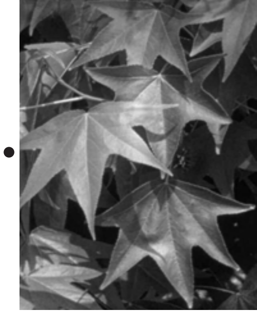
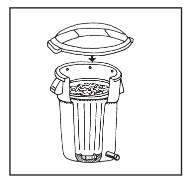


2

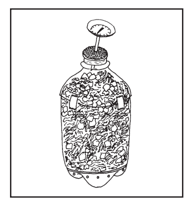
COMPOSTING BIOREACTORS AND BINS

When you think of composting, chances are you envision one of a variety of bins that are used for composting outdoors. But composting can also be carried out right in the classroom, using containers or bioreactors that range in size from soda bottles to garbage cans. Although these bioreactors are generally too small to recycle large quantities of organic wastes, they are ideal for conducting composting research and designing small-scale models of larger composting systems. Because these units are small, they need to be carefully designed and monitored to provide conditions favorable for aerobic, heat-producing composting. Two types of bioreactors for indoor thermophilic composting are described in this chapter:

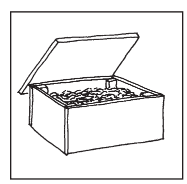
- **TWO-CAN BIOREACTORS** are made from nested garbage cans. Each two-can system will process enough organic matter to fill a 20-gallon can. Temperature increases indicating microbial activity can be observed within the first week of composting, and the compost should be finished and ready for curing within two to three months.



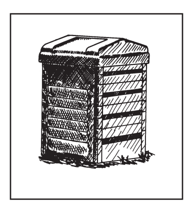
- **SODA BOTTLE BIOREACTORS** are used as tools for research rather than waste management. They are small and inexpensive, enabling students to design and carry out individualized research projects comparing the effect of variables such as reactor design, moisture content, and insulation on compost temperature.



Another option for indoor composting is to use worm bins, which rely on red worms (commonly *Eisenia fetida*) working in conjunction with mesophilic microbes to decompose food scraps and bedding materials, producing finished compost in three to five months. Vermicompost systems provide many opportunities for the study of worm behavior.



We also include recommendations for bins that can be used outdoors in the school yard. The intricate food web that is created by soil invertebrates invading an outdoor compost pile provides an ideal focus for biological and ecological studies. Outdoor compost systems generally are larger than indoor units and can be used to recycle sizable quantities of food and yard wastes. In piles or bins in which thermophilic composting occurs, compost can be produced within a couple of months. If the compost does not get hot, a year or longer will be needed before the materials have broken down.



Students can use the designs included in this chapter, or develop their own composting systems based on their own knowledge and creativity.

Research Possibility: *How does the type of composting system (bin, bioreactor, pile) affect the heat produced, the time it takes to produce compost, or the quality of the end product?*

TWO-CAN BIOREACTORS

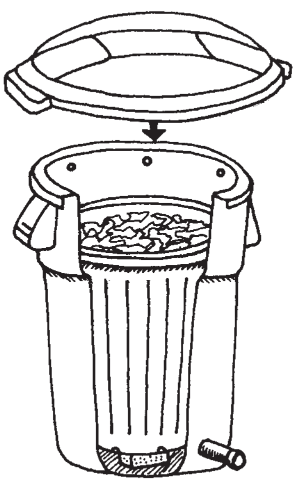
PURPOSE

Two-can composters consist of a 20-gallon garbage can containing organic wastes placed inside a 32-gallon garbage can. Although many classrooms have successfully composted with a single container, placing the can that holds wastes inside another container helps alleviate any odor and fly problems that may arise. The outside container can also be used to collect leachate.

Two-can units are designed to be used for small-scale indoor composting, and as an educational tool in the classroom. A 20-gallon can holds only about 10% of the cubic meter volume commonly recommended for thermophilic composting. Thermophilic composting is possible in these smaller systems, but careful attention needs to be paid to C:N ratios, moisture content, and aeration.

A system using a 10-gallon plastic garbage can inside a 20-gallon can may be substituted if space is a problem. The smaller system may operate at lower temperatures, thereby lengthening the time for decomposition. Or students may want to experiment with various aeration and insulation systems to see if they can come up with a 10-gallon system that achieves temperatures as high as those in a larger system.

MATERIALS



- 32-gal plastic garbage can
- 20-gal plastic garbage can
- drill
- brick
- spigot (optional—see Step 3, below)
- insulation (optional—see Step 5, below)
- duct tape (optional—see Step 5, below)
- 6 pieces of nylon window screen (each about 5 cm^2)
- dial thermometer with stem at least 60 cm long
- peat moss or finished compost to make 5-cm layer in outer can
- compost ingredients, including high-carbon materials such as wood chips and high-nitrogen materials such as food scraps (see Step 8, below)

CONSTRUCTION

1. Using a drill, make 15 to 20 holes (1–2.5 cm diameter) through the bottom of the 20-gal can.

2. Drill five 1–2.5 cm holes just below the rim of the larger garbage can, and cover them on the inside with pieces of nylon window screen.

3. Design and build a spigot at the bottom of the larger can for draining leachate. One way to do this is to fit a piece of pipe into a hole at the bottom edge of the outer can, sealing around the edges with waterproof tape or sealant. Close the outer end of the pipe with a tight-fitting cork or stopper that can be removed to drain the accumu-

lated leachate, and cover the inner end with a piece of nylon screening to block the flow of solid particles.

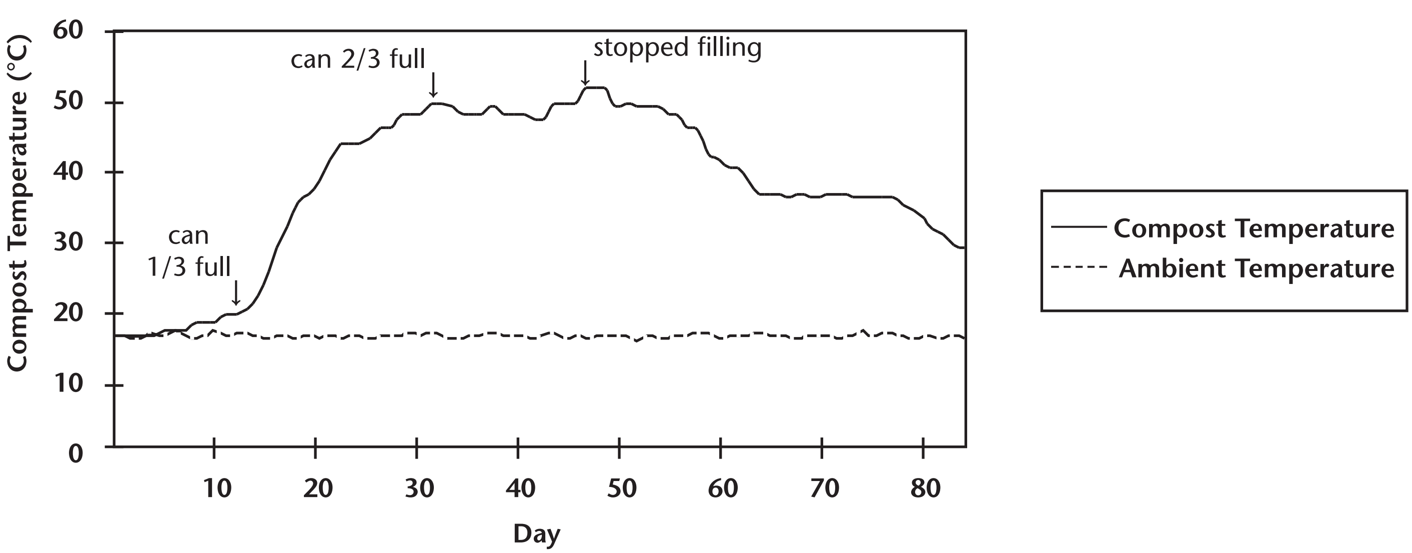
4. Place a brick or some other object in the bottom of the 32-gal can. This is to separate the two cans, leaving space for leachate to collect. (Students may want to measure the leachate and add it back into the compost.)

5. If you are composting in a cold area, you may want to attach insulation to the outer barrel and lid with duct tape, making sure not to block aeration holes.

6. To reduce potential odors, line the bottom of the outer can with several centimeters of absorbent material such as peat moss or finished compost. Periodically drain the leachate to avoid anaerobic conditions that may cause odors. The leachate can be poured back in the top if the compost appears to be drying out. Otherwise, dispose of it outside or down the drain, but do not use it for watering plants. (This leachate is not the "compost tea" prized by gardeners, and it could harm vegetation unless diluted. Compost tea is made by soaking mature compost, after decomposition is completed.)

7. Fill the reactor, starting with a 5–10 cm layer of "brown" material such as wood chips, finished compost, or twigs and branches. Loading can take place all at once (called "batch composting") or in periodic increments. With batch composting, you are more likely to achieve high temperatures quickly, but you will need to have all organic material ready to add at one time. If you are going to add layers of materials over a period of time rather than all at once, the material probably won't begin to get hot until the can is at least 1/3 full (Figure 2–1).

Figure 2–1. A Typical Temperature Profile for Two-Can Composting with Continuous Loading.



Whether you fill the reactor all at once or in batches, remember to keep the ingredients loose and fluffy. Although they will become more compact during composting, never pack them down yourself because the air spaces are needed for maintaining aerobic conditions. Another important rule is to keep the mixture in the inner can covered at all times with a layer of high-carbon material such as finished compost, sawdust, straw, or wood shavings. This minimizes the chance of odor or insect problems.

8. To achieve thermophilic composting, you will need to provide the ingredients within the target ranges for moisture, carbon, and nitrogen. For moisture, the ideal mixture is 50–60% water by weight. You can calculate this by using the procedure described in Chapter 3 (pp. 47–48), or use the rule of thumb that the ingredient mix should feel about as damp as a wrung-out sponge. For carbon and nitrogen, the mixture should contain approximately 30 times as much available carbon as nitrogen (or a C:N ratio of 30:1). Using a specified quantity of one ingredient, you can calculate how much of the other you will need to achieve this ratio (see Chapter 3, pp. 48–50). Or, you can simply make a mixture of high-carbon and high-nitrogen materials. Organic materials that are high in carbon include wood chips or shavings, shredded newspaper, paper egg cartons, and brown leaves. Those high in nitrogen include food scraps, green grass or yard trimmings, coffee grounds, and manure. (Do not use feces from cats or meat-eating animals because of the potential for spreading disease organisms.)

You are now ready to begin monitoring the composting process using the methods outlined in Chapter 4. The composting process should take two to three months after the can is filled. At the end of this period, you can either leave the compost in the can or transfer it into other containers or an outdoor pile for the curing phase.

SODA BOTTLE BIOREACTORS

PURPOSE

Soda bottle bioreactors are designed to be used as tools for composting research rather than as a means to dispose of organic waste. They are small and inexpensive, enabling students to design and carry out individualized research projects comparing the effect of variables such as moisture content or nutrient ratios on compost temperatures.

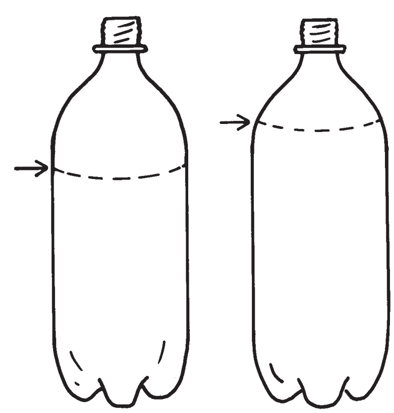
Use the instructions below as a starting point. Challenge students to design their own soda bottle reactors and to monitor the temperatures that their reactors achieve.

MATERIALS

- two 2-liter or 3-liter soda bottles
- Styrofoam plate or tray
- one smaller plastic container such as a margarine tub that fits inside the bottom of the soda bottle (optional—see Step 3, below)
- drill or nail for making holes
- duct tape or clear packaging tape
- utility knife or sharp-pointed scissors
- insulation materials such as sheets of foam rubber or fiberglass
- fine-meshed screen or fabric (such as a piece of nylon stocking) large enough to cover ventilation holes to keep flies out
- dial thermometer with stem at least 20 cm long
- chopped vegetable scraps such as lettuce leaves, carrot or potato peelings, and apple cores, or garden wastes such as weeds or grass clippings
- bulking agent such as wood shavings or 1-cm pieces of paper egg cartons, cardboard, or wood
- hollow flexible tubing to provide ventilation out the top (optional—see Step 8, below)

CONSTRUCTION

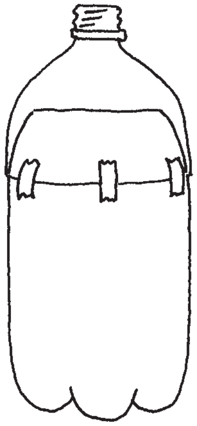
1. Using a utility knife or sharp-pointed scissors, cut the top off one soda bottle just below the shoulder and the other just above the shoulder. Using the larger pieces of the two bottles, you will now have a top from one that fits snugly over the bottom of the other.



2. The next step is to make a Styrofoam circle. Trace a circle the diameter of the soda bottle on a Styrofoam plate and cut it out, forming a piece that fits snugly inside the soda bottle. Use a nail to punch holes through the Styrofoam for aeration. The circle will form a tray to hold up the compost in the bioreactor. Beneath this tray, there will be air space for ventilation and leachate collection.

3. If your soda bottle is indented at the bottom, the indentations may provide sufficient support for the Styrofoam circle. Otherwise, you will need to fashion a support. One technique is to place a smaller plastic

container upside down into the bottom of the soda bottle. Other possibilities include wiring or taping the tray in place.



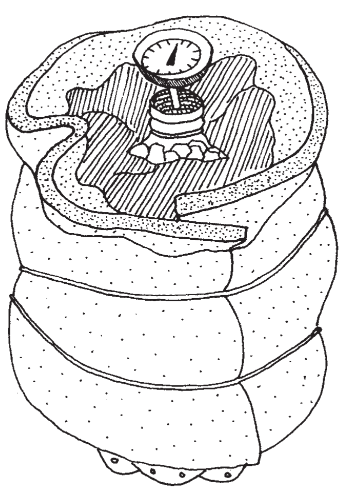
4. Fit the Styrofoam circle into the soda bottle, roughly 4–5 cm from the bottom. Below this tray, make air holes in the sides of the soda bottle. This can be done with a drill or by carefully heating a nail and using it to melt holes through the plastic. If you are using a plastic container to hold up the Styrofoam tray, you may need to drill holes through the container as well. The object is to make sure that air will be able to enter the bioreactor, diffuse through the compost, and exit through the holes or tubing at the top.

   Avoid making holes in the very bottom of the bottle unless you plan to use a pan underneath it to collect whatever leachate may be generated during composting.

5. Next, determine what you will compost. A variety of ingredients will work, but in general you will want a mixture that is 50–60% water by weight and has approximately 30 times as much available carbon as nitrogen (a C:N ratio of 30:1). You can estimate moisture by using the rule of thumb that the mixture should feel as damp as a wrung-out sponge, or you can calculate optimal mixtures using the procedures in Chapter 3 (pp. 47–48).

   Similarly, mixtures that will achieve optimal C:N ratios can be either estimated or calculated. Materials that are high in carbon include wood chips or shavings, shredded newspaper, and brown leaves. High-nitrogen materials include food scraps, green grass or yard trimmings, and coffee grounds. By mixing materials from the high-carbon and high-nitrogen groups, you can achieve a successful mixture for thermophilic composting. Try to include more than just a couple of ingredients; mixtures containing a variety of materials are more likely than homogeneous ones to achieve hot temperatures in soda bottle bioreactors. To calculate rather than estimate the amounts needed, use the equations in Chapter 3 (pp. 48–50).

   The particle size of compost materials needs to be smaller in soda bottle bioreactors than in larger composting systems. In soda bottles, composting will proceed best if the materials are no larger than 1–2 cm.



6. Loosely fill your bioreactor. Remember that you want air to be able to diffuse through the pores in the compost, so keep your mix light and fluffy and do not pack it down.

7. Put the top piece of the soda bottle on and seal it in place with tape.

8. Cover the top hole with a piece of screen or nylon stocking held in place with a rubber band. Alternatively, if you are worried about potential odors, you can ventilate your bioreactor by running rubber tubing out the top. In this case, drill a hole through the screw-on soda bottle lid, insert tubing through the hole, and lead the tubing either out the window or into a ventilation hood.

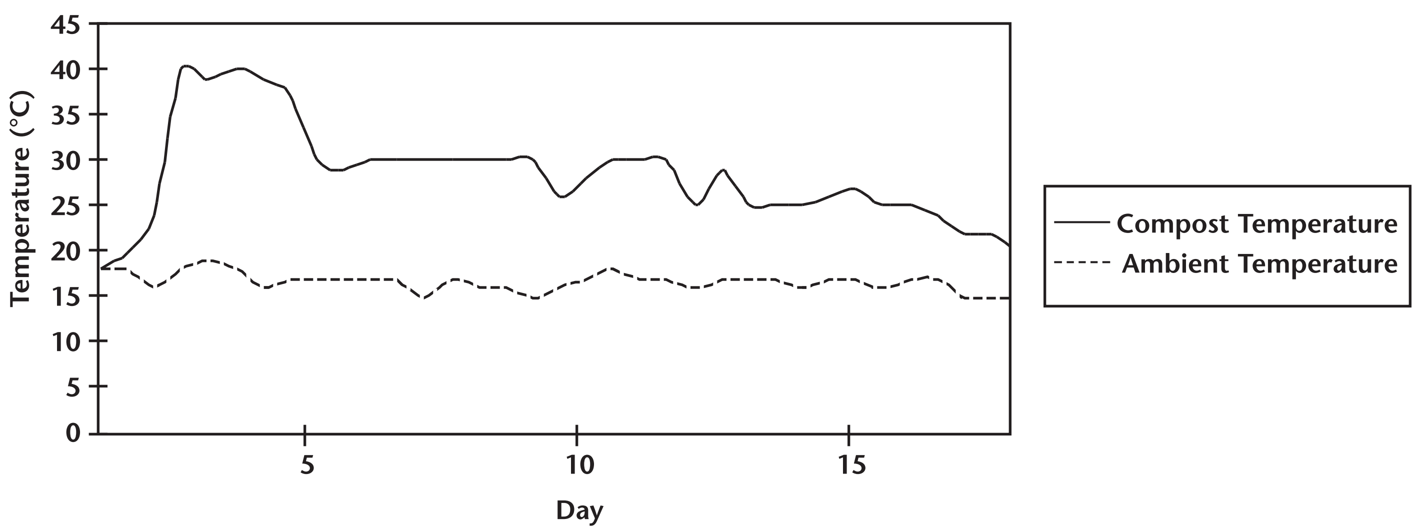
9. If you think flies may become a problem, cover all air holes with a piece of nylon stocking or other fine-meshed fabric.

10. Insulate the bioreactor, making sure not to block the ventilation holes. (Because soda bottle bioreactors are much smaller than the typical compost pile, they will work best if insulated to retain the heat that is generated during decomposition.) You can experiment with various types and amounts of insulation.

Now you are ready to watch the composting process at work! You can chart the progress of your compost by taking temperature readings. Insert a thermometer down into the compost through the top of the soda bottle. For the first few days, the temperature readings should be taken at least daily, preferably more often. In these small systems, it is possible that temperatures will reach their peak in less than 24 hours. To avoid missing a possible early peak, use a max/min thermometer or a continuously recording temperature sensor, or have the students measure the temperatures frequently during the first few days.

Soda bottle reactors generally reach temperatures of 40–45°C, somewhat lower than temperatures achieved in larger composting systems (Figure 2–2). If conditions are not right, no noticeable heating will occur. Challenge your students to design systems that show temperature increases, and use their results as a starting point for a discussion of the various factors that affect microbial growth and decomposition (C:N ratios, moisture levels, air flow, size, and insulation).

Figure 2–2. A Typical Temperature Profile for Soda Bottle Composting.



Research Possibility: *How do different soda bottle reactor designs affect the temperature profile during composting? How do different mixtures of organic materials affect the temperature profile in soda bottle reactors?*

Because soda bottles are so small, you may not end up with a product that looks as finished as the compost from larger piles or bioreactors. However, you should find that the volume shrinks by one-half to two-thirds and that the original materials are no longer recognizable. You can let the compost age in the soda bottles for several months, or transfer it to other containers or outdoor piles for curing.

WORM BINS

PURPOSE

Thousands of schools around the world use worm bins to teach students about recycling organic wastes and to involve them in investigations of worm biology and behavior. Vermicomposting (from the Latin *vermis*, for worm) is also used in large-scale industrial applications, with waste streams including sewage sludge, animal manure, and food wastes. Unlike thermophilic composting, vermicomposting does not get hot. In fact, temperatures above 35°C would kill the worms. In all types of composting, microorganisms play the key role in decomposition. In vermicomposting, worms help by physically breaking down the organic matter and chemically altering it through digestion. The end product, vermicompost, contains plant-available nutrients and compounds that enhance plant growth.

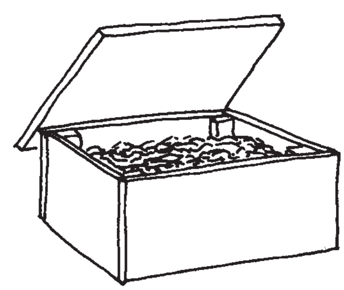
Vemicomposting provides a wealth of opportunities for student research on topics such as worm behavior, life cycles, feeding preferences, and effects of worms and other invertebrates on decomposition. For more information on the biology and ecology of worms, see Chapter 1 (pp. 22–26).

MATERIALS

- a worm bin (see Steps 1 and 2, below)
- bedding (see Step 3, below)
- red worms (see Step 4, below)
- food (see Step 5, below)

CONSTRUCTION

1. **Decide on the bin size:** If you plan to use your worm bin for classroom observation and scientific investigation, but not for recycling of a set amount of food scraps, then any size bin will do. It can be as small as a shoe box or as large as you'd like to make it. However, if you plan to put in a set amount of food, such as all the non-meat lunch scraps from your classroom, then you will need to calculate the size of the bin based on the amount of food you plan to compost. Conduct a waste audit by collecting food scraps for a week and then weighing how much has accumulated. The rule of thumb is that roughly a square foot of bin space is needed for every pound of waste composted per week. (Since red worms are surface dwellers, surface area rather than volume is used for this calculation).



2. **Prepare the bin:** Many different types of containers are successfully used for vermicomposting. Wooden boxes, Styrofoam coolers, and plastic tubs all are possibilities. Whatever type of container you use, providing adequate ventilation is the key to success. Worm bins usually have a tight-fitting lid, with many small ventilation holes drilled through the bin sides for ventilation. The most fail-proof design uses drain holes in the bottom, with the bin propped up on blocks so that excess moisture can drain into an underlying tray. (Most food scraps are wet, and without drainage the bedding can become mucky and

anaerobic.) If you want to build a self-contained unit, it is possible to maintain proper moisture conditions without bottom drainage, as long as you are willing to keep a watchful eye on the moisture level and mix in dry bedding whenever the compost mixture begins to look soggy. (You want the mix to be moist but without puddles.)

Some commercially available worm bins use a tiered system of stacking bins. When the worms have depleted the food in the bottom bin, they crawl upward through holes or mesh into the next higher bin, where fresh food scraps have been added. Students may want to design a system such as this, using a stack of mesh-bottomed trays or boxes.

3. **Prepare the bedding:** The bedding holds moisture and contains air spaces essential to worms, and it gets eaten along with the food wastes. Common types of bedding include strips of newspaper, office paper, corrugated cardboard, or paper egg cartons. Machine-shredded paper or cardboard is ideal if available. If not, paper or cardboard will need to be torn into strips 1–3 cm wide. Other popular bedding materials include leaves, sawdust, peat moss, and shredded coconut fiber, which is similar in consistency to peat moss and is available from companies that sell red worms.

   Whatever type of bedding you choose, you will need to soak it until saturated, then drain off any excess water. Place the damp bedding in the bin, filling it to a depth of about 20 cm. Do not pack the bedding down—leave it loose to provide air spaces for the worms. You may wish to add a couple of handfuls of sand or crushed egg shells to provide the grit that worms use to grind their food.

4. **Add the worms**: The species most commonly used for vermicomposting is *Eisenia fetida*, commonly called red worms, red wigglers, manure worms, or tiger worms. You will need a pound or two (1000–2000 worms) to get started, after which the worms will replace themselves as long as conditions remain suitable for their reproduction and growth. If you can't obtain *Eisenia fetida* from a composter or worm farm in your community, you can mail-order them.[1] *Lumbricus terrestris*, the common night crawlers found in gardens, will not thrive in worm bins because they are adapted to burrowing deep into soil. In contrast, *Eisenia fetida* are surface dwellers, adapted to living in organically rich surface soils and the overlying layers of decomposing leaves and organic debris.

5. **Add food:** Bury a few handfuls of fruit and vegetable scraps in the bedding. Wait several days for the worms to acclimatize, then gradually increase the amount of food based on how quickly it is disappearing. You can add food every day, or you can leave the bin untended for a week or even up to a month once it has become established.

   Any food that humans eat can be fed to worms, but some types are more suitable than others for indoor worm bins. Vegetable and fruit scraps are ideal, such as carrot peels, melon rinds, and apple cores. Coffee grounds, tea bags, bread crusts, and pasta all are suitable. If you add a large amount of citrus fruits or other acidic foods, it would be a good idea to monitor the pH to make sure it does not drop below the 6.5 to 8.5 range that is ideal for worms (see **pH**, below). It is best to limit the quantities of foods such as onions and broccoli, which tend to have strong odors as they decompose. Avoid meats, fats, and dairy products because these foods decompose slowly and may attract pests. You may want to cut or break large food scraps into small pieces for faster decomposition.

6. **Cover the bin** with a lid made of plastic, wood, or fabric to provide shade and conserve moisture.

7. **Locate the bin** in an area where it will not be exposed to extreme heat or cold. Red worms thrive at room temperature (15–25°C). They can survive in colder locations, but their rate of feeding will be reduced. They will die if they freeze or are subjected to temperatures above about 35°C. Avoid placing bins on surfaces that vibrate, such as the surface of washing machines, because the vibrations may trigger the worms to try to leave the bin.

MAINTENANCE

Maintaining a worm bin is simple. No mixing or turning is needed. All you need to do is to keep an eye on the amount of food, the moisture level, and possibly the pH, and to harvest the worms once the composting process is completed.

Food: Monitor the bin and add more food once the first scraps have started to disappear. How much food should you add? Red worms can eat up to half their weight per day, so a simple calculation based on their initial weight will provide a guideline for the appropriate amount of food. But, it is important not to rely on numbers alone—instead, check once a week or so to see if the food is disappearing, and adjust feeding levels accordingly.

Research Possibilities: *Worm feeding provides many opportunities for experimentation. Which types of food disappear the fastest, and which decompose slowly? Which foods tend to attract large groups of worms, and which ones do the worms avoid? Does the initial size of food particles affect how quickly they disappear?*

Moisture: If the bedding appears dry, add moist food scraps or lightly spray with water. If the bedding becomes soggy, add dry newspaper strips or other dry bedding material, and avoid adding wet food scraps until the moisture is back in balance.

pH: Although not essential, periodic pH measurements are useful in monitoring the conditions in your worm bin. Simply insert pH paper into damp vermicompost, or follow one of the other measurement techniques described on p. 54. *Eisenia fetida* do best at a pH around neutral or slightly alkaline, in the range of 6.5 to 8.5. If conditions become acidic, mix in a sprinkling of crushed egg shells or powdered lime ($CaCO_3$, *not* hydrated lime).

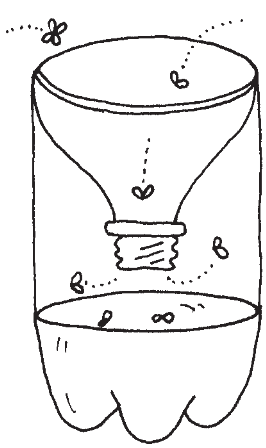
Bedding: Within several months, most of the original bedding will have been replaced with brown, soil-like castings. At this point, it is time to remove the completed vermicompost and harvest the worms to start a new batch. This can be done all at once or through a gradual process (see **Harvesting the Worms**, p. 39).

TROUBLESHOOTING

Escaping Worms: When you first put worms into fresh bedding, they may initially try to escape. If you keep the lid on, they will gradually get acclimatized and remain in the bin even when it is uncovered. Once your vermicomposting is underway, worms attempting to escape is a signal that conditions in the bin are not favorable. The bedding may be too moist, which you can solve by mixing in some dry bedding. Or, the conditions may have become too acidic (see **pH**, p. 37). Another possibility is that the worms are not getting enough to eat. If all of the food and bedding have decomposed, the remaining castings will not continue to adequately nourish the worms, and it is time to harvest them and begin again with fresh bedding.

Worm Mortality: In a properly maintained worm bin, worms will continually die and decompose without being noticed, and the population will replenish itself through reproduction. If you notice many dead worms, there is a problem. Either the mixture has become too wet or dry, too hot or cold, or available food supplies have become depleted (see remedies listed under **Escaping Worms**, above).

Fruit Flies: Although fruit flies do not pose any health hazards, they can be a nuisance. To avoid breeding flies in worm bins, make sure to bury all food scraps in bedding. Monitor the decomposition of food that you add, and hold off on adding more if the scraps are sitting longer than a few days before disappearing. Keep bedding material moist but not too wet, since overly wet conditions encourage the proliferation of fruit flies.



If a fruit fly problem does develop, stop adding food until the worms have had a chance to catch up with the existing supply, and add dry newspaper strips if the bedding appears soggy. If the outdoor weather is suitable, you might want to air out the bin by leaving it uncovered outside for a few hours.

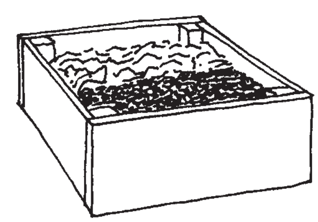
You can build a simple but effective fruit fly trap that can be placed either right in the worm bin or anywhere in the classroom where flies congregate. Take a soda bottle and remove the lid. Cut the bottle in two, with the top part slightly shorter than the bottom part. Pour cider vinegar into the bottom part to a depth of about 2 cm. Then, invert the top of the bottle into the bottom, forming a funnel leading into the bottle. Fruit flies will be attracted to the vinegar, and they will drown or get trapped.

Other Invertebrates: Many types of soil invertebrates can inhabit worm bins without causing problems. If you use leaves for bedding or if you add soil for grit, you are likely to introduce into the bin a variety of invertebrates such as millipedes, sowbugs, slugs, and springtails (see pp. 19–21 for a description of common soil invertebrates). These organisms are decomposers and will aid in making compost. You may notice some tiny white worms in your vermicompost. These often are mistaken for baby red worms but can be distinguished by their white rather than pink coloration. They are potworms, or enchytraeids (see p. 19). Potworms will not harm red worms, and they will aid in decomposition, but if you have many of them in your bin it may indicate that conditions have become acidic. Mites usually are present in worm bins but rarely present a problem. However, if your vermicompost becomes too moist or acidic, it may become infested and appear to be swarming with mites. At this point, it is a good idea to harvest the worms, rinse them, and start over with new bedding and food in a clean bin.

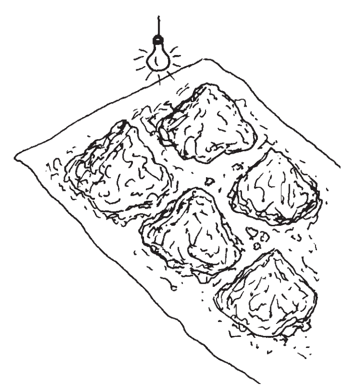
Odors: A properly functioning worm bin will not have a noticeable odor. If unpleasant smells do develop, there are several possible reasons. The bedding may have become too wet or may not be getting enough air. Another possible source of odors is food such as onions or broccoli that are naturally smelly as they decompose, or foods such as dairy products that turn rancid because they are not eaten rapidly by worms. To correct a problem of this sort, simply remove and dispose of the offending foods.

HARVESTING THE WORMS

If you want to use the compost on plants, and reuse the worms to make more compost, you will need to harvest the worms. This is generally done after three or more months, when the bin is filled with compost and very little bedding remains. Two methods are commonly used to separate worms from the castings. In the slower but easier method, you simply push all of the worm bin contents to one-half of the bin. In the empty half, start a new batch of compost by providing fresh bedding and food scraps. Over the next several weeks, the worms will move to the side with new food, conveniently leaving their castings behind in the other section. After this occurs, you can remove the finished compost and replace it with fresh bedding.



A faster but more labor-intensive method of removing worms involves dumping the entire contents of the worm bin onto a sheet of plastic or paper in a sunny or brightly lit location. Shape the compost into several cone-shaped piles. The worms will burrow downward to avoid light. Scoop the top layer off each pile, wait a few minutes for the worms to burrow farther, and then remove the next layer of compost. Repeat this process until the worms have become concentrated at the bottom of each pile. Collect the worms, weigh them (to compare with your initial mass of worms), and put them back in the bin with fresh bedding.



***Research Possibility:** Design some experiments to find a better way of separating worms from compost. Are there any chemical or physical factors that will cause the worms to migrate, without impairing the beneficial properties of finished vermicompost?*

USING VERMICOMPOST

Once the food and bedding have fully decomposed, vermicompost can be used in the same way as other types of compost, either mixed into the soil or added to the surface as a top dressing. By mixing vermicompost with water, you can make a compost tea solution that enriches plants as they are watered. Many claims are made about the growth-inducing properties of vermicompost. See Chapters 6 and 7 for ideas about experiments to test the effects of various types of compost on plant growth.

Research Possibility: *How does vermicompost compare with thermophilic compost in plant growth experiments?*

OUTDOOR COMPOSTING

Outdoor composting systems can be larger than indoor bioreactors, allowing students to compost greater quantities of food scraps and landscaping trimmings. Although slightly less convenient than a system right in the classroom, students can monitor the temperature, moisture content, and other aspects of an outdoor system, and they can bring samples of the compost inside for observation and experimentation. Many schools have developed outdoor composting systems into demonstration sites, with signs explaining the composting process.

Unlike indoor systems, outdoor systems are home to a diverse range of invertebrates such as millipedes, centipedes, earthworms, pseudoscorpions, beetles, snails, mites, and springtails. These organisms form an intricate food web, and they can be used for illustrating ecological principles as well as for investigating topics such as life cycles and feeding preferences.

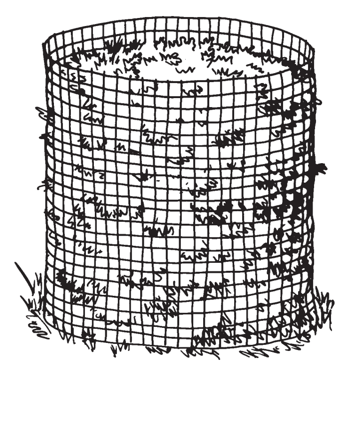
In some outdoor systems, the organic materials are periodically mixed or "turned." This redistributes materials that were on the outside of the pile and exposes them to the higher levels of moisture, warmth, and microbial activity found in the center. It also fluffs up the compost materials, allowing better air flow through the pile. The net result generally is to speed up the composting process (see pp. 10–11).

Bins should be located close to a water source in case they become too dry. Good drainage is also important in order to avoid standing water and the build-up of anaerobic conditions. Other considerations include avoiding exposure to high winds which may dry and cool the pile, and to direct sunlight which may also dry out the pile. The pile should not touch wooden structures or trees because it may cause them to decay. There should be space nearby for temporary storage of organic wastes.

There is an endless variety of outdoor composting systems. Bins may be purchased or constructed. Three types of systems are described below. Refer to *Composting: Wastes to Resources* (Bonhotal and Krasny, 1990) for more details on outdoor bin designs, or have the students design their own outdoor bins using readily available scrap materials.

HOLDING UNITS

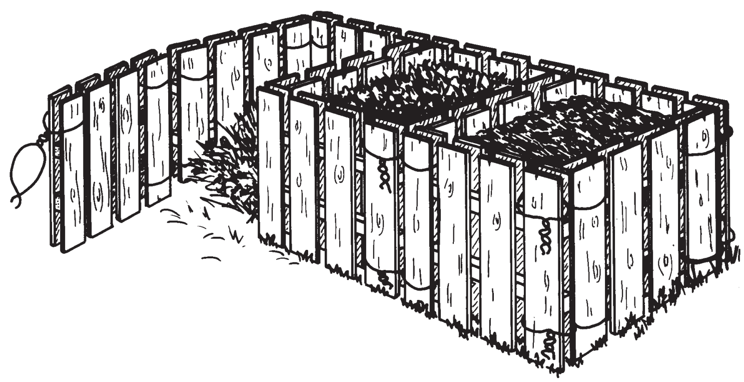
Holding units provide a low-maintenance form of composting. You simply build the unit, fill it with organic materials, and then wait for the materials to decompose. A holding unit can be any container that holds organic materials while they are breaking down. The unit should be about a cubic meter in size (1 m x 1 m x 1 m), and it can be built from wire mesh, snow fence, cinder blocks, wooden pallets, or other materials. You can fill holding units with high-carbon materials such as autumn leaves and yard trimmings, realizing that these materials by themselves will not heat up and will require a year or more to fully decompose. If your system is dominated by leaves, you may want to avoid adding any food scraps, which might attract rodents or raccoons during the slow decomposition process. Alternatively, if you start with a mix that has the



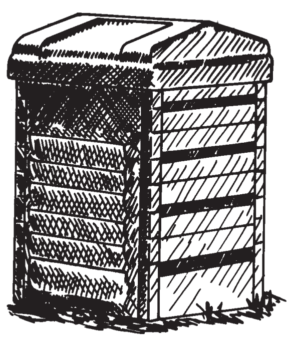
right C:N ratio and moisture level to become thermophilic, food scraps should break down quickly before any pests become a problem.

TURNING UNITS

A turning unit looks like three holding units placed side by side. Each unit should be a cubic meter (1 m x 1 m x 1 m) in size. Leave one side open or build a gate along one edge for easy access. Fill one bin at a time, using a mixture of high-nitrogen and high-carbon materials. For rapid



composting, turn the contents into the empty adjoining bin every week or two, or each time the temperature begins to decline. A pile that is kept "hot" like this should produce compost within a couple of months, although an additional period of curing is necessary before the compost is used for growing plants. The final bin provides the space needed for curing while a new batch of compost is started in the first bin.



ENCLOSED BINS

For small-scale outdoor composting, enclosed bins are an option. They can be purchased from home and garden centers or inexpensively built from a large garbage can. Simply drill 2-cm aeration holes in rows at roughly 15-cm intervals around the can. Fill the cans with a mixture of high-carbon and high-nitrogen materials. Stir the contents occasionally to avoid anaerobic pockets and to speed up the composting process. Although no type of bin is rodent-proof, enclosed bins do help to deter rodents and are popular for food scrap composting.

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[1] Worms are available by mail from sources such as Beaver River Associates, PO Box 94, West Kingston, RI 02892 (401) 782–8747, or Flowerfield Enterprises, 10332 Shaver Rd., Kalamazoo, MI 49002 (616) 327–0108.