Composting With Worms

This guide was adapted by the Chittenden Solid Waste District from various sources in 2011.
For additional information and related activities, visit the CSWD School Programs web page at
http://www.cswd.net

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Acknowledgments:

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Worm Composting

What is Worm Composting?

Research recently conducted in Chittenden County revealed that 30% of household garbage could have been composted. Additional research in the cafeteria of a local elementary and middle school indicated that nearly 50% of their lunch-time waste could have been composted. This material, instead of being utilized as a valuable resource, is buried in a landfill, where environmental conditions delay decomposition for decades (see photo of partially decomposed carrots in the appendix). Furthermore, food scraps are generally high in moisture, and this liquid gradually leaches through the landfill, absorbing other toxins present in the waste. This considerably toxic liquid, called leachate, must be pumped out of the landfill and purified at waste water treatment plants.

Worm composting (or vermi-composting) is one method to recycle this material into a nutrient-rich soil amendment for school gardens or classroom plants. Worms work with fungi, bacteria, and other invertebrates to transform this organic matter into a usable material, which improves soil structure, nutrient storage and availability, and water retention capability.

How is Worm Composting Relevant to Schools?

For millions of years, worms have been hard at work breaking down organic materials and returning nutrients to the soil. By bringing a worm bin into the classroom, you are simulating the worm's role in nature. This technique is simple, effective, and convenient. It saves water, energy, soil, and landfill space. Best of all, it's a fun, hands-on learning experience. Students learn the responsibility of caring for a fellow life-form.

A worm bin can provide many valuable, exciting, and experimental opportunities for students. Worms are very popular with children, and most are fascinated by these creatures. A classroom worm bin can be used to introduce the concept of biodegradation, to enhance a recycling unit, or as catalyst for a variety of other educational experiences. As students observe and witness worms eating their fruit and vegetable scraps that would otherwise be thrown away, they learn to identify composting as one method for managing their waste responsibly. With this knowledge, students can educate their friends and families and even start a worm composting system at home.

What to Feed Your Worms

Though worms can eat most organic material, certain foods are better for your classroom worm bin.

Classroom Worms Love

- Fruit and vegetable scraps[1]
- Eggshells
- Tea bags
- Coffee grounds and filters

Classroom Worms Prefer Not to Eat

- Meats, oils, cooked foods and dairy products[2]

[1] Here are a few exceptions: Worms will eat orange peels and other citrus fruits, however, if citrus materials constitute a majority of the foods being fed to the worms, conditions in the bin may become too acidic for the worms. Just like you and I, worms like a varied diet. Generally speaking, the more vegetable matter, the better the worm bin. Worms also prefer to have their food cut into small pieces. Finally, some people have observed that decomposing onions and broccoli tend to produce strong odors.

[2] Don't feed these items to your classroom worms. They take longer to break down than fruits and vegetables, produce strong odors, and can attract pests.

The above list is not comprehensive; there are plenty of exceptions. But here is my rule of thumb: If you're unsure about feeding a certain food to your worms, take a small sample of the food item in question. Bury it under the newspaper and mark the location. Each day, have a student check the food and give a progress report on whether the worms or other organisms are consuming it. I did this once with a piece of cheese. It eventually decomposed, but it took longer than most foods I feed to my worms. During the process, it gave off a strong odor which annoyed even my liberal sensitivities. Fortunately, the covering newspaper kept the odor in the bin. On another occasion, I fed my worms a chunk of tofu which had gone bad in my refrigerator. It took several weeks to decompose, and I never once observed worms anywhere near the piece of tofu. Go figure!

Of the food scraps produced in your classroom, which *will* the worms enjoy eating, and which will the worms prefer not to eat?

Taking Care of Your Worms

The following instructions assume the reader already has a completely constructed worm bin. If not, please consult Mary Appelhof's Worms Eat My Garbage.

Choose Your Worm-Feeding Day

Assign one day during the week to feed your worms. Keep this same day from week to week.

Feed Your Worms

Refer to page 3 for a more comprehensive list.

- **Roll back the covering of damp newspaper strips to expose the worms.**
- **Notice if and what material is still remaining from prior weeks.** Monitor the bin every week to see if the worms are or are not eating the food. The worms will need a few weeks to settle into their new home; they may eat less than normal during this period of adjustment.
- **Place *one handful* of food scraps on top the worm compost.** In about one month, you should have a pretty good sense for how much food your worms can eat on a regular basis. Adjust feeding levels accordingly. If the food seems relatively untouched, you may want to forego feeding for one week; if much of it has disappeared or is clearly being eaten, feed them the same amount as the week before; if it is completely gone, increase the amount you include.
- **Feed the worms once per week.**
- **Cover the food scraps with newspaper.** This is one of the more important aspects of maintaining your home for worms. The bedding will keep odors inside the bin, it will help regulate moisture levels and flow of oxygen within the bin, and it will help prevent fruit flies from making a home in the bin.
- **Add more shredded newspaper to the bin.** After several months, you will notice that the newspaper as well as the food is disappearing. In order to maintain proper moisture levels (newspaper should be moist, but there should be no standing water in the bin) and to keep decomposing food covered, you will need to add more strips of newspaper from time to time.

Cover and Choose a Spot for the Bin

Keep the bin in a dark place and away from windows and heaters.

Using Worm Compost

Harvesting

If you take care of your worms and create a favorable environment for them, they will work tirelessly to eat your "garbage" and produce compost. As time progresses, you will notice less and less bedding and more and more compost in your bin. After 3-5 months, when your bin is filled with compost (and very little bedding), it is time to harvest the bin. Removing the finished compost from the bin is considered harvesting the worm castings. After several months, worms need to be separated from their castings which, at high concentrations, create an unhealthy environment for them.

To prepare for harvesting, don't add food to the bin for two weeks. Try one of two methods for harvesting:

Hands-Off

Push all of the contents in your worm bin to one half of the bin, removing any large pieces of non-decomposed food or newspaper. Put fresh bedding and food scraps in empty side of bin. Continue burying food scraps only in freshly bedded half.

Over the next 2-3 weeks, the worms will move over to the new side (where the food is), conveniently leaving their compost behind in one section. When this has happened, remove the compost and replace it with fresh bedding. To facilitate worm migration, cover only the new side of the bin, causing the old side to dry out and encouraging the worms to leave the old side.

Hands-On

Dump the entire contents of the worm bin onto a sheet of plastic or paper. Make several individual cone-shaped piles. Each pile will contain worms, compost and non-decomposed food and bedding. As the piles are exposed to light, the worms will migrate towards the bottom of the pile. Remove the top layer of compost from the pile, separating out pieces of non-decomposed food and newspaper. After removing the top layer, let the pile sit under the light for 2-3 minutes as the worms continue migrating downward. Then remove the next layer of compost. Repeat this process until all of the worms are left at the bottom of the pile. Collect the worms, weigh them (for your record keeping), and put them back in their bin with fresh bedding.

Regardless of which method you choose, the compost you harvest will most likely contain some old food scraps and bedding. If you are using the compost outdoors, the food scraps and bedding will eventually decompose. If you are using the compost indoors, remove old bedding and food scraps for aesthetic purposes. Furthermore, though it is unlikely that you'll be able to remove every worm, please be aware that red worms prefer not to live in soil. For an explanation, please refer to #3 in the Frequently Asked Questions section.

For both methods, you may continue composting your food scraps after harvesting. Just add fresh bedding and food scraps (check appendix A for a check list on setting up a worm bin). If, for some reason, you do not want to continue composting, please offer the setup to another teacher or call Chittenden Solid Waste District at 872-8111. A staff member will be able to reuse the worms and container in another classroom.

Using Worm Compost

Mix your worm compost with potting soil for added nitrogen. Unlike chemical fertilizers, worm castings provide a slow release of water-soluble nutrients. Castings contain nitrogen 5x the available nitrogen, 7x the available potash and 1.5x more calcium than that found in 15 cm of good top soil. Experiment with planting seeds in containers with and without castings and you'll observe significant differences!

Cross-Curricular Applications and Activities

Language Arts

- **read** and **write** stories about worms
- **strengthen** composting vocabulary
- **keep** worm bin journals
- **create** worm puppet shows
- **publish** a newsletter or information sheet on worm composting
- **research** information and books about worms and recycling
- **request** information on recycling and composting at home from the Chittenden Solid Waste District

Math

- **count** worms
- **weigh** worms and food scraps
- **convert** measurements to metric equivalents
- **graph** worm information (population increase or amount of food eaten)
- **measure** area and volume of worm bin
- **calculate** ratios (worms to garbage, big worms to small worms, etc.)

Science

- **study** worm anatomy, reproduction, and life cycles
- **identify** worm needs
- **utilize** scientific method
- **conduct** worm experiments
- **understand** organic vs. non organic
- **observe** fungi, bacteria, and other invertebrates
- **investigate** food webs
- **classify** different species of worms
- **grow** plants with experimental mixtures of compost and potting soil
- **test** soil quality on school grounds
- **create** and **monitor** outside compost pile

Geography and Social Studies

- **explore** worm climates
- **compare** garbage generation rates for countries around the world

Other Potential Topics

- **improve** school recycling program
- **tour** local compost facility
- **visit** local landfill

Extended Worm Information and Activities

- Worms can eat their weight in food each day. Over one million worms may be present in one acre of soil, and these worms can produce 700 pounds of castings each day. Two thousand red worms in a worm bin can produce seven pounds of castings in one month.

  - Ask your students to estimate how much food waste they produce each day. What happens when it's *not* fed to the worms?

- Worms do not have teeth. Their food is softened by moisture and by microorganisms which break it down. Food is further broken down in the worms' gizzards, which contain hard particles (such as soil) and muscles to grind ingested food.

  - Observe which foods decompose the fastest, and try to explain why. What are your worms' favorite foods? Do they like dry or wet garbage best? Why?

- Worms don't have eyes, but they can sense light at their front ends. They move away from light and become paralyzed if they are exposed to light for too long (approximately an hour). If a worm's skin dries out, it will die.

  - Observe worms' reactions to light. Why do they stay inside your covered worm bin?

- Worms breathe through their skin and need a moist environment to survive. But too much moisture will kill them. Have you ever noticed worms on the sidewalk after a rainstorm? This happens because the worms' homes in the soil got flooded, and the worms came to the surface in search of less soggy conditions. On the pavement, worms often get disoriented and cannot find their way back to the soil; they dry up and die when the sun comes out.

  - After a heavy rainstorm, go out on a worm hunt. What should you do when you see worms on the pavement? (Stepping on them is not the right answer!) Be a worm rescuer; put them back in the soil where they belong and can survive. Why do we want worms to survive?

- Worms are hermaphrodites, so each worm has both male and female organs. Two worms mate by lining up in opposite directions and joining at their clitella (the swollen area near the heads of mature worms which contain their reproductive organs). They remain attached for about 15 minutes to exchange sperm. Several days later, a cocoon develops on their clitella, which each worm will shed into the castings in seven to ten days. Egg capsules are lemon-shaped, dirty yellow/amber in color, and about the size of a match head. As they mature, they grow darker in color. After 14-21 days, two to five baby worms will hatch from the cocoons. However, during inclement conditions, baby worms may stay in their cocoons for many weeks until temperatures warm up again. When the baby worms eventually crawl out, they are the thickness of a piece of thread and approximately one cm long. Usually the worms appear white with a faint red streak under a microscope, this is an ideal time to observe their beating hearts. As they grow, their pigmentation will develop fully, giving them the reddish-brown color common to "red" worms. They will reach sexual maturity in two to three months.

  - Try to find mature worms, young worms, and worm cocoons in your worm bin.

- Worms have amazing healing powers, but contrary to popular belief, they *cannot* reproduce by being cut into small pieces. 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 wiggling until the nerve cells die. It *will not* grow a new head.
    - What other animals can regenerate parts of their bodies?
- Red worms can live as long as four years, but most die after about one year. You will rarely notice a dead worm in your bin because their bodies are 90% water and they decompose very quickly.
    - If you notice dead worms in your bin, what might be the cause?
- Worm castings are toxic to live worms. After all the food scraps in a bin are recycled, the worms may eat their own castings, which will poison them.
    - Harvest your worm bin when it is filled with compost. Encourage your students to take some of the compost home with them.
- Worm castings contain nitrogen and other nutrients necessary for plant growth. When added to soil, worm compost increases nutrient availability and improves soil structure and porosity.
- In addition to producing compost, worms till layers of soil while tunneling through the earth. These burrows help air and water reach plant roots. Tiny bristles, called setae, on worms' bodies help them move through the soil.
- There are over 3000 species of earthworms in the world. Red worms (Eisenia fetida or Lumbricus Rubellus) are ideally suited to living in worm bins because they are surface feeders, don't burrow very deeply, and thrive in close proximity with other worms. Night-crawlers, on the other hand, are known to burrow several feet into the ground and might feel confined by the small size of most worm bins. In nature, red worms can be found living in leaf mounds, compost heaps, manure piles, and other decaying vegetation with high moisture levels. They are also commonly raised on worm farms.
    - Look for worms in gardens, vacant lots, and other locations. How many kinds of worms can you find? Where do you think you will find the most worms? Research worms from around the world. Where do some of the most unusual worms live?
- Worms are not the only living organisms in the worm bin. All sorts of microorganisms (in fact, billions of them) live in a worm bin. These microorganisms are introduced to the bin from the skin of the worm and from soil added to the bedding. Food scraps introduce microorganisms, as do fungal and bacterial spores that land in the bin from the air.
    - Are other creatures besides worms present in your classroom worm bin? What do they look like? How do they behave? Look for these same composting critters outside in piles of decaying leaves. Where else can you find them?
- Many people mistakenly believe that garbage sent to landfills decomposes quickly, like it does in a worm bin or compost pile. However, this is not at all true because landfills lack sufficient quantities air and moisture—key ingredients in decomposition. Consequently, worms and other important decomposers cannot survive in landfills.
    - Put some worm food in an air tight bag. Compare what happens to this food to what happens to food in a worm bin.

Common Worm Bin Complaints

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:

- **Avoid putting rotting or rotten food in your worm bin.** Fly larvae are more likely to be present on rotten food.
- **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.
- **Don't over-feed worms.** Ripe food that sits around in the bin attracts (and may contain) flies.
- **Bury food.** Generally speaking, fruit flies are attracted to the odors of decomposing foods. Ensuring that all food scraps are sufficiently buried underneath strips of newspaper should contain these odors and keep unwanted pests from intruding on your bin.
- **Keep bedding material moist, but not too wet.** Overly wet conditions encourage fruit fly proliferation.
- **Feed worms a varied diet.** If citric foods dominate the bin, the bin may become too acidic, which may attract fruit flies. Furthermore (and this is what you can tell your students to sufficiently gross them out), it is not uncommon for fruit flies to lay their eggs in citrus and banana peels prior to human consumption of the fruit. This helps to explain the occasional, sudden, and unexplainable infestation of fruit flies that most of us worm workers are familiar with.
- **Loosely place a full sheet of newspaper on top of the worm bin contents.** This newspaper cover will create another barrier to help prevent flies from getting in or out of the bin.

Sometimes—in spite of these preventative efforts—outbreaks still occur. To help control an existing fruit fly problem, try the following:

- **Create a fly trap.** Place a bowl of apple cider vinegar, mixed with a drop of dish detergent, near the bin. The fruit flies are attracted to the vinegar, and when they fly down for a sip, the detergent kills them. Change the liquid regularly to keep the trap potent. If the invertebrates buzzing around your room are, in fact, fruit flies, this solution should remedy the problem quite quickly. Apple cider vinegar appears to be the most effective and consistent vinegar by which to attract fruit flies.
- **Cover the contents of the bin with a whole sheet of newspaper.** Change this sheet regularly because flies tend to congregate here.
- **Take the bin outside, and remove the cover.** Undoubtedly, some fruit flies will alight into the surrounding environs while others remain in the bin. The primary goal here is to reduce the available population of fruit flies capable of reproducing. Its effectiveness is limited unless combined with the other techniques mentioned on these pages. (Remember to keep the bin out of direct sunlight so the bin doesn't dry out.)

- **Remove rotten food.** This is a drastic measure, but its aim is two-fold: Fruit flies feed off of and often lay their eggs on decomposing food. By removing rotten food, you eliminate their food source and the medium on which their larvae mature.
- **Hang flypaper strips near the bin.** Inexpensive flypaper can be purchased at hardware stores.
- **Sprinkle lime in the bin.** This will neutralize excessively acidic conditions. I have been able to eliminate all of my fruit fly outbreaks without resorting to this technique.
- **Employ the preventative tactics described above.**

You may notice in your bin invertebrates which, at first glance, appear to be fruit flies. However, fruit flies can be identified by their ruby or green eyes and their linear flight patterns. If the organisms you observe do not match this description, you need not necessarily be concerned by their presence.

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

- **Decomposing food is naturally smelly.** For example, certain decomposing foods, such as onions, broccoli, and citrus rinds are known to produce unpleasant odors. If you think a particular food may be the culprit, remove it from the bin. Regardless, ensure that *all* food scraps remain covered by newspaper. This will suppress and contain odors inside the bin.
- **Bin is too wet.** Solve this problem by adding more dry bedding to absorb the excess moisture. Remove the top of the bin to allow some of the moisture to evaporate.
- **Bin is not getting enough air.** Anaerobic bacteria produce strong odors and thrive in environments with little oxygen. Aerate the bin by adding fresh bedding and mixing the contents of the bin.
- **Bin contains meat, dairy, and oily products.** Classrooms are recommended NOT to feed these items to their worms because they become rancid and produce strong odors when decomposing.

Worm Death: If your worms are trying to escape the bin, or if their population is dwindling, check for the following:

- **Bin is too wet.** Worms are drowning. Read above response.
- **Bin is too dry.** Worms are suffocating. Worms need a moist environment in order to breath.
- **Bin is not getting enough air.** Worms are suffocating. Read above response.
- **Worms are not getting enough food.** Once the worms devour all of the food, they will start eating their own castings, which are poisonous to them. Feed them more, or harvest the compost.
- **Bin is exposed to extreme temperatures.** Worms thrive in temperatures from 55 to 77 degrees F.

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

Finally, if the problem cannot be controlled, have your class analyze the problem and speculate on its causes. 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 maintain a better worm home. Please don't hesitate to call Chittenden Solid Waste District (872-8111) with any questions.

Frequently Asked Questions

Are the red worms used in a worm bin the same as earthworms?

When most people think of "earthworms", they usually mean "night crawlers," which can be 8-10" long and 1/2" in diameter. These night crawlers are different from red wigglers, although both may be called "earthworms" since they are found in the earth.

Night crawlers are soil-dwellers and like to burrow several feet into the ground. By burrowing, the night crawlers mix different layers of the soil; their tunnels aerate the soil. On the other hand, red wigglers are surface-dwellers and prefer to live within the top six inches of the soil, which is why red wigglers prefer shallow boxes as homes. Red wigglers also prefer to live in mediums with a high concentration of organic matter and are often found among the fallen leaves of the forest floor as well as in manure piles.

Should I add red worms to my garden?

According to some worm workers, red worms can be transplanted to gardens for the short-term. However, gardens aren't the most suitable environment for red worms, and in time, their populations will drop significantly.

Why is it important to sprinkle some soil into the worm bin?

Soil provides the worm bin with an inoculation of beneficial microorganisms. The gritty soil particles also aid the worms' digestive process. Potting soil or soil from outside is fine.

I have an outdoor compost pile. Should I add worms to it?

Even in a worm bin, fungi, bacteria, and other invertebrates play a significant role in decomposing the food scraps and newspaper. Adding worms to your outdoor pile, where bacteria are the primary decomposers, is unnecessary. In outdoor bins, the temperature inside the pile often exceeds worms' zone of comfort. Worms living in the soil may, however, find their way into a compost pile on their own.

I have been told that turning my outdoor pile is essential to producing compost. Should I turn the contents of my worm bin?

In both processes, the decomposing organisms (fungus, bacteria, and invertebrates) depend on oxygen. First, **outdoor compost piles:** Turning them serves to aerate them and speed up the rate of decomposition. However, many people would rather let their piles sit and let nature do the work. It may take a little longer, but as cliché's go, "compost happens". If you turn your pile frequently, you may produce compost in one month; if you turn your pile once in a while, you may produce compost in three to six months.

And now, worm bins: Except in certain circumstances, it is *not* recommended to turn the contents of your worm bin. Worms are natural aerators and need little assistance with this task. Furthermore, it disturbs them to have the bedding and food scraps turned and mixed.

Can worms bite?

Worms do not have teeth and cannot bite you. Do not be afraid to hold a worm. Most people find them to be soft and ticklish.

What is the yellow liquid which the worms sometimes release when we are holding them?

The yellow liquid is not urine, which many people first guess. The yellow liquid, called coelomic fluid, is released when a worm is stressed, which often happens when students touch them. When a worm is placed on a student's dry hand, the worm's body will begin to dry out. The worm will start wiggling, trying to find its way back to the soil or bin, and in the process, it will release this yellow liquid in order to make its body moist again. Exposure to light also triggers the release of the coelomic fluid. This yellow liquid may smell like garlic, hence the scientific name eisenia fetida: fetida means smelly. When conducting experiments with worms, you may want to gently spray the worms with water every few minutes.

What happens if you cut a worm in half?

Almost everyone wants to know the answer to this question. If you cut a worm in half, you will most likely end up with two dead pieces of one worm. If you are lucky, the piece with the head *may* grow a new tail, but the piece with the tail *will not* grow a new head. More likely than not, cutting a worm in half will only result in two dead pieces of one worm.

Why is worm compost so good for plants?

Worm compost makes nutrients available to plants. When compost is mixed with water, it has the ability to hold many positively-charged mineral ions (cations) and nutrients, which can then be taken up by plants. Also, as worms process (digest) the food scraps, the nutrients in the food are changed into forms which can be reused by plants.

Glossary

acid See *pH*.

actinomycetes Fungi-like bacteria. HINT: say this one out loud with your students; it's a perfect tongue twister! It's singular form is pronounced 'ak-tin-oh-**mahy**-seet'. Gray web that often forms on the surface of the worm bedding. Responsible for the earthy smell characteristic of worm bins.

aeration Exposure of a medium to air which allows exchange of gases.

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

air Mixture of atmospheric gases, including nitrogen, oxygen, carbon dioxide, and other gases.

albumin A protein in cocoons that serves as a food source for embryonic worms. Also found in egg white.

alkaline See *pH*.

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

animal A living being capable of sensing its environment and moving about. Animals live by eating the bodies of other organisms, whether plant or animal.

annelid Term for a member of the Phylum, Annelida, containing segmented worms like Eisenia Fetida.

anterior Toward the front.

bacteria Plural for bacterium, a one-celled organism which can be seen only with a microscope. Bacteria may be shaped like spheres, rods, or twisted springs. Some bacteria cause decay; others may cause disease. Most bacteria are beneficial because they help recycle nutrients. Bacteria are the main decomposers in both outdoor and worm composting bins.

bedding Moisture-retaining medium which provides a suitable environment for worms. Worm beddings are usually cellulose-based, such as newspaper, corrugated cartons, leaf mold, or compost.

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

bristles See *setae*.

burrow Tunnel formed when an earthworm eats its way through soil, or pushes soil aside to form a place to live and move more readily through the earth.

carbon dioxide Gas produced by living organisms as they utilize food to provide energy. Also produced through the burning of fossil fuels.

castings See *worm castings*.

centipede A predator sometimes found in worm bins. Centipedes have more than eight jointed legs with one pair of legs attached to each of many segments.

clay As a soil separate, the mineral soil particles which are less than 0.002 mm in diameter. As a soil type, soil material that is 40% or more clay, less than 45% sand, and less than 40% silt. Clay has smooth particles and feels sticky when wet. Clay absorbs moisture readily.

clitellum A swollen region containing gland cells which secrete the cocoon material. Sometimes called a girdle or band, it is present on sexually mature worms.

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

cold-blooded Having blood that varies in temperature approximating that of the surrounding air, land, or water. Fish, reptiles, and worms are cold-blooded animals.

compost Used generically to refer to the raw material, the process, and the end product: Compost (leaves, manure, food scraps, etc.) is composted (transformed biologically) into compost (a valuable soil amendment). The soil amendment enhances soil texture and fertility in gardens.

consumer An organism that feeds on other plants or animals.

contract Action of muscle as it draws up or gets shorter.

culture To grow organisms under defined conditions. Also, the product of such activity, as a bacteria culture. vermiculture is growing worms in culture.

decompose To decay; to rot; to break down into smaller particles.

decomposer An organism that breaks down cells of dead plants and animals into simpler substances. These include fungi, bacteria, and invertebrates.

Decomposition The process of breaking down complex materials into simpler substances. End products of much biological decomposition are carbon dioxide and water.

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

dorsal The top surface of an earthworm.

earthworm A segmented worm of the phylum, annelid, which contains some 4000 species. Most earthworms are terrestrial; that is, they live in the ground. Earthworms have bristles known as setae which enable them to burrow in the soil. Earthworms help aerate and enrich the soil.

egg A female sex cell capable of developing into an organism when fertilized by a sperm.

egg case See *cocoon*.

Eisenia Fetida Scientific name for one of several red worm species used for vermicomposting. Color varies from purple, red, dark red to brownish red, often with alternating bands of yellow in between segments. Found in manure, compost heaps, and decaying vegetation where moisture levels are high. Frequently raised in culture on earthworm farms. See also *Lumbricus rubellus*.

enchytraeids Small, white segmented worms common in vermicomposting systems. Also called pot worms, they do not harm earthworms.

excrete To separate and to discharge waste.

food web The sequence defined by who eats whom, starting with producers and progressing through various levels of consumers, including predators and decomposers. Many organisms may be more than one level of consumer, depending on whether they eat a plant, a microorganism which has consumed a plant, or an animal which ate the microorganism which ate the plant.

fungi Plural for fungus, a large group of plants having no green color and which reproduce by spores. The group includes mushrooms, toadstools, microscopic plants including molds and mildew, and more.

garbage Often used generically to refer to various waste items, but *garbage* can also refer specifically to wet discards, food waste, and offal; trash refers specifically to discards that are dry.

genus A category of classification which groups organisms with similar characteristics. These are more general than species characteristics.

gland A specialized type of tissue which produces secretions. Glands in worms' skin produce mucus.

girdle See *clitellum*.

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

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

humus Complex, highly stable material formed during breakdown of organic matter.

inoculate To provide an initial set of organisms for a new culture.

larva Early form of any animal that changes structurally before becoming an adult. A caterpillar is an insect larva which may become a moth or butterfly as an adult.

leach To run water through a medium, causing soluble materials to dissolve and drain off.

leaf mold Leaves in an advanced stage of decomposition.

lime A calcium compound which helps reduce acidity in worm bins. Use calcium carbonate, ground limestone, egg shells, or oyster shells. Avoid caustic, slaked, and hydrated lime.

litter (leaf) Organic material on forest floor containing leaves, twigs, decaying plants, and related organisms.

loam A rich soil composed of clay, sand, and some organic matter. Soil material that is 7-27% clay particles, 28-50% silt particles, and less than 52% sand particles. The organic matter acts like a sponge to hold water.

Lumbricidae Name of family to which several red-worm and night-crawler species of earthworms belong.

Lumbricus rubellus A scientific name for a red-worm species. Color is ruddy-brown or red-violet, iridescent dorsally, and pale yellow ventrally. It has been found in a wide variety of habitats, including under debris, in

stream banks, under logs, in woody peat, in places rich in humus, and under dung in pastures. Grown in culture by worm growers.

Lumbricus terrestris Scientific name for large burrow-dwelling night-crawler. Also known as the Canadian night-crawler or dew worm.

macroorganism Organism large enough to see with the naked eye.

membrane A tissue barrier capable of keeping some substances out and letting others in.

microorganism Organism requiring magnification for observation.

mold A downy or furry fungal growth on the surface of organic matter, found especially in the presence of dampness or decay.

mucus A watery secretion, often thick and slippery, produced by gland cells. One function is to keep membranes moist so that gas exchange can take place.

nematodes Small (usually microscopic) round-worms with both free-living and parasitic forms. Not all nematodes are pests.

night-crawler See *Lumbricus terrestris*.

nitrogen An odorless, colorless, tasteless gas which makes up nearly four-fifths of the earth's atmosphere. When it combines with oxygen through the action of nitrogen fixing bacteria, it can become incorporated into living tissue as a major part of protein.

nocturnal Coming out at night.

oligochaeta Name of the class of annelids to which earthworms belong, characterized by having setae.

organic matter Material which comes from something which was once alive.

organism Any individual living thing.

ovary Organ which produces eggs.

oxygen Gaseous element in the earth's atmosphere essential to life as we know it.

pH An expression for degree of acidity and alkalinity based upon the hydrogen ion concentration. The pH scale ranges from 0 to 14, pH of 7 being neutral, less than 7—acid, and greater than 7—alkaline. Acids are normal by-products of decomposition. Red-worms do best in a slightly acidic environment. Below pH 5 can be toxic. Add pulverized egg shells and/or lime to neutralize acids in a worm bin. Alkaline bases (hydroxides, carbonates) neutralize acids to form salts.

plant An organism which is green at some stage of its life and which uses the energy from sunlight to produce its own food.

posterior Toward the rear, back, or tail.

pot worms See *enchytraeids*.

prostomium Fleshy lobe protruding above the mouth or an earthworm.

protein Complex molecule containing carbon, hydrogen, oxygen, and nitrogen; a major constituent of meat. Worms are approximately 60% protein.

protozoa Plural for protozoan, a one-celled organism belonging to the animal kingdom. Most protozoa live in water and can be seen only with a microscope. Some move by means of tiny hairs called cilia, others by a whip-like tail called a flagellum, and others by false feet called pseudopodia like amoebas have.

red-worms See *Eisenia fetida* or *Lumbricus rubellus*.

respire To exchange oxygen and carbon dioxide to maintain bodily processes.

salt Salts are formed in worm bins as acids and bases combine, having been released from the decomposition of complex compounds.

sand Loose, gritty particles of disintegrated rock ranging in size from 0.05 mm to 2.0 mm in diameter. Soil that is 85% or more sand and not more than 10% clay is classified as sandy soil. Sandy soil particles feel gritty. Water drains quickly through sandy soil.

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

setae Tiny rigid structures on most segments of earthworms which serve as brakes during movement. The patterns they form are a major distinguishing characteristic of earthworms.

silt As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of fine sand (0.05 mm). As a soil textural class, silt is 80% or more silt and less than 12% clay.

soil Soil is made up of mineral particles, organic matter, air, and water. The mineral particles are called sand, clay, or silt, depending on their size. Sand has large particles and feels gritty. Clay has fine particles and feels sticky or slippery when wet. Silt particles range between clay and very fine sand. Soil types have differing amounts of each of these particles. Loam is a mixture of sandy soil, clay, and organic matter. The organic matter acts like a sponge to hold water.

sow bug A small crustacean with ten pairs of legs which breathes with gills and lives in organic litter.

species Basic category of biological classification, characterized by individuals which can breed together.

sperm Male sex cells.

springtail A small primitive insect which uses a spring-like projection on its abdomen for motion.

subsoil Mineral bearing soil located beneath humus-containing topsoil.

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

trash Refers specifically to discards which are theoretically dry, such as newspapers, boxes, cans, and so forth. The term is commonly used to indicate anything we throw away, including organic matter. With increasing emphasis on recycling, less material should be thrown away as trash.

turgid Swollen, distended, pressing out against sides.

ventral Term for the underneath surface of an earthworm.

vermicompost Mixture of partially decomposed organic waste, bedding, worm castings, cocoons, worms, and associated organisms. As a verb, to carry out composting with worms.

Vermiculture The raising of earthworms under controlled conditions.

white worms See *enchytraeids*.

worm bin Container designed to accommodate a vermicomposting system.

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

worm : garbage ratio Relationship between weight of worms and garbage used in a bin to convert the garbage to a useful end-product.

Appendix

1. **D.L. Dindall's *famous* Soil Organisms Food Web, 1978.**
2. **Soil Critter Chart from Shelburne Farms: Project Seasons, 1995.**
3. **The Outside of a Worm from Shelburne Farms: Project Seasons, 1995.**
4. **The Inside of a Worm from Shelburne Farms: Project Seasons, 1995.**
5. **William Laurens Rathje's 10 year-old, landfill carrots**

   W. Rathje is an American archaeologist with a PhD in anthropology from Harvard University. He was the longtime director of the Garbage Project which studied trends in discards by field research in Tucson, AZ, and in landfills elsewhere.

   Rathje's research uncovered some misconceptions about landfills. In particular, it was revealed that *the rate of natural biodegradation is far slower than had been assumed*.

   In natural systems, anything organic, or derived from something that was alive, is capable of decomposing. Something as natural as a carrot cannot decompose at a normal rate in a landfill because it is buried by trash. Oxygen, water, sunlight, and organisms are all limited in a landfill. If composted, the carrot will rot and turn into healthy soil between 3 months to a year!

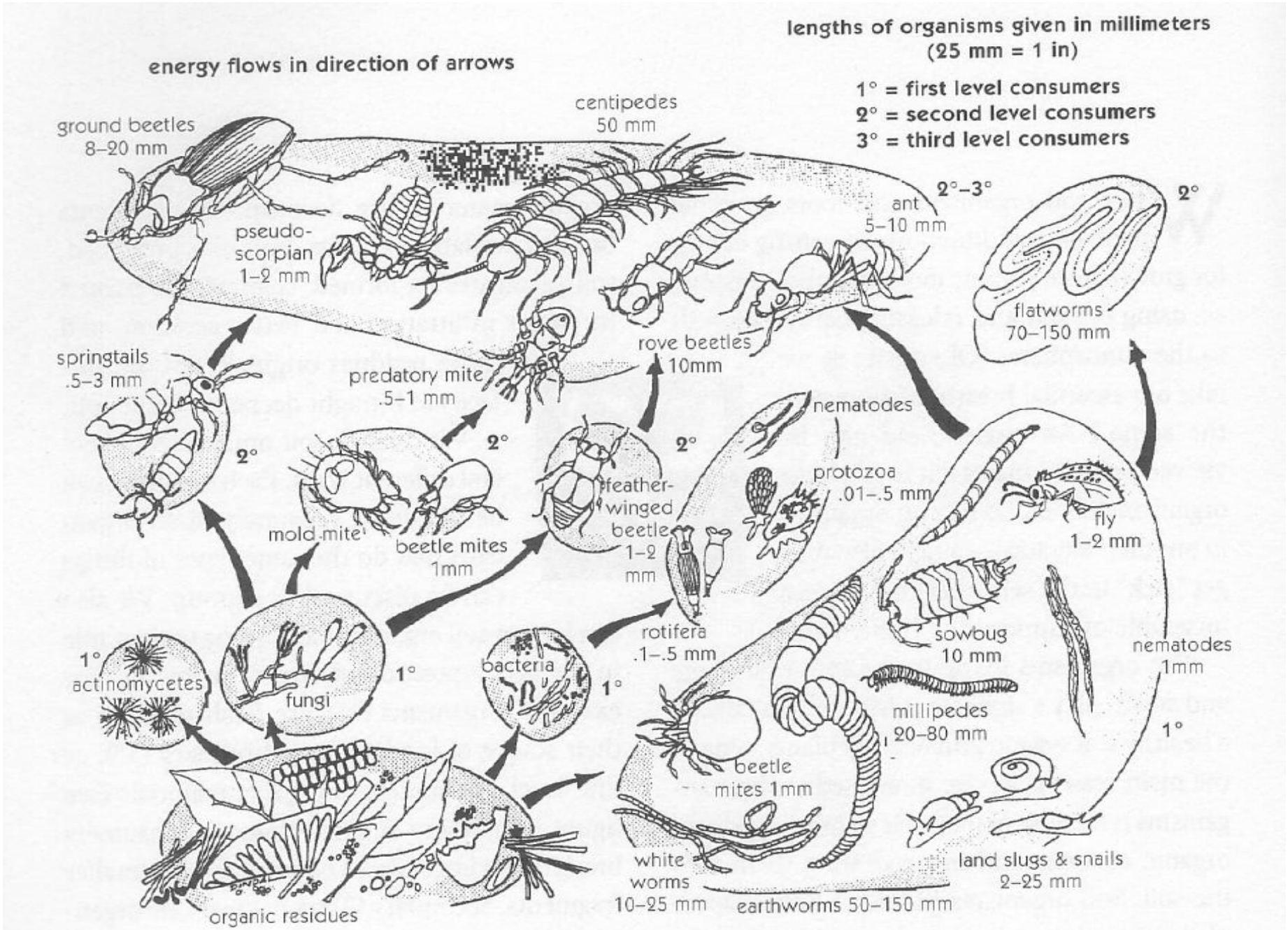
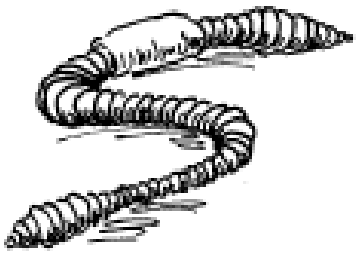


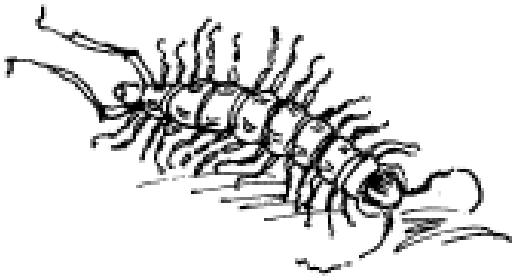
Figure 3.1 Soil organisms and their role in decomposing residues. Modified from D.L.Dindal, 1978.

Soil Critter Chart



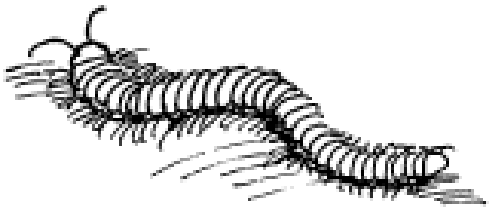
EARTHWORM

Segmented soil critters without legs that move by expanding and contracting their bodies like an accordion. As earthworms eat, they break down plant materials into smaller pieces, aerate the soil, and add nutrients in the form of castings.



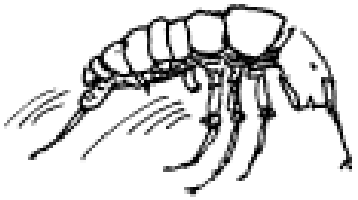
CENTIPEDE

Predatory soil critters that move about quickly on many legs. Their bodies are flattened and each body segment has only one set of legs. Gloves should be worn when handling these critters as they have a poisonous bite.



MILLIPEDE

Long, rounded soil critters that have hard segmented bodies with many legs. Each body segment has two pairs of legs. As vegetarians, millipedes eat holes in fallen leaves (among other things), thus enabling smaller decomposers to continue the decay process.



SPRINGTAILS

These soil critters literally spring to life when approached. A pointed projection folded inward at the tip of their abdomens can be quickly extended, acting like a spring to propel them into the air, hence their name. Springtails feed on fungi and other molds, bacteria and decaying matter. They are important producers of humus.

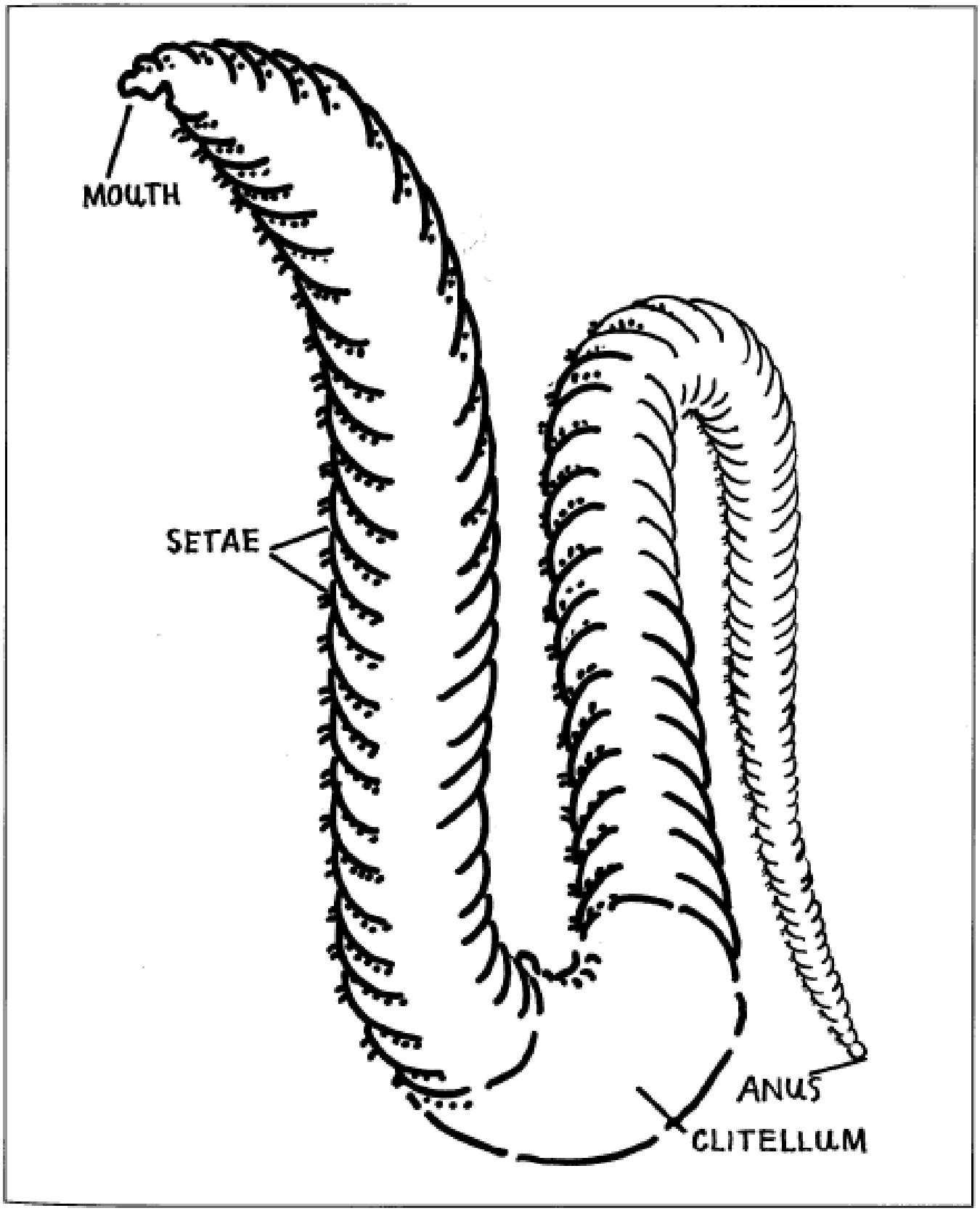
MITE

These very small soil critters look like minute dots moving about in the soil. There are thousands of species and they range in color from white to bright red. Mites are related to spiders and have eight legs and a round body. They eat fungi, other molds, and decaying wood and leaves.

ISOPOD

These soil critters are covered with flattened plates of armor, resembling tiny armadillos. They are brown or gray in color. Isopods eat decaying leaves and wood and are often found in damp leaf litter and rotting wood. They are commonly called woodbugs or, if they roll into balls when disturbed, pillbugs.

The Outside of a Worm



The Inside of a Worm