

Content Standard C:
The student will develop an understanding of the behavior of organisms.

Essential Questions:
- What is vermicomposting and how can we compost with worms (vermiculture) in the classroom?
- How can we recycle foods from the school cafeteria?
- Can we learn about population dynamics from worms?
- How do we build a worm composter?

Outcomes:
After completing this lesson, students will learn:
- How to build a worm composting bin.
- About the materials needed in a worm composter.
- How to care for and what to feed their worms.
- How to develop a school cafeteria recycling program.
- How to graph and begin understanding population dynamics.

Materials:
Several 2 foot x 3 foot plastic bins with tight fitting lids; newspaper soaked in water; 2 inch wood blocks and a tray that will keep the plastic bin off the floor and catch any moisture that may leak out; redworms (Eisenia fetida) work best (these are available from various stores and catalogs that sell garden or fishing supplies); food scraps (almost any fruit, grain, or vegetable matter, other than oil, is good for worm composting- watermelon, banana peels, tortilla chips, tomato; ***absolutely no meat, poultry, fish or dairy products, or anything with colored inks*** – see page 90); a monthly school cafeteria menu; a kitchen scale; soil or fine sand to provide grit; leaves and other yard trimmings; colored pencils or crayons; glue gun; screening material; drawing paper; plastic gloves; journal for students to be used for all five lesson plans following.

Websites for content research and purchasing materials:

http://www.wormsway.com/articles/10_04_wormbins.asp
http://www.challenge.state.la.us/edres/lessons/middle/lesson4.htm
http://www.earth911.org/master.asp?s=organics/composting/wormcompost.asp
http://www.gnb.ca/0009/o372/0003/0013-e.html
http://www.tandjenterprises.com/andj lawnworms buildsoils.htm
http://www.anr.state.vt.us/dec/wastediv/compost/pubs/dr_inghams_article.htm
http://www.anr.state.vt.us/dec/wastediv/compost/vermicompost.htm
http://www.nasaexplores.com/show_912_teacher_st.php?id=030307125651

Time Needed:
2 - 3 class periods to set up the vermicomposting bin, then one half-hour of time per week for upkeep of bins (this may be done during lunch periods or after school as extra credit). This is an excellent ongoing science experiment your students will truly enjoy while learning about recycling and population dynamics.

Teacher Background Section:

The average American throws away 4.5 pounds of materials/goods per day. Nationally, this adds up to approximately 240 million tons of trash, a small portion of which is either recycled (from 20-40%, depending on state) or incinerated. The majority of waste, however, was once dumped into more than 2300 landfills. Many of these repositories were closed under EPA regulations, causing communities to seek alternative means of disposal. Many communities are now recycling but we are clearly not doing enough.

Paper, plastics, and food/yard wastes constitute substantial waste inputs. Food and yard waste represent about 1/4 of total waste and represent materials that can effectively be removed from the waste stream of both communities and individuals via the process of composting.

Early in the 20th Century, Barrett promulgated the idea of using composted materials, aided by the natural decomposer processes of earthworms. He found that fruits and vegetables became healthier and more productive when fertilized with worm castings (Rodale 1992). By mid-century, Howard found that worms provided fertile castings as well as soil aeration (see: Rodale 1992 and Jenness, Mendolia, and Rushlow 1996). Zaller and Arnone (1999) demonstrated a unique relationship between plant growth and earthworm castings under different levels of carbon dioxide. While their research is primarily focused on the concept of climate change, they too demonstrate the beneficial role of plant growth in the presence of earthworms.

Research shows that the Eisenia fetida (redworms) are the most effective “composters” due to their ability to digest large amounts of wastes and to produce nutrient-rich castings. This process, known as vermicomposting, can be implemented in both urban and rural settings, requires minimal space, and represents an inexpensive, low-maintenance form of waste management.

Vermicomposting produces a more nutrient-rich soil additive than traditional composting and can easily be used for household plants and gardens. The controlled environment of a vermicompost bin reduces both the risk of soil contamination by leachates, other pollutants and the amount of time taken for food to decompose. This is simply because worms eat the food scraps, thus quickening the process of decomposition.

Nationally, vermicomposting has been demonstrated to be an effective waste management strategy. Although it is similar to composting, this form of solid waste management is becoming a new and popular way to help control biodegradable forms of waste. As the public becomes more aware of the positive effect that vermicomposting has on the environment, it may well become an integrated tool in our nation’s efforts to more effectively manage our waste stream. Moreover, it can provide an important tool in our nation’s attempt to replenish our diminishing soil reserves. It is estimated, for example, that states in the Northeast lose from 4 to 6 tons of soil/acre/year due to erosion. This rate “corresponds to a loss of about 0.2 to 0.4 inches from the soil surface in 10 years. If we recognize that the top 4 to 12 inches of most soils hold the greatest proportion of nutrients and organic matter, then these rates may lead to removal of much of this fertile layer in just a few decades” (Cutter and Renwick 1999,130).

Furthermore, vermicomposting could help us reduce our dependence on chemical inputs in our agricultural system, thus reducing soil depletion, and the loss of beneficial, soil enhancing organisms.

Cutter, S. and W. Renwick. 2004. Exploration, Conservation, Preservation (4th Ed.). NY: Wiley; Jenness, L., R. Rushlow, and D. Mendolia. 1996. The Wide World of Worms. Geography Department, Keene State College, Keene, NH; Rodale, J. 1992. The Complete Book of Composting. Emmaus, PA: Rodale Books; Zaller, J. and J. Arnone III. 1999. Interactions Between Plant Species and Earthworms Casts in a Calcareous Grassland Under Elevated CO2. Ecology 80 (3) April: 873-881.

LESSON PROCEDURES AND ACTIVITIES

1. Teacher provides lecture about worms and an explanation of red wigglers, touching on reproduction. Explain briefly the worm's digestive system and how composting with worms can help recycle foods that would ordinarily end up in the school's and community's landfill.

2. 1/8" holes need to be punched or drilled into the sides and bottom of the plastic bins. Teacher explains these are for ventilation and drainage so the material inside can drain and obtain needed air for the worms and the ecosystem being constructed. Use the glue gun to glue small pieces of screening material over the holes on the inside of the plastic bins. This is to block off exits so the worms cannot escape.

3. Newspaper needs to be shredded into long, thin strips about 1/2 inch to 1 inch wide. This paper serves as "bedding" in which the worms will live. The worms will also consume it, along with the other materials. Once torn into strips the paper is soaked in water and set aside to drain.

4. The moist paper (bedding) is then added to the bottom of the bin until the bin is 1/3 full. Keep the bedding damp, but don't let it become soaking wet. Add dry paper as needed to soak up excess water. Keep your bin in a sheltered location where the bedding can stay below 30°C.

5. Set your bin up on the wood blocks and place the tray underneath it to catch any drainage that might occur.

6. Mix in several handfuls of soil or fine sand to the bedding. Well-crushed egg shells, which also act as grit for the worms, can be added every several months.

7. Your bins need to be only 30 – 40 cm deep, since compost worms are surface feeders. The rule of thumb for bin size is two square feet of surface area per two pounds of food waste per week.

8. Weigh the amount of food scraps you will be supplying to your bins, keeping in mind that .5 kilogram of worms can consume about .25 kilograms of kitchen scraps daily.

9. Start your bins off with .5 kilogram of worms for each .5 kilogram of food scraps you plan to compost each week. Students should count and record by date in their journals the actual number of worms added to the bin. Unless you start composting more food scraps, you should never need to add any more worms. Add food scraps in small amounts, especially at first, or your bin may get smelly or heat up.

10. Each time you add food, gently stir the bedding to loosen it and keep it from becoming packed down. It is important to keep the air circulating to enhance the process of decomposition. (Plastic gloves should be made available.)

11. When you add food, spread it out in a shallow layer and cover it with about another 5 cm of damp bedding. On top of this add 3 to 5 cm of dry bedding to keep other insects out of your bin.

12. Never let the bedding dry out. In addition to food, you may need to add water from time to time. Fruit juice or water from cooking vegetables are excellent additions because they provide added nutrients and minerals.

13. Once the bins are developed and the worms are added, have your students draw and write in their journal a concise entry of what has been accomplished to this point. They should include in their entries the number of worms placed in the bin, the date, and any other pertinent information you deem necessary.

14. The process is slow and makes for a wonderful year-long science project. You won't see much change from day to day. The worms will grow if you provide them with the basics: moist environment, food, bedding to allow air circulation, and a stable temperature between 18° and 22° C inside the bin.

15. Hand students a copy of the monthly school cafeteria menu. Students should decide what days would be best to recycle foods that would ordinarily be thrown out. This will vary depending on what is served on various days. Have students speak with the cafeteria staff and inform them of the recycling program they would like to set up. Initially, this might only include recycled food from their class, keeping in mind you will need about .25 kilos of food scraps per day per bin. Have students record the types of food scraps used as well as the weight of scraps added to the bins each day.

16. Every 2 to 3 months, with enough good food and the proper environment, your worms should double their population. To quantify this, simply have worms counted and returned to the bin, offer them fresh bedding and food scraps, and watch the cycle begin again. (When separating the worms from the soil, place a large piece of plastic sheeting on the floor and slowly empty the contents of the bin onto the sheeting). This worm composted soil is excellent to use in gardens or with houseplants. If you have enough from your classes it can be sold to parents to support this project or for other projects in the future.

Extension Activity:

1. Have students keep a detailed journal (with drawings) of the process of setting up their composting bins. Have them set up a data chart recording the amount of food fed to worms, how often they were fed, what they were fed, how many worms you started with, and how many worms there were after every three month harvest. This can be detailed with hand-drawn diagrams, video, or photography. Students should develop graphs (page 61) that show the number of worms they started with, as well as how that population grew as the year progressed.

2. As the project progresses, have students do oral reports on the worm:
- a. digestive system- What do they eat?
- b. reproductive system- How do they reproduce?
- c. respiratory system- How do they get their oxygen and energy?
- d. muscular system- How do they move about in soil?

3. Have students research human population growth and compare its stages to their findings about the population growth of worms. Did some bins have greater or lesser population growth rates than others? What factors might have contributed to those differences? Can we set up experiments to find the answers? Do some human populations (countries) have greater or lesser population growth rates than others? What might be the contributing geographical factors?

WORM POPULATION GROWTH

Create a bar or line graph plotting the growth in population of your worms. Plot the total number of worms in your bin for each day that you count. Record date and number of worms.

Total number of worms

Date/Day

Grades 9 – 12

Lesson 2: Where In The World?

STANDARDS

Geography Content Standard 3:
How to use maps and other geographical representations, tools, and technologies to acquire, process and report information from a spatial perspective.

Geography Content Standard 14:
How human actions modify the physical environment.

Science Standards (Grades 9- 12), Content Standard C:
The student will develop an understanding of the organization of living systems, ecosystems, and the reproduction and adaptation of organisms.

Essential Question:
- What countries and cities in the world are using vermicomposting?
- What are the economic and environmental advantages for each of these countries and cities in adopting vermicomposting?
- What are the primary environmental conditions or factors that underlie successful adoption of vermicomposting?

Outcomes:
After completing this lesson, students will be able to:
- Complete an internet search to locate 10 countries and cities involved in vermicomposting projects.
- Complete a chart listing 10 countries and their urban centers which have adopted vermicomposting and describe economic benefits, environmental advantages, and environmental conditions for each project.
- Complete a world map locating countries and urban areas involved in vermicomposting projects.
- Compare worldwide patterns of vermicomposting adoption to major world soil and climate zones.

Materials:
Computer Internet access; map "Vermicomposting Cities Around the World" (page 65); blank world map; journals; classroom atlases.

Web sites for research initiation:

www.nir.org/books/zb,,74_a_o_o_a/The+Complete+Technology/Book+on+vermiculture+and+vermicompost/
www.nabard.org/roles/ms/ph/vanilla.htm
www.environmentnepal.com.np/news_d.asp7id-821
www.city.toronto.on.ca/compost/wormyour/html
www.tibet.ca/en/wtnarchive/20003/9/6_5.html
www.ibiblio.org/london/agriculture/vermiculture/1/msg00012.html
www.odla.nu/garden_links/composting.shtm

NOTE: Students can initiate their search using "vermicomposting around the world." This will produce many "hits" from which to find more useful sites.

Time Needed:
2 class periods (more for extended activity)

LESSON PROCEDURES AND ACTIVITIES

1. Starter: What is vermicomposting? What are the advantages of vermicomposting for cities and rural regions? Speculate: What countries in the world might benefit from such an activity? Take students' ideas and make a list on the board.

2. Tell students that they will use their computers to undertake a search to verify their speculation. Pass out the map "Vermicomposting Cities Around the World". Students will create a list of 10 countries and cities involved in vermicomposting programs. Students should also research and write on economic benefits, environmental advantages, and the major environmental conditions necessary for successful vermicomposting, with the help of their classroom atlases. This phase should take one class period and can be promoted by group work.

3. Research should be shared on the second day of the activity. The teacher should make a list of all countries and cities as students present their findings.

4. Students should be asked to make a list in their notebook or lab journal of all places not on the charts. Pass out a blank world map and classroom atlases. Assign students the task of locating all countries and cities identified in vermicomposting programs.

5. Create an overhead map showing cities that have adopted vermicomposting (page 65) and compare it to a world climate map and a world soils map, found in their classroom atlases. Discuss the interrelationships and tie them into the environmental conditions that the students noted in their research.

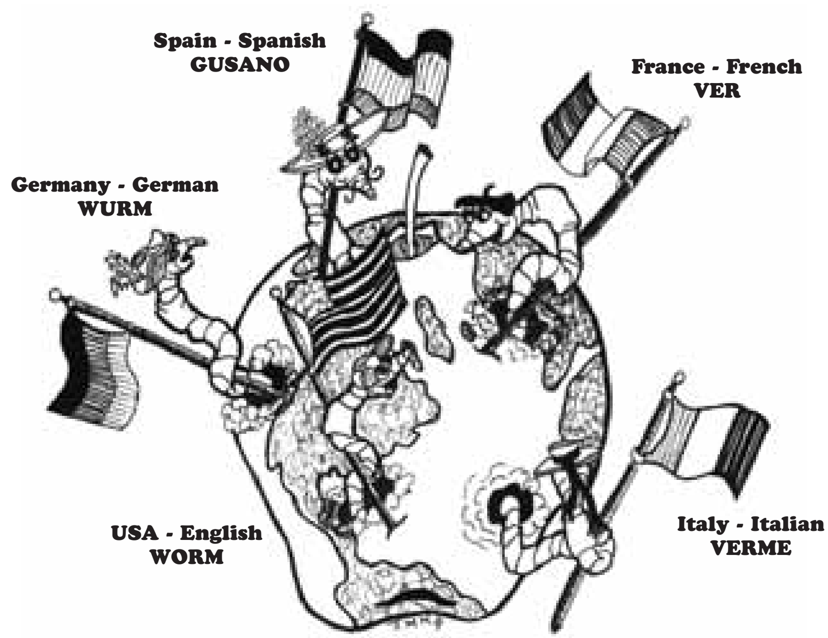
Extension Activity:

1. Have students choose one national program and complete further research on the economic and environmental advantages in the country of choice. This can be presented as an oral report and shared with the class.

2. Have students complete their research with a poster presentation.

3. Have advanced students present their research by creating a PowerPoint presentation for their school as a way to broaden the adoption of classroom vermicomposting bins. (See Lesson 5 for a community project.)

4. Discuss the possibility of your school/community adopting a vermicomposting program. Are the environmental conditions right for your area?



CITIES THAT VERMICOMPOST

Canberra, Australia:

This city developed a project to vermicompost almost 40 cubic yards per week of pre-processed food scraps. This takes place in covered brick beds on a concrete slab inside a shed. They will probably use the castings as an agricultural fertilizer.

Havana, Cuba:

Here they have an innovative system for home use, called the "Sanitary Box System." It consists of two boxes designated for stacking on top of one another. Kitchen scraps are added to the first box and wetted daily until the feedstock reaches a height of 15cm. Waste paper can be added up to 20 - 40% of the volume of space. The earthworms are added at a rate of 1 kg/meter2 and fed in the first box until it is full.

The second box, slatted on the bottom, is then placed on top of the first and food provided. As worms move up through the slats to the fresh food, they separate themselves from the finished vermicompost. There are currently 300 or more sanitary boxes in use in Cuba.

Newcastle, New South Wales, Australia:

Vermicomposting occurs for about 33 cubic yards per week of biosolids and vegetable scraps. The windrows are underlain by a plastic ground sheet and watered with an overhead system. A windrow is a half-circular mound of vermicomposting that extends length-wise (on the ground) to however long the creator wants it to be. About 40% of the input is harvested weekly as vermicastings, which are bagged, marketed and sold to major supermarkets in Melbourne and Sydney.

Pinar del Rio, Cuba:

Windrows are formed with a tractor-drawn manure spreader, under the shade of large mango trees. A windrow is a half-circular mound of vermicomposting that extends length-wise (on the ground) to however long the creator wants it to be. The first layer of a new windrow is 10 - 15 cm. high. The worms are put into the windrow at the rate of 1kg/meter2 and they feed from the bottom to the top of the bed. Once the worms seem to be at the top, another 7-10 cm layer of feedstock is added.

Pune, India:

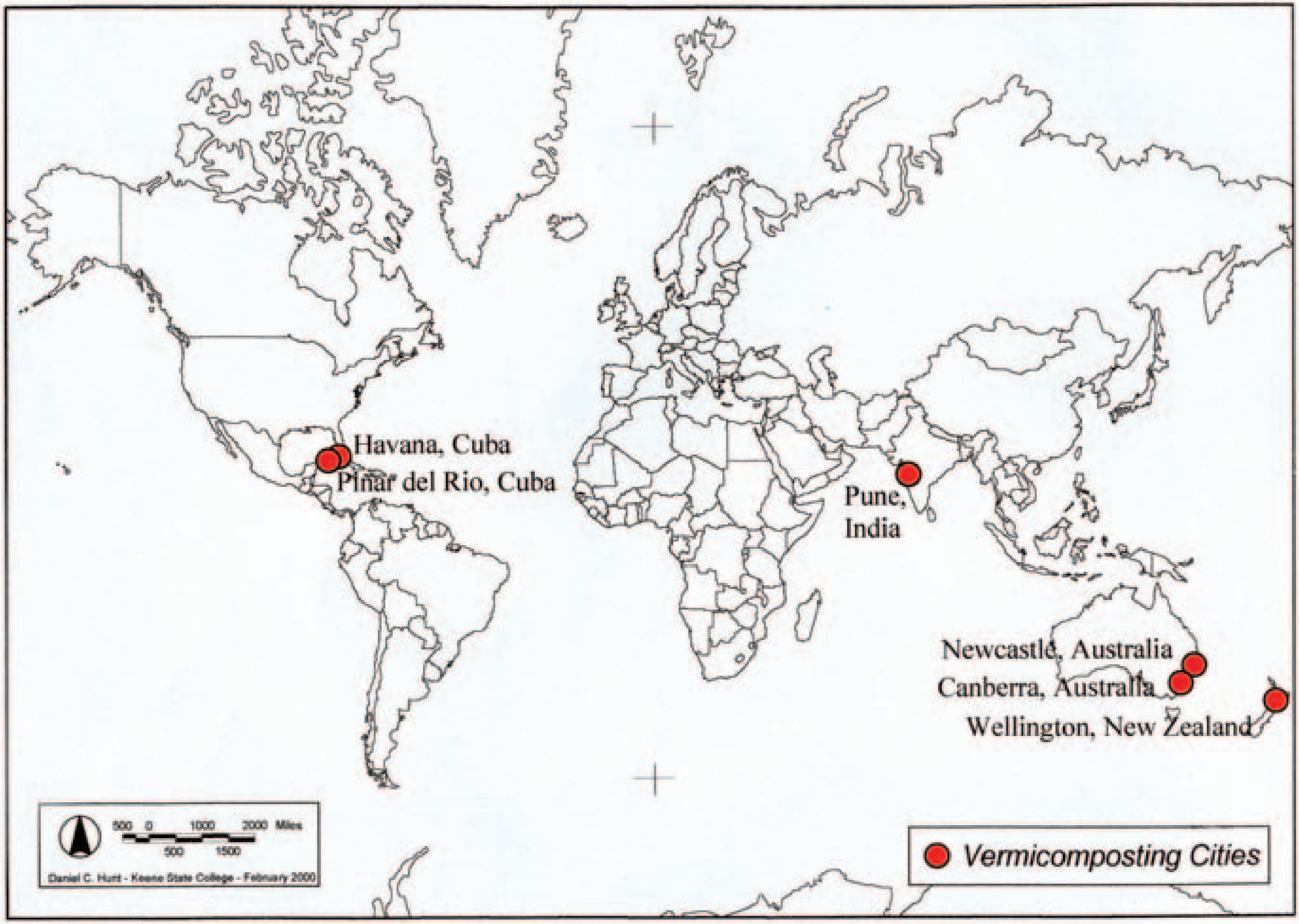
Both solid waste and sewage from a colony of 500 homes are being processed with vermiculture at the Indian Aluminum Co. One system consists of seven concrete block bins (one for each day of the week) measuring 7m by 20m or roughly 21ft by 60ft, which receive all compostable garbage. The colony's sewage is fed to a 600ft square vermifilter. The filter usually has a 30cm deep bed of vermicastings and selected earthworms and selected plants. The filter helps to purify the water.

Wellington, New Zealand:

The city has a volunteer project working to create low-cost, small-scale techniques for turning food scraps into vermicasting. Materials are hauled to two sites where several designs of outdoor worm beds are being tested.The beds have lids and are constructed flat to harvest the vermicasting, and also incorporate a leachate collection system made of plastic sheeting.

(Source: Feed it to the Worms, 2001)

VERMICOMPOSTING CITIES AROUND THE WORLD



Grades 9 – 12

Lesson 3: How Do Earthworms* Work?

STANDARDS

Science Standards (Grades 9-12), Content Standard A:
The student will develop abilities necessary to do scientific inquiry.

*** Note: Earthworms, rather than red wigglers, will be used here because they are larger and easier to dissect.**

Essential Questions:
- What can be learned by dissecting an earthworm?
- Do all worms have segments?
- How can we learn about the physiology of earthworms?
- Do earthworms have sophisticated body systems?

Outcomes:
After completing this lesson, students will learn:
- How to dissect and identify internal and external features of the earthworm.
- How to label a diagram of the internal and external anatomy of the earthworm.
- Describe the major features of the earthworm phylum.
- Name the organs that make up various systems of the earthworm.
- Understand some of the evolutionary adaptations of the earthworm.

Materials:
Colored pencils; dissecting pins; dissecting pan; gloves; forceps; scissors; water; dissecting probe; hand lens or stereoscope; scalpel; preserved earthworm (we suggest the purchase of earthworms rather than the red wigglers used in vermicomposting bins); laboratory apron; safety goggles; diagram of internal and external parts of an earthworm (pages 72 - 77)); journal.

Websites for content research and purchasing materials:
http://www.wardsci.com/
http://www.carolina.com/

Time Needed:
2 class periods

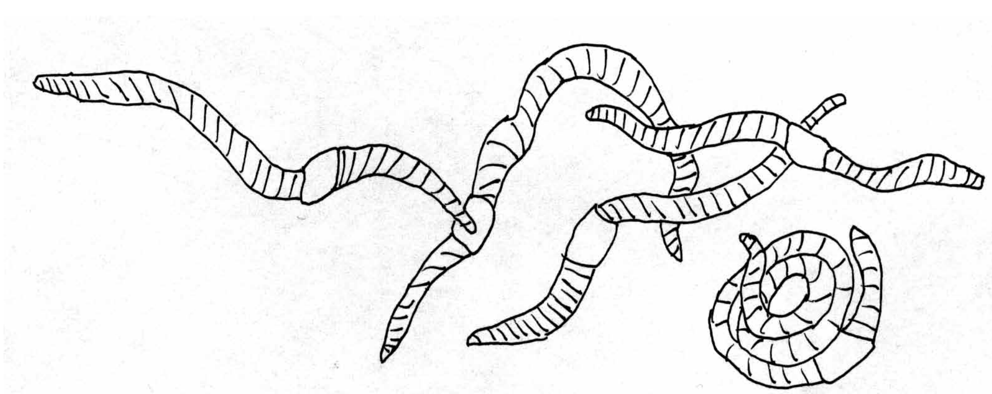
Teacher Background Section:
Lesson 3 will examine the biology and evolution of the earthworm. It is important to understand that the earthworm is a valuable adjunct in the soil's expression of fertility. The earthworm eats and digests the soil and thus conditions the soil we live on. To a great extent the earthworm has produced a major portion of our topsoil. That is probably the reason Aristotle referred to the earthworm as the "intestines of the soil." Their castings are far richer than the soil which they ingest. It is believed that the earthworm can produce its weight in castings every 24 hours. They burrow into the earth breaking up hardpans, aerating soil, and creating holes which the rain can penetrate. Their dead bodies provide a considerable amount of nitrogen-rich fertilizer, which, according to The Encyclopedia of Organic Gardening, can amount to a thou-

sand pounds per acre in highly organic soil. Noted earthworm researcher Charles Darwin found that the amount of soil passed through their bodies could be as much as 15 tons of dry earth an acre! All soil, animal, and vegetable matter taken in by an earthworm passes through its digestive system.

Earthworms are an invertebrate animal divided into five families or classes. In turn they are divided into two orders in the phylum annelida, with the entire division containing over two thousand species. Earthworms are among the most familiar invertebrate animals. They range in size from microscopic to several feet and all are headless, eyeless, and toothless. The word annelida means "ringed" and refers to the segments that make up the bodies of the members of this phylum. These segments are divided by internal walls called septa. There can be more than 100 segments in an adult worm. The external swelling of the body found in sexually active worms is called the clitellum. The earthworm is a hermaphrodite, having both male and female reproductive organs (ovaries and testes). They are capable of producing egg capsules, but must come into contact with another earthworm to produce them. Egg capsules can be produced every week to ten days under ideal conditions. The capsules are deposited on or near the surface and wormlets emerge in about 21 days as small white threads about an eighth of an inch in length. They are self-sufficient and thrive for about two years. An average mature worm can produce 150 worms each year of its life.

The heart or pumping organ of the circulatory system is made up of five aortic arches which pump circulatory fluids through the ventral and dorsal blood vessels. The earthworm uses its mouth, the beginning of its digestive tract, to take in a mixture of soil and organic material. This food enters the pharynx (located in segments 1-6). The esophagus (segments 6-13) connects between the pharynx and the crop, which temporarily stores the food. Next, the gizzard grinds up the food before it enters the intestine, which makes up over two-thirds of the body length and serves to digest and absorb the food. Any undigested organic matter passes out of the anus. The nervous system is made up of the ventral nerve cord, which is found along the entire ventral side and ganglia, which are groups of tissue containing nerve cells. Each segment has a ganglion within it which responds to external stimuli for movement and response to the environment. Each body segment also has nephrida, which make up the excretory system and allow waste to pass out of the body. The earthworm exchanges gasses between the circulatory system and the environment through its moist skin.

The earthworm can be found everywhere on Earth except the extreme northern and southern latitudes. The tropical and temperate zones have up to two thousand species thriving. The largest specimens are found in the equatorial humid jungles.



LESSON PROCEDURES AND ACTIVITIES

Teacher can get as detailed as needed.
Not all systems of the earthworm need to be dissected.

1. Put on the safety goggles, gloves and laboratory apron. Rinse the earthworm well with water and then place it in a dissecting pan.

2. Examine the ring-like segments that make up the length of the earthworm's body. Draw a diagram in your journal of what you observe.

3. Identify the anterior (head) and posterior ends. At the anterior end is a small lobe (prostomium) on the ventral (lower) surface that is used for burrowing. Just behind the lobe is the mouth, which opens into a long, tubelike digestive system that ends at the anus.

4. Rub the ventral surface of the earthworm in both directions with your finger. The bristles you feel are called setae. The setae are used in movement and to anchor the worm into the ground. Use your hand lens to count the setae and include an entry about them in your journal.

5. Locate the clitellum, which extends from segment 33 to segment 37. This structure is important in reproduction. Using a diagram supplied by your teacher, locate and identify the external parts of the reproductive system. Find the pair of sperm grooves that extend from the clitellum to about segment 15, where one pair of male genital pores is located. Look also for one pair of female genital pores on segment 14.

6. Make a diagram of the ventral side of the earthworm in your journal. Label a segment, the mouth, setae, clitellum, and genital pores.

7. Stretch out the earthworm in the dissecting pan so that the dorsal surface faces up. Place a pin through each end of the worm to hold it in place.

8. Make a shallow cut (incision) lengthwise with your forceps and scissor along the dorsal surface of the clitellum at segment 33. An earthworm's skin is very thin. Make a very shallow cut. Continue the incision forward to segment 1. Using the forceps and scissor or scalpel, spread the incision open, little by little. Separate each septum from the central tube using a dissecting needle, and pin down the loosened skin.

9. Use the diagram (page 76) to locate and identify the five pairs of aortic arches, or hearts. Look for smaller blood vessels that branch from the dorsal blood vessel.

10. Make a drawing of the aortic arches and dorsal blood vessel in your journal.

11. Locate the digestive system, which lies below the dorsal blood vessel. Refer to the diagram (page 77) to locate the pharynx, esophagus, crop, gizzard, and intestine.

12. To find organs of the nervous system, carefully push aside the digestive and circulatory organs. Locate the ventral nerve cord that runs along the ventral surface of the earthworm and trace the nerve cord forward to the nerve collar, which circles the pharynx. Find one pair of ganglia under the pharynx and another pair of ganglia above the pharynx. A small white ganglia, above (dorsal) to the pharynx in the area of the third segment, serves as the brain of the earthworm.

13. The worm's excretory organs are tiny nephrida. There are two in every segment.

14. Use the diagram(page 75) supplied by the teacher to locate and identify a pair of ovaries in segment 15. Look for two pairs of tiny testes in segments 10 and 11. To find these organs, you will have to carefully push aside parts of the worm you have already dissected.

15. In your journal, draw the internal anatomy of the earthworm from what you have seen. Draw and label the digestive system yellow, the circulatory system red, the nervous system blue, and the reproductive system green.

16. Dispose of your earthworm and clean up according to your teacher's instructions.

Extension Activity:

1. Have students complete the following "Earthworm Worksheet".

EARTHWORM WORKSHEET

Directions: From your dissection activity, complete the questions below:

1. What is the name of the pumping organs of an earthworm?

2. Trace the parts of the digestive tract through which food passes.

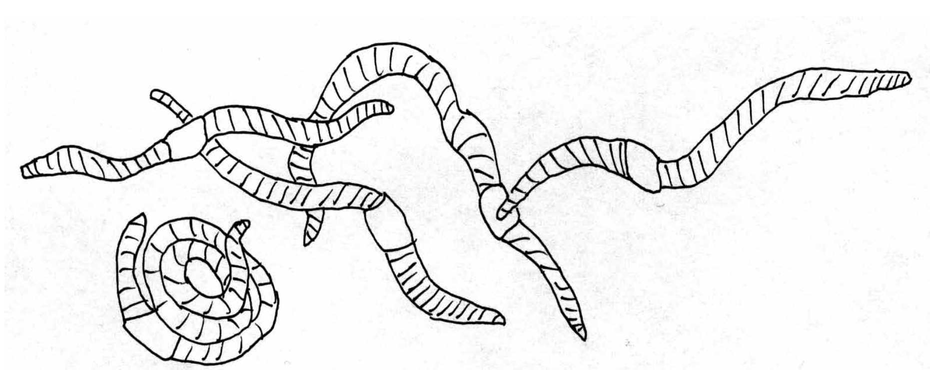
3. Which parts of the earthworm serve as its brain? How are these parts connected to the body?

4. How can you find out whether an earthworm eats soil?

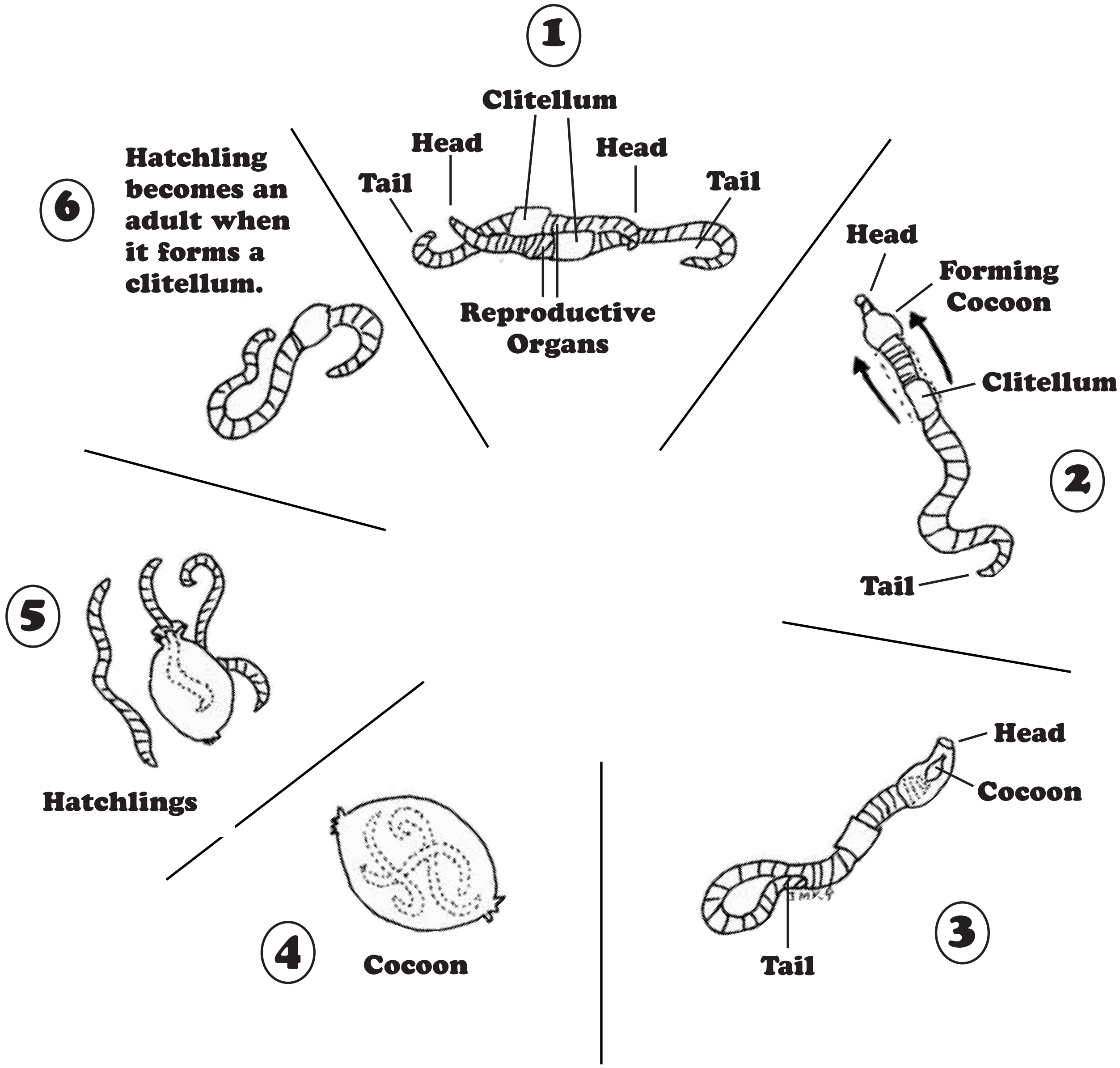
5. Among the earthworm's structural adaptations are its setae. How do you think the earthworm's setae make it well adapted to its habitat?

6. How is the earthworm's digestive system adapted for extracting relatively small amounts of food from large amounts of ingested soil?

7. Your dissection of the earthworm did not go beyond segment 32. What will you observe if you dissected the remainder of the worm to its posterior end?

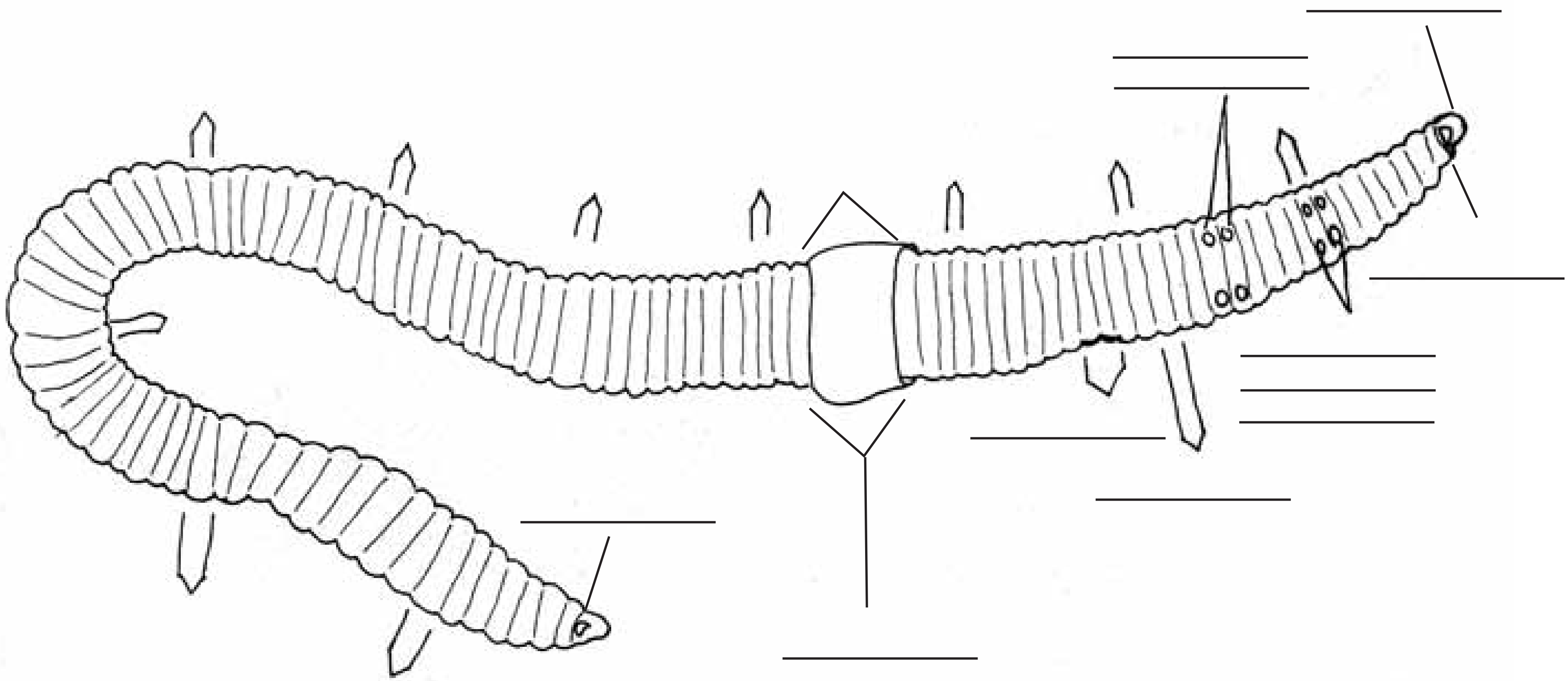


STAGES OF THE LIFECYCLE OF THE REDWORM



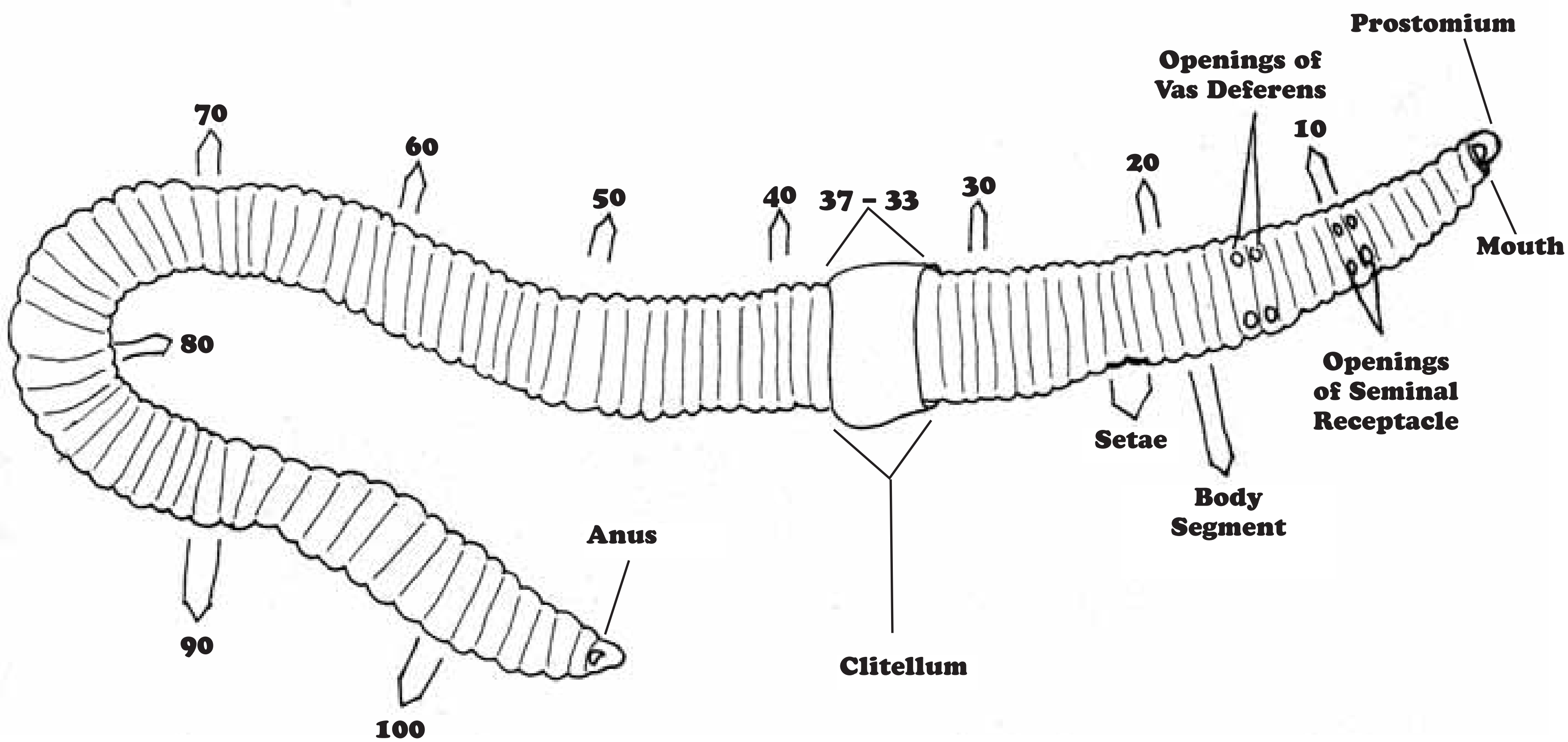
THE EXTERNAL ANATOMY OF THE EARTHWORM:

Can you identify the body parts?

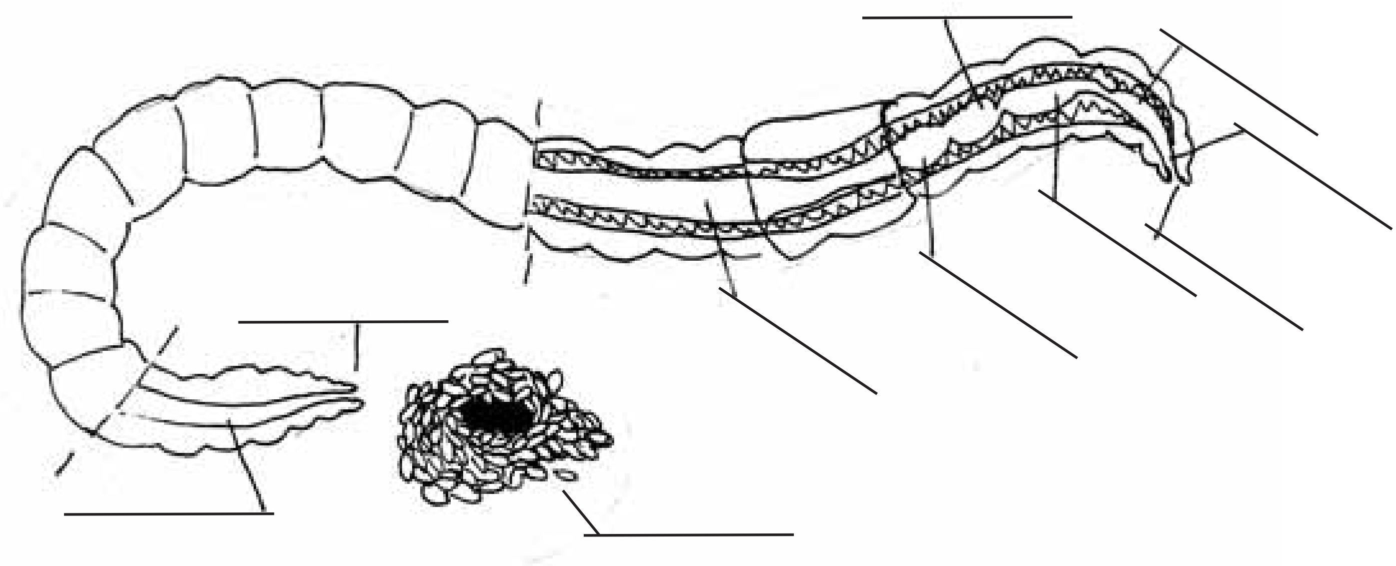


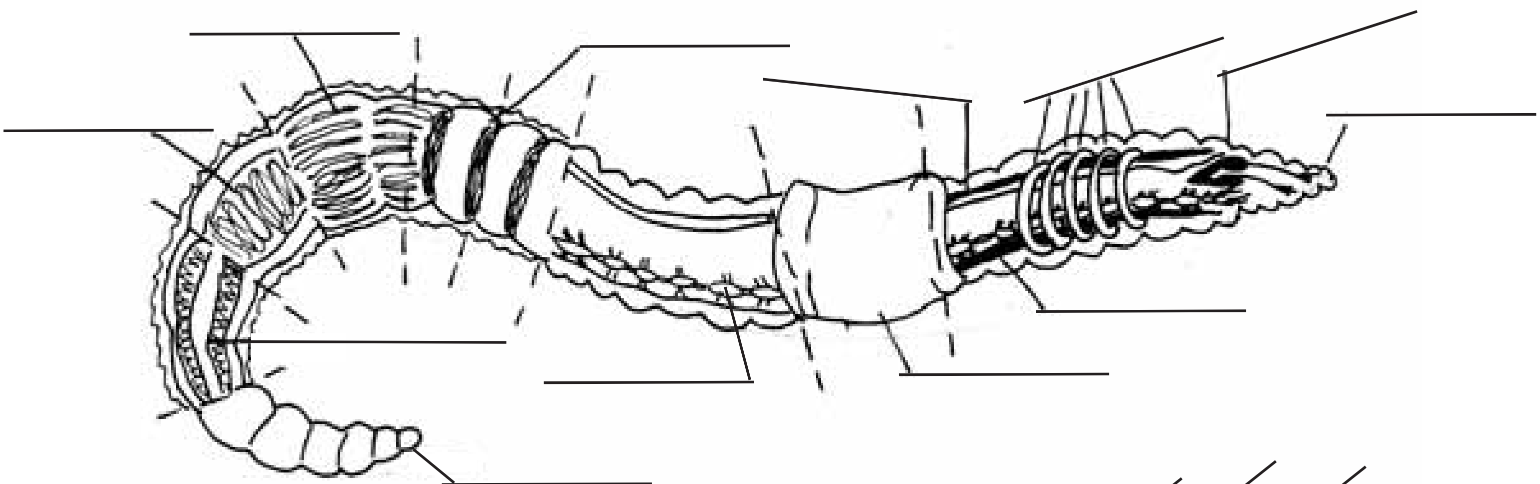
THE EXTERNAL ANATOMY OF THE EARTHWORM

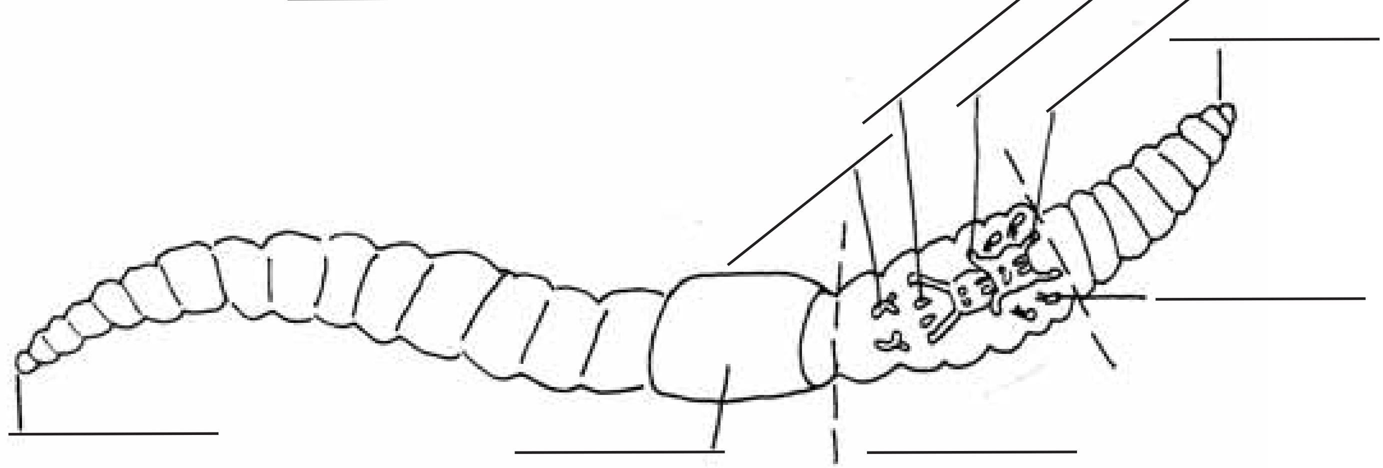
Adult Earthworms have over 100 segments!



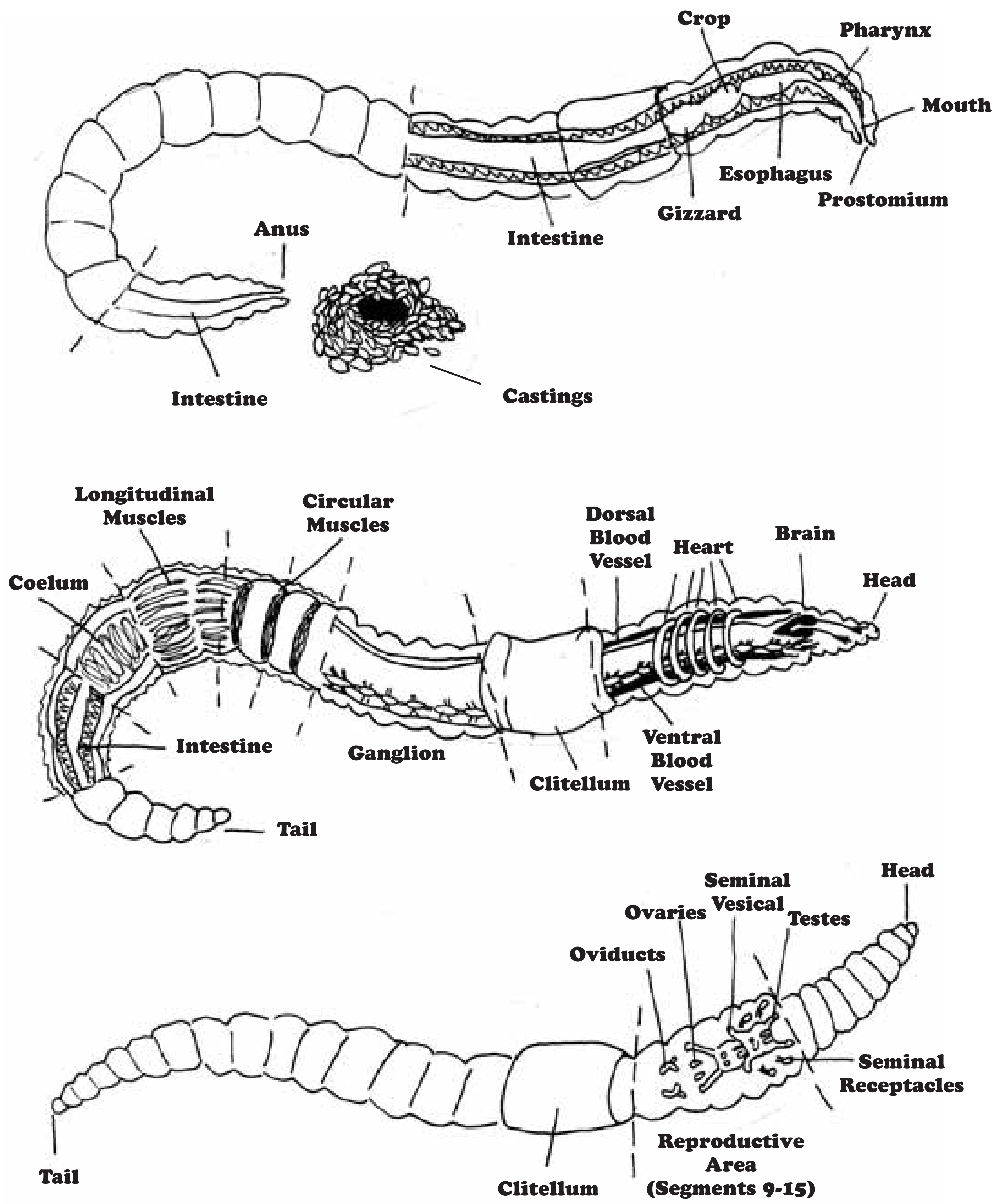
THE INTERNAL ANATOMY OF THE EARTHWORM:
Label the Parts



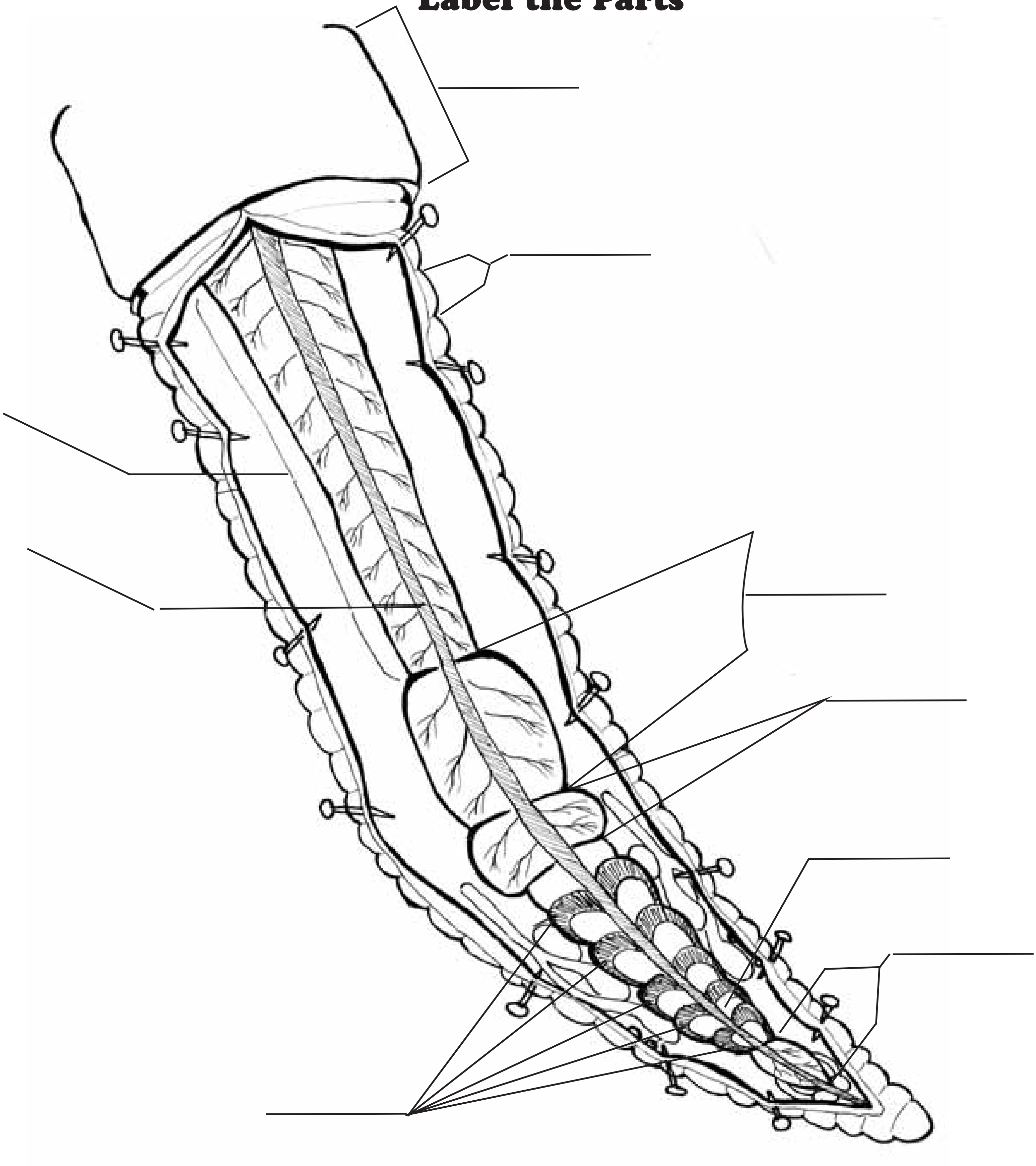




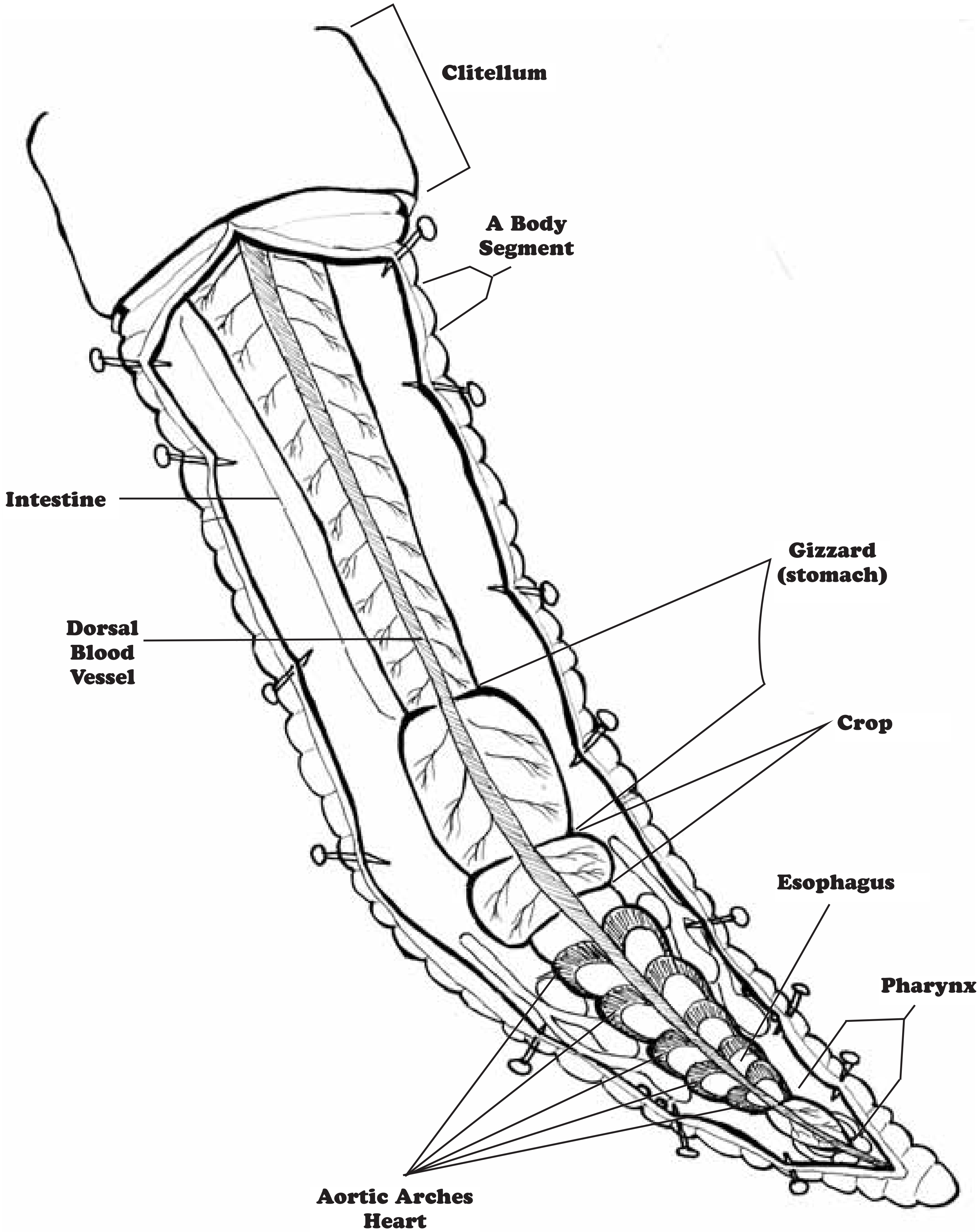
INTERNAL ANATOMY OF THE EARTHWORM



INTERNAL EARTHWORM ANATOMY – DETAILED VIEW:
Label the Parts



INTERNAL EARTHWORM ANATOMY – DETAILED VIEW



Grades 9 – 12
Lesson 4: What is the Composition of Composted Soil?

STANDARDS

Geography Content Standard 8:
A geographically informed person should know and understand the characteristics and spatial distribution of ecosystems on Earth's surface.

Geography Content Standard 16:
A geographically informed person should know and understand the changes that occur in meaning, use, distribution, and importance of resources.

Science Standard (Grades 9-12), Content Standard A:
The student will develop abilities necessary to do scientific inquiry.

Content Standard F:
The student should develop an understanding of natural resources.

Essential Questions:
- What are some of the important elements in soils?
- How are the composted soils different than soil in our backyards?
- Why is soil chemistry important and how is it measured?
- How can the scientific method help us to better understand soils?

Outcomes:
After completing this lesson, students will learn:
- About the important elements in our soils and why they are important.
- How composted soils are enriched with those elements.
- How to properly conduct soil tests and follow a testing protocol.
- How to develop a hypothesis and conduct a scientific experiment.

Materials:
LaMotte Soil Test Kit that includes tests for nitrates and nitrites, phosphorous, potassium, and pH (these test kits are fairly inexpensive so you might order enough kits for each student to do each test on the soil from their compost bin); safety goggles; plastic pipettes; assorted beakers and flasks; journal; graph paper.

Websites for purchasing materials and research:
http://www.carolina.com
http://www.wardsci.com
http://www.seedsofchange.com
http://www.nrcs.usda.gov/

Time Needed:
1-2 class periods the first time (once the students know the procedures, these tests will take 15 to 20 minutes).

Teacher Background Section:
Lesson 4 is designed to study the composition of composting soils. Compost is defined as a rich soil mixture that is produced when organic matter breaks down. It is more than fertilizer or a heal-

ing agent for the soil. It is a symbol of the continuing cycle of life. The addition of the redworm (Eisenia fetida) to an artificial compost bin gives this life-continuing process many advantages over outdoor composting. Chief amongst these advantages is that worm castings or manure are superior to animal manure and it can be produced in only 60 days. A combination of the worms, bacteria, and fungi produces the best kind of compost. This is ideal for the small gardener in your community.

The compost bin used in our project calls for the use of newspaper and food composed of organic products often put into our trash. However, a bin can also include grass clippings, leaves, and weeds.

Activities in this lesson will have students working with scientific methods to determine soil pH, nitrogen and phosphorus, and potassium content, as well as the effects when compost is used in plant development.

LESSON PROCEDURES AND ACTIVITIES

1. Have students do independent research on nitrogen, potassium, phosphorous and pH and how they affect soils and the plant life that grows from the soil. (Their research should be included in their journal.)

2. Organize the students together in groups (one group of students for each of the nutrients and pH assigned) and have them develop learning posters from their research. Students can report their findings to the class so that everyone understands how each of these minerals or the acid / base levels of the soil affect plant life and growth. This is an excellent way for the student to be the worker and the teacher to be the coach.

3. Once the students understand the importance of these minerals in the soil, open the soil test kits and (teacher) make copies of the protocols for each of the tests.

4. Introduce the test kit components (page 80) to the students and pass out copies of the protocols for all tests to each group of students.

5. Review the instructions carefully so that each student understands each test. Students can either work individually or in the previously set up groups.

6. Have the students use the soil from their composting bins as they develop their skills in administering these tests. Some of the tests take longer than others and you should initially allow 1-2 class periods for accurate test results and data collection. (These tests should run every two weeks as the soil in the composting bins "develops.")

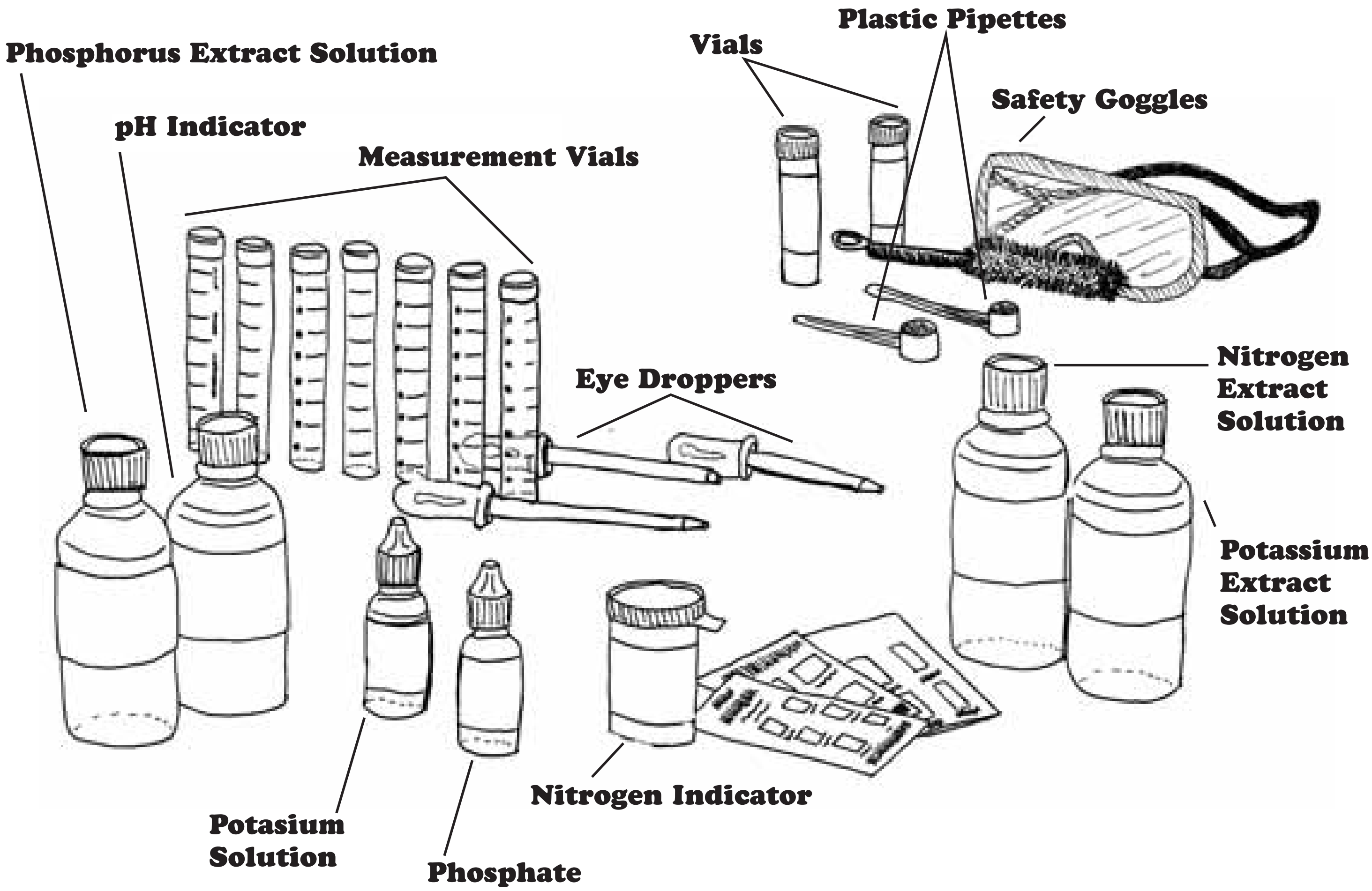
7. As students begin noting the results of their tests, create a chart on the board so all students can see the results and record the data in their journal.

8. If all results are not the same for an individual test (potassium as an example) this is an excellent time to talk about methodology and why the results are not the same. From where are the inaccuracies coming? Where might sources of error have occurred? This is also a teachable moment on the scientific method and writing up a scientific lab report.

9. Have students graph the results of their tests as they develop their skills. This will take a relatively short period of time as students tend to get better at deciphering the results as they get used to the simple protocols.

9\. Have students relate soil factors to regional soil patterns (see Lesson 2, Grades 7-8, Section 1) and regional vermicomposting programs (Lesson 2, Grades 9-12).

SAMPLE SOIL TEST KIT MATERIALS



Extension Activity:

1. Have students run the same tests with soils they bring in from around the school or from home. Have them also graph the results and compare with the results of the composted soils.

2. Using these results, have students develop a hypothesis as to why they differ. From their hypothesis, have them set up an experiment based upon their hypothesis.

3. Use these two different soil types to begin raising various types of plants. Students should record in their journal plant height, rate of growth, color, vigor, number of leaves, etc., as well as how the plants appear to grow. Students should then begin developing experiments based on their hypothesis.

4. This can be a wonderful, hands-on project that both teacher and student can use in a variety of ways. This can be a short lesson on the important minerals of soils and how they are affected by vermiculture or a year-long project that could lead to an excellent science fair project. This can also be extended as an extra credit project that takes place after school.

5. Tie this lesson to Lesson 2, Grades 7-8, in Section 1 of this curriculum.

Grades 9 – 12

Lesson 5: Worms Invade Your Community!

STANDARDS

Geography Content Standard 18:
The student will know and understand how to apply geography to interpret the present and plan for the future.

Essential Questions:
- How can vermicomposting benefit your community?
- What programs can benefit organic waste disposal in your community?

Outcomes:
After completing this lesson, students will:
- Gather and organize research on recycling, vermicomposting, and economic benefits associated with these activities.
- Prepare and make a presentation to a local civic body in support of a community recycling vermicomposting program.

Materials:
A letter of support from a recognized environmentally respected organization; lab journal and notes from Lessons 1-4. Other research may also be necessary using the internet or interviewing local activists or community leaders.

Time Needed:
This will vary from community to community. The teacher should set a time limit on the research and presentation preparation segments for this lesson.

Teacher Background Section:

The final exhibition for the vermicomposting unit will have students apply previous learning from Lessons 1 - 4 by starting a community-based vermicomposting program. The teacher will prepare students to make a presentation to community leaders such as town, city, or county officials. Differences in each community will determine the direction of each presentation. First, a letter of support from an appropriate organization such as the Environmental Protection Agency or local Conservation Commission should be obtained. The teacher should begin the process by contacting an organization and outlining the idea behind the class project. This letter or letters can be used in the initial contact with the town body (page 83).

Second, divide the students into groups. Topics for research and review on vermicomposting can be assigned using student interests (see lessons 1-4).

Third, students should use their research and prior knowledge to prepare a presentation for a community vermicomposting program to a town or city governing body. This could be extended to include presentations to civic groups that could provide financial and moral support for the program.

LESSON PROCEDURES AND ACTIVITIES

1. Contact your town, city or county governing body and present your class project with the letter of support. Request their permission for you to use their letterhead and develop a letter asking your class for help. This will represent a legitimate problem that your class is being asked to help with and makes the entire project a real world situation for the students to solve. Present your class with the letter (that you have written) from the civic body you have contacted. Arrange a date for a presentation of your class's vermicomposting proposal to the civic body.

2. Organize students into groups and assign the following topics:
- How can a vermicomposting bin be set up at home? A presentation of several models with materials and costs should be included.
- Where and how is vermicomposting used worldwide?
- What is the best type of worm for a home/community project? What is the potential for raising community revenue?
- How can recycling of organic waste benefit the community? If recycling is in use, how can the community benefit from vermicomposting?
- Where in the community can vermicomposting be implemented? (Is there a transfer station, town dump, etc.?)
- How can composting benefit the soils in the community?
- What would it cost our community to implement a vermicomposting program? Who would manage it?
- How can vermicomposting help homeowners with floral and vegetable gardens? Would our community save money by implementing such a program?

3. Groups should use their notes and lab journals from Lessons 1-4 to support and organize research around their assigned topics. Students should make appointments to meet with community leaders (Town Managers, Selectmen, etc.) to determine the costs associated with rubbish/trash removal in their community.

4. Groups now develop a PowerPoint presentation utilizing all the information they researched for this project. Each PowerPoint is then offered to the class for assessment, constructive criticism, editing, and refinement.

5. The final proposals are then presented to their town, city, or county body.

Extension Activity:

1. Students could organize a volunteer community vermicomposting program at their town or city recycling center. The sale of worms for home vermicomposting projects, fish bait, or the sale of compost could be used to help defray the cost of the recycling center.

2. Students could organize a program to sell worms to local farmers for animal feed. Money from sales could be used to finance various community programs. (With a little research, students will find that farmers feed cattle worms from such programs in various parts of the world.)

3. Students could use compost created in the community vermicomposting program to help with community gardens in town or city parks and/or roadside plantings. Appropriate signs could be posted to enhance community awareness of the student project.

SAMPLE LETTER OF SUPPORT

Chairman I.M. Pure
Board of Selectmen
Anytown, USA 00001

January 1, 2006

Mr. C. Crawler
John F.Kennedy High School
Anywhere, USA 00001

Re: Community Vermicomposting Project

Dear Mr. Crawler:

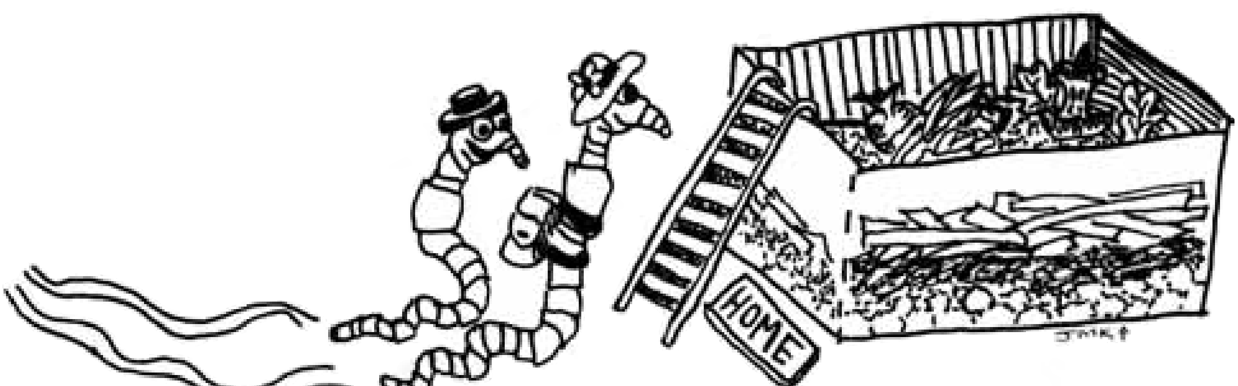
The Selectmen of Anytown, USA, enthusiastically supports the integrated Vermicomposting Project proposed by your biology and geography classes at John F. Kennedy High School. Your effort to improve the use of organic waste management in our community is considered a sound, environmentally friendly program. We applaud your efforts and wish your class project success. Please keep us informed as to your project's progress.

As you near the end of the project please get in touch with my office since I know our Board of Selectmen would enjoy seeing the final exhibition of your class findings.

We wish you luck in your meaningful endeavor.

Sincerely yours,

I.M. Pure, Chairperson, Board of Selectmen


HOME

ORDERING YOUR WORMS

You'll need one pound of worms for a 19" x 16" x 12" worm bin.

Flowerfield Enterprise
10332 Shaver Road
Kalamazoo, MI 49002
(616) 327-0108 Sells worms, worm bins, and worm bin guides.

Gardener's Supply Company
128 Intervale Road
Burlington, VT 05401
(802) 863-1700 Sells worms, worm bins and worm bin guides.

Real Goods
966 Mazzoni Street
Ukiah, CA 95482-3471
1-800-762-7325
Sells worms, worm bins and worm bin guides.

Seventh Generation
49 Hercules Drive
Colchester, VT 05446-1672
1-800-456-1177
Sells worms, worm bins and worm bin guides.

Smith and Hawken
2 Arbor Lane, Box 6900
Florence, KY 41022
1-800-776-3336 Sells worm bins and related supplies, including worm bin guides. No worms for sale. Offers classes on worm bin composting.

POTENTIAL PROBLEMS & CURES

Fruit Flies

Though fruit flies do not pose any health hazards, these little creatures can be a nuisance in the classroom. To help prevent these potentially prolific pests, do the following:

1. Avoid putting rotting or rotten food in your worm bin. Fly larvae are more likely to be present on rotten food.

2. Cut food scraps into small pieces. Worms will be able to eat smaller pieces more quickly, thereby limiting the possibility of fruit flies thriving on decomposing food.

3. Don't overfeed worms. Ripe food that sits around in the bin attracts (and may contain) flies.

4. Bury food. Burying the food will help keep unwanted pests and pets from intruding on your bin.

5. Keep bedding material moist, but not too wet. Overly wet conditions encourage the proliferation of fruit flies. Wet conditions might also cause an odor problem, as anaerobic bacteria thrive when it is too wet.

6. Feed worms a varied diet. If citrus foods dominate the bin, the bin may become too acidic, which may attract fruit flies.

7. Loosely place a piece of plastic or a sheet of newspaper inside the bin on top of the worm bin contents. This plastic or newspaper cover will create another barrier to help prevent flies from getting in (or out) of the bin.

8. Limit citrus fruits.

To help control an existing fruit fly problem, try the following:

1. Remove rotten food from the bin when fruit flies are present. Fruit flies often lay their eggs on decomposing food.

2. Tape or staple flypaper strips on the inside of the bin lid, and/or hang a strip near the bin. Flypaper strips can be purchased inexpensively at most hardware stores.

3. Create a fly trap to put in the bin. A bowl of apple cider vinegar with a drop of dish detergent, placed near the bin, will attract and kill flies. Change liquid regularly to keep fly trap potent.

4. Place a whole sheet of newspaper on top of bin contents. Change this sheet regularly as flies tend to congregate on the newspaper.

5. Sprinkle lime in the bin to neutralize excessively acidic conditions.

6. For temporary relief, take bin outside and leave uncovered for up to four hours to air out the bin (out of direct sunlight).

If the problem cannot be controlled, have your class analyze the problem, and speculate about what is causing it. The best solution may be to harvest the worms and start a new bin from scratch, using what you have learned from your past experience to create a better bin.

Odors

If your worm bin has an unpleasant odor, one of the following may be the culprit:

1. Bin is too wet. Solve the problem by not adding any water or foods with a high percentage of water (e.g., melons) and by adding more dry bedding.

2. Bin does not get enough air. Anaerobic bacteria (bacteria which thrive without air) is smelly. To aerate, add fresh bedding and mix bin contents daily.

3. The food in bin is naturally smelly. For instance, we have found that onions and broccoli do not smell very pleasant when they decompose in the worm bin. Simply remove any food source that smells bad from the bin.

4. Bin contains non-compostables. Meat, bones, dairy and oily products should not be fed to the worms because these items become rancid when decomposing.

Dying Worms

If you notice the worm population dwindling, or worms crawling all over the bin trying to escape, check for the following:

1. Bin is too wet and worms are drowning.

2. Bin is too dry and worms dry out.

3. Bin does not get enough air and worms suffocate.

4. Worms do not get enough food. Once the worms devour all of their food and newspaper bedding, they will start to eat their own castings which are poisonous to them. TIME TO HARVEST.

5. The bin is exposed to extreme temperatures. The worms thrive in temperatures from 55° to 77°F.

NOTE: Dead worms decompose rather quickly. If you do not monitor the above conditions you can have a box of dead worms before you even realize it.

BINS & BEDDING

Once you have worms and a bin, follow these six easy steps to set up a worm bin. Soon worms will be recycling food scraps into a healthy, nutrient-rich soil amendment called compost.

1. Acquire a bin.

Reuse an old dresser drawer or fish tank, build a box out of wood or find/buy a plastic bin. The approximate size is 16" x 24" x 8" or 10 gallons. Make sure the bin is clean by rinsing it with tap water to remove any residues which may be harmful to the worms. For wooden bins, line the bottom and sides with plastic (an old shower curtain or plastic garbage bag works well).

2. Prepare the bedding.

Instead of soil, composting redworms live in moist newspaper bedding. Like soil, newspaper strips provide air, water, and food for the worms.
a. Using about 50 pages, tear newspaper into 1/2" to 1" strips. Avoid using colored print, which may be toxic to the worms.
b. Place newspaper strips into a large plastic garbage bag or container. Add water until bedding feels like a damp sponge, moist but not dripping. Add dry strips if it gets too wet.
c. Add the strips to the bin, making sure bedding is fluffy (not packed down) to provide air for the worms. Bin should be 3/4 full of wet newspaper strips.
d. Sprinkle 2-4 cups of soil in bin, which introduces beneficial microorganisms. Gritty soil particles also aids the worms' digestive process. Potting soil, or soil from outdoors, is fine.

3. Add the worms.

Before adding the worms, find out how many worms you are starting with. The easiest method is to weigh the worms. If you do not have access to a scale, determine the worms' volume. The amount of worms is important for knowing how much food to feed them and for record keeping.

4. Bury food scraps under bedding.

Feed the worms fruit and vegetable scraps that would normally be thrown away, such as peels, rinds, cores, etc. Limit the amount of citrus fruits that you place in the bin. NO MEATS, BONES, OILS, OR DAIRY PRODUCTS.
a. Cut or break food scraps into small pieces--the smaller, the better.
b. Measure the amount of food. Feed worms approximately 3 times their weight per week. Monitor the bin every week to see if the worms are or are not eating the food. Adjust feeding levels accordingly. (If you start with one pound of worms, add 3 pounds of food per week.)
c. Bury food scraps in the bin. Lift up bedding, add food scraps, then cover food with bedding.

5. Place a full sheet of dry newspaper on top of the bedding.

This will help maintain the moisture balance, keep any possible odors in the bin, and help prevent fruit flies from making a home in the bin. Replace this sheet frequently if fruit flies are present, or if bin gets too wet.

6. Cover and choose a spot for the bin.
Cover the bin with a lid made of plastic, plywood or cloth, but leave the lid ajar so the bin receives some air. If desired, you may drill holes into the bin. Place the bin away from windows and heaters.

FEED, WATER and FLUFF!!! To keep worms happy, feed them about once a week. If bedding dries up, spray with water. (If bedding gets too wet, add dry newspaper strips.) Fluff up bedding once a week so the worms get enough air.

HOW TO BUILD A WOODEN BIN

Contact the Cornell Cooperative Extension for a complete diagram
http://www.cfe.cornell.edu/compost

Materials:
1 - 4 foot x 8 foot x 1/2" sheet exterior plywood
1 - 14 foot construction grade 2" x 4"
1 - 16 foot construction grade 2" x 4"
1 - lb 4d galvanized nails
1/4 lb. 16d galvanized nails
2 - 3" door hinges

Tools:
Tape measure; skill saw or rip hand saw; hammer; saw horses; long straight edge or chalk snap line; screwdriver; chise; wood glue; drill with 1/2" bit. Use eye and ear protection.

Construction Details:
Measure and cut plywood as follows.

To make base, cut the 14 foot 2" x 4" into five pieces: two 48" and three 20" long. The remaining 12" piece will be used in making the sides as described below. Nail the 2" x 4"s together on edge with two 16d nails at each joint. Nail the plywood piece onto the 2"x 4" frame using the 4d nails.

To build the box, cut three 12" pieces from the 16 foot 2" x 4". Place a 12" 2" x 4" under the end of each side panel so that the 2" x 4" is flush with the top and side edges of the plywood, and nail the boards into place. Nail the side pieces onto the base frame.

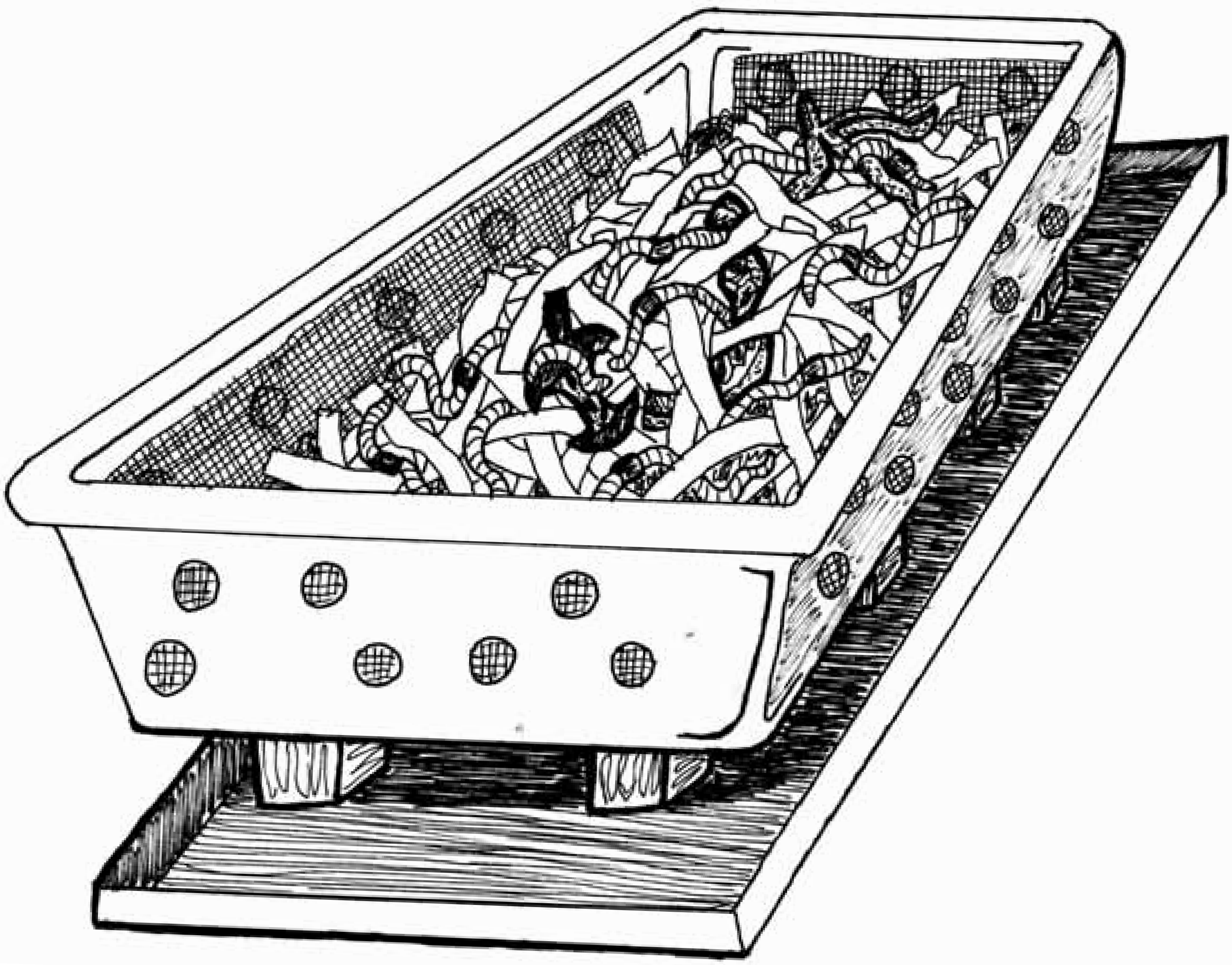
To complete the box, nail the ends onto the base and sides.

To reinforce the box, place a nail at least every 3 inches wherever plywood and 2" x 4"s meet. Drill twelve 1/2" holes through the bottom of the box for drainage.

To build the lid, cut the remainder of the 16 foot 2" x 4" into two 51" lengths and two 27" pieces. Cut lap joints in the corners, then glue and nail the frame together. Center the plywood onto the 2" x 4" frame and nail with 4d nails. Lay top on ground with plywood surface touching the ground. Attach hinges to the top and back. Position hinges so the screws go through plywood and 2" x 4"s.

FOODS FOR WORMS

Apples	Coffee Grounds	Molasses	Pizza Crust
Beans	Corn	Oatmeal	Potatoes
Bread	Cream of Wheat	Onion	Rice
Cabbage	Cucumber	Orange	Tea Leaves
Carrot	Egg Shells	Pancakes	Tomatoes
Cauliflower	Grapefruit	Pasta	Turnip
Celery	Grits	Peas	Waffles
Cereal	Lettuce	Pineapple	Watermelon



GLOSSARY

actinomycetes
Microorganisms that have the characteristics of both fungi and bacteria. They create cobweb-like growths throughout the compost and give compost an earthy aroma.

aortic arches
The five “hearts” of the earthworm circulatory system.

aerobic
Pertaining to presence of free oxygen. Organisms that utilize oxygen to carry out life functions.

aeolian
Deposited or eroded by wind.

aeolian erosion
The process of wind removing and helping to move rock material.

A-horizon
Upper soil layer in which humus and other organic materials are mixed with mineral particles.

alluvium
Any stream-deposited sedimentary material.

anaerobic
Pertaining to the presence of free oxygen. Organisms that can grow without oxygen.

anterior
Toward the front.

anus
The posterior opening of the alimentary canal.

arthropods
Animals with segmented bodies, exoskeletons, and jointed appendages.

bacteria
A one-celled organism that comes in many shapes that can only be seen with a microscope. They can cause decay and disease but most are beneficial because they help recycle nutrients.

barrier
A geographic zone such as an ocean, desert, or glacier which would prevent the migration of animals or worms.

bedding
Moisture-retaining medium which provides a suitable environment for worms.

B-horizon
Mineral soil layer below the A-horizon.

biodegradable
Capable of being broken down into simple parts by living organisms.

biome
A large recognizable assemblage of plants and animals in functioning interaction with its environment.

biosolid
The solid residue from a wastewater treatment system.

calcification
Soil- forming process of subhumid and semi-arid climates. The soil is in the mollisol order and is characterized by little leaching or eluviation. Humus accumulates along with minerals, especially calcium carbonates.

carbon
An element that is abundant in wood chips, sawdust, straw, and leaves. Carbon provides energy for living things.

castings
Worm manure.

chemical weathering
The decomposition of rock by an alteration of rock-forming minerals.

C-horizon
Lower soil layer composed of weathered parent material that has not been significantly affected by translocation or leaching.

climate
The average weather conditions of a place over a period of years.

clitellum
A swollen region containing gland cells which secrete the cocoon material. This is sometimes present on sexually mature worms and called bands or girdles.

cocoon
Structure formed by the clitellum which protects the embryonic worms until they hatch.

compost
A rich soil-like mixture that is produced when organic matter breaks down.

continental drift
The hypothesis that an original single landmass (Pangaea) broke and that the continents have moved very slowly over the asthenosphere to their present locations.

continental glacier
Vast blankets of ice that covered large parts of the earth during times of extreme cold. They completely inundate the underlying terrain to depths of hundreds or thousands of feet.

continental ice sheet
Mass of glacial ice thousands of feet thick that is of continental proportions and covers all but the highest points of land. The sheet usually flows from one or more areas of accumulation outward in all directions.

crop
In earthworms, part of the digestive system in which food can be stored.

crust
The outermost solid layer of the earth.

decompose
To decay or rot; To break down into simpler substances.

decomposer
An organism that breaks down cells of dead plants and animals into simpler substances.

decomposition
The process of breaking down complex materials into simpler substances.

diastrophism
The deformation of the earth's crust. Folding and faulting are examples.

digestive tract
The long tube where food is broken down into forms which animals can use. It begins at the mouth and ends with the anus.

dorsal
The top surface of an earthworm.

drumlin
Streamlined, elongated hill composed of glacial drift.

ecosystem
Collection of all the organisms that live in a particular place, together with their nonliving environment.

Eisenia Fetida
Scientific name for one of several redworm species used for vermicomposting. Color varies from purple, red, dark red to brownish red, often with alternating bands in between segments. Found in manure, compost heaps, and decaying vegetation where moisture levels are high.

enchytraeids
Small, white, segmented worms common in vermicomposting systems. They are also called pot worms and as decomposers, they do not harm earthworms.

environment
Surroundings, habitat.

erosion
Detachment and removal of rock material.

esker
A narrow winding ridge composed of glacial gravels formed by meltwater.

esophagus
Part of the food tube in earthworms that connects between the pharynx and the crop.

excrete
To secrete and discharge waste.

faulting
The movement of adjacent crustal blocks along joints, or fracture planes, in bedrock.

female genital pores
The female sexual organs of the earthworm.

fluvial erosion
The action of water removing and helping to move rock material.

folding
The movement of the earth's crust created by internal pressures.

ganglia (singular: ganglion)
Groups of nerve cells.

genital pores
Sexual organs.

geomorphic processes
Various movements that have taken place within the earth's crust creating landforms.

geomorphology
The scientific study of landform origins, characteristics, and evolutions and their processes.

glacial drift
Sediment transported by glaciers and deposited in water bodies.

glacial lake
A large water remnant of a receding glacier.

glacial till
The deposits of rocks, silt, and sand after glacier has receded.

glaciation
To cover with a glacier.

gland
A specialized type of tissue which produces secretion. In worm's skin, it is mucus.

gizzard
Structure in the anterior portion of the digestive tract whose muscular contractions help grind food in the presence of grit.

gradational processes
Processes that derive their energy indirectly from the sun and directly from earth gravitation and serve to wear down, fill in, and level off the earth's surface.

harvest
To gather-in or process.

hatchlings
Worms as they emerge from a cocoon.

heart
Muscular thickening of blood vessels whose valves control the direction of blood flow. Earthworms have several, commonly five pairs, of these vessels which connect the dorsal to the ventral blood vessels.

hermaphrodite
An animal or plant with both male and female reproductive organs.

humus
A dark, stable organic material found on top or in soil.

immigrate
To move into a region.

inorganic
Being or composed of matter other than plant or animal; like a mineral.

intestine
The tubular part of the alimentary canal that extends from the stomach to the anus.

kettle hole
Water-filled pit formed by the melting of a remnant ice block left buried in drift after the retreat of a glacier.

kettle lake
Formed in a kettle hole with glacial water from receding ice.

Koppen classification
A climatic classification system.

land configuration
The terrain or shape of the land.

laterites
Iron, aluminum, and manganese rich layer in the subsoil (B horizon) that can be the end product of laterization in the wet-dry tropics.

laterization
A soil-forming process of hot,wet climates. The soil type is often an oxisol with little or no humus and a heavy accumulation of iron or aluminum compounds.

leachates
Inorganic soil components from the surface layer of the soil. They are removed by gravitational water.

limestone
A type of rock created by the calcification process which has a high concentration of calcium carbonate.

loess
Wind deposited soil.

macroorganism
Organism large enough to see by the naked eye.

manure
Animal excreta. Worm castings.

mass wasting
The collective movement of surface materials downslope as a result of earth gravitation.

mature
Having completed natural growth and development.

mechanical weathering
The physical disintegration of rock material without any changes in chemical composition.

male genital pores
The male sexual organs of the earthworm.

microclimate
Climate associated with a small area at or near the earth's surface.

microorganism
Organism requiring magnification for observation.

moist skin
Outer layer of skin that is wet.

moraine
The largest and most conspicuous landform feature produced by glacial deposition.

mucus
A watery secretion, often thick and slippery, produced by gland cells. One function is to keep membranes moist.

muskeg
A thick deposit of partially decayed vegetable matter of wet boreal regions. A bog.

nephridia
The excretory of an annelid that filters fluid in the coelom.

nerve collar
Part of the nervous system that circles the pharynx in the earthworm.

nutrient cycle
Cycling of nutrients in the ecosystem or environment.

O-horizon
The immediate surface layer of a soil profile, consisting mostly of organic material.

organic activity
Processes promoted by living organisms like plants and animals.

organic matter
Material which comes from something once alive.

overload
To deposit more garbage in a worm bin than can be processed aerobically.

outwash plain
An extensive, relatively smooth plain covered with sorted deposits carried forward by the meltwater from an ice sheet.

ovaries
A pair of female reproductive organs.

oxidation
The chemical union of oxygen atoms with various mineral elements to produce new products. It often creates products more easily eroded.

parent material
The source of weathered fragments of rock from which soil is made.

permeability
Soil characteristic in which there are interconnected pore spaces through which water can move.

pharynx
The tubular passage of the vertebrates digestive and respiratory tracts extending from the back of the nasal cavity and mouth to the esophagus. In invertebrates, it is part of the alimentary canal.

phylum annelida
Phylum that contains segmented worms.

plate tectonics
The theory that the lithosphere is composed of segments or plates that move over the earth's surface.

Pleistocene Epoch
An ice age that began 2 million years ago and ended 10,000 years ago. It is believed to have had four major ice advances that helped to form the current surface of earth.

podzol
Acidic, gray, ashy soil often found in cool moist climate regions.

podzolization
A soil-forming process of humid climates with long, cold winter seasons. Spodosols are the typical type of soil, characterized by the surface accumulation of raw humus, strong acidity, and the leaching or eluviation of soluble bases and iron and aluminum compounds.

pollute
To make foul or unclean, to contaminate.

population
The total number of individuals of a single species in a defined area.

population density
Number of specific organisms per unit area.

posterior
Toward the rear, back or tail.

prostomium
Fleshy lobe protruding above the mouth of an earthworm.

recessional moraine
An end moraine deposited behind a terminal moraine, marking pauses in the retreat of a valley glacier or ice sheet.

redworms
A common name for Eisenia Fetida. A common worm used for composting.

residual parent material
Weathered fragments of rock material that accumulate beneath the soil.

segments
Numerous disc-shaped portions of an earthworm's body bounded anteriorly and posteriorly by membranes. People identify earthworm species by counting the number of segments anterior to the position of structures such as the clitellium, ovaries, or testes. Segmentation is a characteristic of all annelids.

septa
The internal wall between the segments of an annelid's body.

setae
Bristles on each segment used in locomotion.

sexually mature
Possessing a clitellium and capable of reproducing.

slime
Mucus secretion of earthworms which helps to keep skin moist so that gas exchange can take place.

slope
The inclination of the earth's surface.

soil
A varying mixture of weathered mineral particles, decaying organic matter, living organisms, gasses, and liquid solutions. Soil is part of the outer skin of the earth.

soil classification system
Developed by soil scientists of the USDA over a long period of time. Many changes have given us a system that identifies six levels or classes in descending categories, beginning with 10 soil orders, 47 suborders, 185 great groups, and ever-increasing numbers of subgroups, families, and series.

soil profile
The vertical cross-section of soil from it's surface to the parent material from which it is formed.

soil horizon
A separate soil layer.

subsoil
Mineral-bearing soil beneath humus-containing topsoil.

tectonic processes
Processes that derive their energy from within earth's crust and serve to create landforms by disrupting, elevating, and shaping the earth's surface.

terminal moraines
A glacial deposit that builds up at the outermost advance of ice advance.

testes
A pair of male sexual reproductive organs.

till
Rock debris that is deposited directly by moving or melting ice.

time factor
The length of time it takes for soil to reach a state of dynamic equilibrium with its environment. It varies with conditions but usually takes hundreds to thousands of years.

top dressing
Nutrient-containing materials placed on the soil surface around the base of plants.

topography
Surface configuration of the earth.

transported parent material
Rock fragments carried by water, wind, or ice to help form new deposits for developing soil surface.

ventral
Term for the underside of a worm.

vermicomposting
Mixture of partially decomposed organic waste, bedding, worm castings, cocoons, and worms.

vermiculture
The raising of earthworms under controlled conditions.

volcanic soils
Soils created from the breakdown of parent materials whose origin came from volcanic, tectonic processes.

volcanism
The upward movement of molten material (magma) to the earth's surface where it is cooled. Cooled rock forms the parent material for the production of soil.

weathering
The physical and chemical disintegration of rock that is exposed to the weather.

worm bedding
The medium, usually cellulose-based, in which worms are raised in culture, such as shredded, corrugated cartons, newspaper, or leaf mold.

worm bin
Container designed to accommodate a vermicomposting system.

worm casting
Undigested material, soil bacteria deposited through the anus. Worm manure.