Chapter 5

Vermicomposting

Objectives

1. Define vermicomposting and describe its important role in waste reduction.
2. Understand how vermicomposting differs from backyard composting.
3. Understand basic worm biology.
4. Define the qualities of composting worms, particularly *E. fetida*.
5. Understand the difference between finished backyard compost and vermicompost and become familiar with using vermicompost.

Terms Defined in this Chapter:

Anecic
Castings
Clitellum
Cocoon
Coelomic fluid
Crop
Dorsal vessel
Eisenia fetida
Endogeic
Epigeic
Gizzard
Hermaphrodite
Invertebrate
N-P-K
Pharynx
Photophobic
Prostomium
Pseudoheart
Setae
Ventral vessel
Vermicompost
Vermicompost Tea
Vermicomposting

Study Materials

(Please note: Much of the information contained in this and the following chapter is derived from M. Appelhof's excellent book, *Worms Eat My Garbage* and from *Worm Digests* No. 19 and No. 23. Please refer to these wonderful resources to supplement your training.)

"A rind is a terrible thing to waste!"
-bumper sticker

What is Vermicomposting?

The term "***vermicomposting***" comes from the Latin "vermis" (meaning worm), and refers to the ***controlled degradation of organic matter primarily by earthworm consumption.***

Although commercial vermicomposting systems can be specialized to remediate virtually any organic material, home systems are designed to handle food waste. **Home vermicomposting systems** generally use one earthworm species, the "redworm" ***Eisenia fetida*** (pronounced "i SEE nee a FET id a"), and its associated organisms to ***break down organic waste into material containing nutrients for plant growth*** (ref. Appelhof, *Worms Eat My Garbage*, p.148).

Why Vermicompost?

As Master Composter/Recyclers, our mission is waste reduction. Clark County buries almost 50,000 tons of food waste per year, and at 20.4%, food was the single largest component of the 2012 solid waste stream. Food waste sent to our landfills takes space, costs money, uses energy, and generates methane gas. Food that is put in a garbage disposal and flushed into our sewers wastes water and places a significant burden on our water treatment plants. More importantly, ***food wastes are a valuable organic resource***. Plants grown with vermicompost require fewer chemical fertilizers and are more pest and disease resistant. Like backyard composting and recycling, vermicomposting is a method of converting a problem into a solution.

How does Vermicomposting differ from Yard Waste Composting?

If we can add food wastes to our backyard bins, why vermicompost? Composting, as you recall, is a method of solid waste management whereby the organic component of the solid waste stream is biologically decomposed under controlled conditions to produce a valuable end product. Yard waste composting is designed to encourage microorganisms (mainly bacteria, fungi and actinomycetes) to dominate the system and a well managed pile passes through a bacterially intense thermophilic phase. Vermicomposting, in contrast, is controlled in such a way to encourage many more earthworms than would be found in a yard waste system. ***The joint action of worms and mesophilic microorganisms decomposes organic matter and vermicomposting does not involve a thermophilic phase***. Because the dominant organisms differ, there are differences in the end products produced. Vermicomposting produces a unique end product that, as you will learn, is truly "Gardener's Gold."

In addition to their chemical and biological differences, composting and vermicomposting systems are managed differently, and vermicomposting has many unique advantages. Table 11 highlights some of the key advantages of vermicomposting. Many people use both systems and find that, although they are different, they are equally valuable.

"Vermi-terminology" 101

Becoming a Master Composter/Recycler has many benefits, not the least of which is having a great excuse to toss around Latin phrases. In addition to making us seem worldly and erudite, learning and using the scientific names of the worms avoids confusion. Common names abound and the same worm may have more than 10 names or three different species may share one name. The composting worm, ***Eisenia fetida,*** is commonly called a redworm, red wiggler, manure worm, red hybrid, fish worm, dung worm, striped worm, tiger worm and apple pomace worm (ref. Appelhof, *Worms Eat My Garbage*, p.38). Since successful vermicomposting requires using the correct worm species, it is important that we learn and teach the scientific names and terms.

Scientists classify all living organisms into **kingdom, phylum, class, order, family, genus and species**. Color, size, external body structure, internal structure, preferred environment, feeding and reproduction patterns are all clues to classification. Most organisms are referred to by their

Table 5-1. Advantages of Vermicomposting.

Consideration	Backyard Composting	Vermi-composting	"Vermi-Comment"
Size	Relatively large pile or bin required.	Small space requirement.	Great for condo, apartment dwellers.
Location	Outdoors only.	Indoors, Garage, Basement, Outdoors.	Very flexible.
Maintenance	Frequent turning and moisture adjustments necessary.	No turning, worms do the work. Rarely needs a moisture adjustment.	Easy for anyone! Little or no physical labor involved.
Predominant Organisms	Bacteria, fungi.	Redworms, bacteria, fungi.	Worm bin conditions favor high worm populations.
End Product	Finished compost is considered a soil amendment.	Vermicompost is considered plant food.	Vermicompost is a significant source of bio-available plant nutrients and beneficial microbes.
Entertainment Potential	Lots of interesting insects to see under a magnifying glass—will keep kids busy for at least 15 minutes.	KIDS LOVE WORMS. Worms and their worm-bin friends are a guaranteed hit! Fishermen will enjoy a captive source of bait, too.	Both systems can be fun and educational. Turn off the TV and get out a magnifying glass.

genus and species names, wherein the name is italicized, the genus is always capitalized and the species is lowercase (example: Human beings = ***Homo sapiens***). Genus and species names are often abbreviated by using just the first letter of the genus name followed by a period and the full species name, for example *Homo sapiens* is abbreviated to *H. sapiens*.

All worms belong to the **Kingdom Animalia (animal)** and the **Phylum Annelida (segmented).** Earthworms belong to the **Class Oligochaetae** while their relatives the aquatic worms and leeches are in a different class. We will focus on the most familiar **Family** of worms, the **Lumbricidae.** The Lumbricidae family includes the common nightcrawler, ***Lumbricus** (genus)* ***terrestris** (species)* and the two most common vermicomposting worms, ***Eisenia fetida*** and ***Eisenia andrei.*** Another family, the **Megascolecidae** is a huge family that includes a few less common species used for vermicomposting.

Worm Biology 101

We are all familiar with the soft, tubular invertebrates we call worms. More than 7000 land-dwelling earthworm species inhabit the earth (ref. Edwards, *Soil Biol Primer*, p.H-1). There are species adapted to nearly every soil type and climate, but only a few worm species are used in vermicomposting. In order to understand why, we must first review a bit of basic worm biology.

All earthworms are ***invertebrates*** (have no backbone), breath oxygen, are ***photophobic*** (shun light), require high moisture levels and are ***hermaphrodites*** (have both male and female reproductive organs). Each earthworm species has specific characteristics that differentiate it, but all earthworms share the same fundamental physiology. Figure 5-1 illustrates the general features of an earthworm. The most important characteristics are discussed in detail below.

External characteristics of earthworms

- **Color**
  Worms range from colorless to deeply pigmented. Pigment can be present on only the top (dorsal) or bottom (ventral) surface of the worm or, cover the entire worm. Worms may be solid colored, striped or patterned. Pigment colors and patterns vary with species.

- **Size**
  Earthworms range from nearly microscopic to four feet in length! Yes, there is an Australian worm that is FOUR FEET LONG. Length and diameter varies with species.

- **Body Segments**
  Body segments are the circular bands that characterize all ***annelids*** (segmented worms). The number of segments varies with species.

- **Mouth/prostomium**
  Worms have no eyes and no teeth. Only foods that have been rotted by bacteria and protozoa are soft enough to be taken into the worm's mouth. A flap called the ***prostomium*** plugs the mouth opening as the worm moves and pushes food into its crop during feeding. The prostomium is covered with chemical receptors that act like eyes to sense food and the slime trails of other worms.

- **Skin**
  A worm's skin is like an external lung. It is covered in a mucous layer that dissolves atmospheric oxygen and transfers it to capillaries and blood vessels inside the body. Like us, worm blood contains hemoglobin that carries oxygen to the tissues.

- **Sensory Organs**
  Worms do not have eyes, but do have light sensitive organs in several places on the surface of their bodies. The most sensitive is on the front of the body near the prostomium. All worms are sensitive to light (photophobic), and excessive exposure will lead to paralysis and death. Worms also have sensitive nerves spread throughout their bodies that react violently to touch. Because birds, moles and other worm predators create soil vibrations as they hunt, all worms are sensitive to vibration. Vibration causes a panic attack and worms will try to escape to an area free of vibration.

- **Clitellum**
  Earthworms are born sexually immature, and the time to maturity varies with each species. One can identify a mature worm by the presence of a thick band or "saddle," called the

clitellum that encircles the worm. Depending on the species, the clitellum may be toward the mouth end, in the middle or toward the anus end of the worm.

- **Setae and Locomotion**
  Setae are a worm's "legs." Setae are tiny bristle-like structures that are arranged along the length of the worm. Setae can be arranged in various patterns. They may appear on only the ventral (bottom) surface of the worm's body, or go all around. The pattern of setae arrangements is one of the criteria scientists use to differentiate various worm species. A worm moves by planting the setae on the rear segments of its body in the soil to anchor itself. It then constricts the muscles that circle its body, causing the body to bulge forward and extend the worm's front end. The worm then plants the setae on the front segments of its body to hold it in place and releases the rear setae while constricting the long muscle running the length of the body to pull its back end forward.

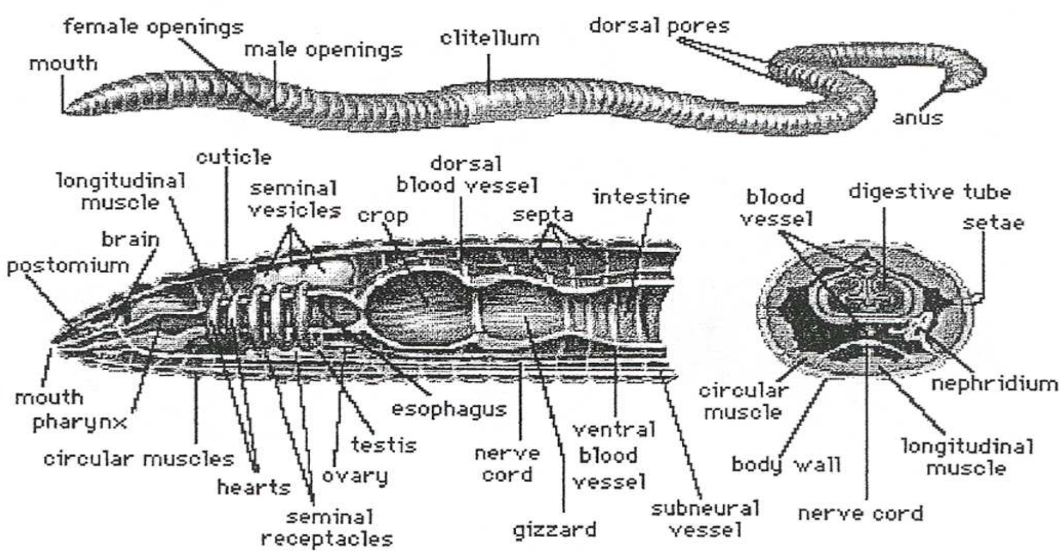
Internal characteristics of earthworms

- **Coelomic Fluid**
  Worms have no bones or cartilage. Their structure is due solely to the hydrostatic pressure of the thick ***coelomic fluid*** that fills the body cavity.

- **Blood Vessels and Hearts**
  There are three principal blood vessels in a worm's body: the ***dorsal vessel***, which runs above the alimentary canal, and the two ***ventral vessels***, which run along the bottom side of the worm. Worms have five "***pseudohearts***," which are really no more than valved enlargements of the blood vessels that move blood from the dorsal blood vessel to the ventral blood vessels.

- **Digestive System**
  Like birds, worms have no teeth and rely on their crop and gizzard to grind foods. After the mouth, the digestive system of the worm is basically a straight tube made up of specialized sections that runs from pharynx to anus. Food passes from the mouth into the pharynx. The ***pharynx*** secretes mucous that moves the food into the crop. The ***crop*** is basically a thin walled storage chamber that holds food until it enters the gizzard. The ***gizzard*** is a thick, muscular organ that grinds food particles with the help of gritty materials taken in with the food. In nature, sand and other fine grit work to grind food in a worm's gizzard. Foods ground in the gizzard pass into the ***intestine***. Here, intestinal bacteria digest them and the nutrients are absorbed into capillaries. Undigested materials, or ***castings***, are excreted through the ***anus***. Castings are rich in nutrients and microbes.

Figure 5-1. General Features of Earthworms (from Edwards, *Biology and Ecology of Earthworms).*



- **Reproduction**
  Earthworms are hermaphrodites, meaning each has both male and female reproductive organs. Although worms are technically capable of self-fertilization, reproduction generally requires two different worms. Earthworms are born sexually immature and each species matures at a different age. Only mature worms have a clitellum. Earthworms find their mates by using sensory organs located on the prostomium to follow each other's slime trails.

  Figure 5-2 illustrates earthworm mating and cocoon formation. When worms mate they lay close together with their heads pointed in opposite directions. Their bodies make contact at a point just above the clitellum so that the ovaries and testis of one worm line up with the clitellum of the other worm. During this contact sperm is exchanged and held in pores on the surface of each worm. Ova are not exchanged. Each worm holds its own ova in another pore on its surface. After sperm is passed, the worms separate. The clitellum of each worm then secretes a thick nutrient-rich mucous sheath. The outside of this sheath hardens, forming a shell, while the inside (closest to the worm's body) remains sticky. The worm then backs out of the hardening mucous, and as it backs out, the sticky inside passes over and collects the sperm and eggs from their pores and fertilization occurs. Once the mucous sacs are freed from the worms they seal on both ends and are called ***cocoons***. Cocoons are small and shaped like lemons.

Each mating often leads to multiple cocoons, and each cocoon contains several fertilized eggs. The nutrient-rich material in the cocoon feeds the developing worms and two or more baby worms usually hatch from each cocoon. Some species mate throughout the year, while others mate only during specific seasons. The number and incubation time varies with environmental conditions and with each species. Earthworms do not care for their young.

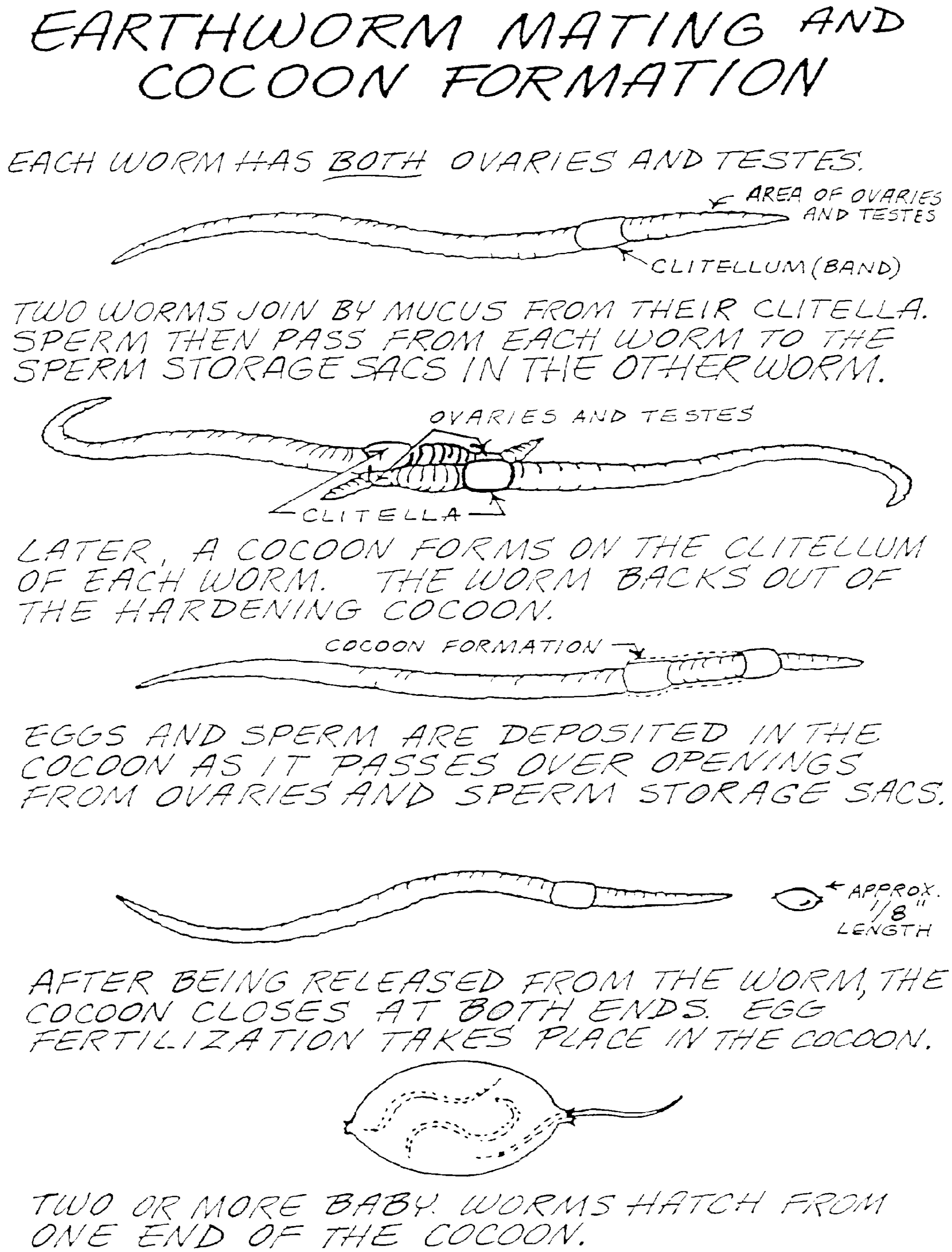
Each species of worm is a "closed species," which means that they can only reproduce and produce viable young with others of the same species. THERE IS NO SUCH THING AS A HYBRID WORM.

- **Lifespan**

  Earthworm longevity is species dependent. Various specialists report that certain species have the *potential* to live 4-8 years. In protected culture conditions (no predators, ideal conditions), individuals of *Allolobophora longa* have been kept up to 10 1/4 years, *Eisenia fetida* for 4½ years and *Lumbricus terrestris* for 6 years.

  Worms continue to grow once they reach sexual maturity, but once at this stage there is a much slower increase in weight until the disappearance of the clitellum indicates the onset of old age or senescence. During this period, there is a slow decline in weight until the death of the earthworm.

Figure 5-2. Earthworm Reproduction (from *Worms Eat My Garbage*. Copyright © 1997 Flower Press. Used with permission).



General characteristics of earthworms

- **Moisture, Temperature and pH Requirements**

  More than 75% of the total body weight of an earthworm is water. All earthworms are sensitive to moisture. The ideal moisture level varies with species.

  There are worm species adapted to nearly every temperature range. One species actually lives on the edges of fractured ice sheets in glaciers and feeds on blown-in pollen and algae! Thousands of species are adapted to temperate, sub-tropical and tropical climates. Only hot, dry deserts cannot support earthworms.

  Worm species vary in their pH (acid/base) tolerance. Some worms are extremely sensitive to pH and can survive only in a narrow range; others tolerate extremes.

- **Habitat**

  All earthworms can be divided into three categories based upon the soil they inhabit (ref. Edwards, *Soil Biol Primer*, p.H-3):

  Anecic worms: Anecic worms build and live in deep, permanent, vertical burrows that extend more than four feet into the soil. They feed on decaying organic matter that they pull into their burrows. Anecic worms tend to be large, have low reproductive rates and long lives. They have profound effects on organic soil formation, soil porosity, water penetration and plant growth. The common nightcrawler, *Lumbricus terrestris* is an anecic worm. Nightcrawlers can live in a worm bin, but they are slow decomposers and will not reproduce in a bin. They are not recommended for vermicomposting.

  Endogeic worms*:* Endogeic worms move and live in the top twelve inches of the soil. They do not build permanent burrows, but instead create extensive temporary channels as they move through the soil. Endogeic worms feed on mineral soil, are medium sized, tend to be lightly pigmented or have no pigment, and have a medium life span. Because they require mineral soil to survive, they cannot survive in a worm bin and are not used in vermicomposting.

  Epigeic worms: Epigeic worms are those species that prefer a plant litter environment to a soil environment. They live in or near decaying plant materials on the surface of the soil. They build no permanent burrows, feed on decaying organic material, are deeply pigmented, reproduce rapidly, tend to be small and are relatively short-lived. ***Epigeic worms are ideal for vermicomposting***. Species include *Eisenia fetida, Eisenia andrei, Perionyx excavatus* and *Eudrilus eugeneai*.

- **Predators**

  Our hard working, peaceful earthworms have enemies. Although these predators play an important role in balancing earthworm populations and ensuring genetic diversity in nature, we must strive to keep them out of our worm bins. Below is a brief description of the most common earthworm predators taken from the article entitled "Earthworm Predators" published in Worm Digest No.19.

One of the most deadly enemies is the common mole. Moles can consume 15-20 worms each day. Because both earthworms and moles create burrows, earthworms often fall prey to moles by innocently falling into their burrows. Several larger mammals also feed on worms. These include shrews, the European hedgehog, the red fox and the European badger. Birds are another earthworm enemy. We have all witnessed hungry robins searching the soil for hapless worms. Other birds including black birds, starlings, thrushes, seagulls and crows also dine on worms. In addition, snakes, salamanders and toads delight in earthworms.

Many invertebrates also prey on earthworms, including some species of centipedes, flatworms, slugs, leeches, beetles and parasitic mites.

Despite all these natural predators, earthworms have flourished worldwide for millions of years. The biggest threat they face comes from man. Heavy mechanical tilling and indiscriminate use of pesticides and fungicides kills more earthworms than all the natural predators put together. Hopefully, armed with knowledge, we can instill a new respect for earthworms.

Why is *Eisenia fetida* the preferred species for Vermicomposting?

The goal of any vermicomposting system is to efficiently recycle organic waste into a valuable resource. An ideal system is self-contained, self-sustaining, odorless, high-yielding, low maintenance and easy to operate. The system must mimic the worm's natural environment closely enough to optimize the feeding rate and encourage reproduction. Because vermicomposting systems contain no soil, they cannot sustain burrowing or soil-eating worms and only litter feeding epigeic worms are suitable. Of the many epigeic worm species tested in vermicomposting systems, none is as well suited as the redworm, *Eisenia fetida*. It is a voracious eater and will eat a wide range of organic materials. It reproduces well in captivity and can produce over four cocoons per week, each containing three babies. *E. fetida* is a forgiving creature who tolerates human handling and a wide range of temperatures, moisture levels and pH levels. Table 12 highlights the specific characteristics of *E. fetida*.

Less Common Worms Used in Vermicomposting

Although *E. fetida* is by far the most common North American vermicomposting worm, other species are used in Europe and the tropics. Although it is doubtful that you will be called upon to answer questions about these less common worms, you may wish to familiarize yourself with them. A quick summary is provided below. More detailed information can be found in the article entitled "The Worms Themselves" in Worm Digest No. 21, available at the MCR Program Office.

One species that commonly coexists with *E. fetida*, and is probably found in every worm bin in America, is ***Eisenia andrei***. *E. andrei* so closely resembles *E. fetida* that even experts have difficulty identifying them. Having more than one species in a worm bin is actually beneficial. As conditions change, the species best adapted will dominate and the system will function at peak efficiency.

Table 5-2. Characteristics of *E. fetida.*

Size	Usually 1.25-5 inches at maturity.
Number segments	80-120.
Color	Medium to deep red top and bottom, sometimes alternating red and buff stripes.
Setal arrangement	Setae are closely paired.
Habitat	Epigeic (litter dweller). Builds no permanent burrows.
Temperature range tolerated	39 – 90 degrees F. Optimal range between 65 and 75 degrees F.
Moisture level preferred	Tolerates 30-100%, optimal is 65-85%.
pH level	Tolerates pH 2-9, prefers pH 5.5-7.0.
Preferred foods	Decaying organic matter.
Appetite	At least ½ its body weight per day. Immature worms eat more than sexually mature worms (Think of them as teenagers!)
Age of sexual maturity	6 weeks.
Reproduction	Can mate year round, not seasonal. Prolific breeder, can produce over 4 cocoons per week, average 3 babies per cocoon.
Incubation time	Babies hatch after 32-73 days depending upon environmental conditions.

Most of the less common worm species cannot tolerate temperatures below 50°F and are used only in tropical climates. These include *Eudrilus eugeniae, Amynthas hawayanus, Dendrobaena veneta,* and *Polypheretima elongata.*

Because vermicomposting is in its infancy and so few worms have been studied, we can expect many exciting developments as the industry matures.

Other Creatures in the Worm Bin: The Worm Bin Food Web

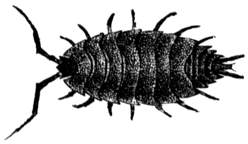
Although worms are the focus of vermicomposting, they do not work alone. The decaying organic materials in a worm bin are food to a wide variety of organisms. In fact, if you consider sheer numbers, there are fewer worms in the bin than any other organism!

Figure 5-3 illustrates the participants in the Worm Bin Food Web. This is the same figure you in a previous chapter because the backyard compost bin and the worm bin are simply two different man-made adaptations of natural decomposition. Both are systems to reduce solid waste. A vermicomposting system is simply controlled in such a way to encourage many more redworms than would be found in a backyard system.

Bacteria, Fungi, Actinomycetes: As in the backyard bin, the primary decomposers--bacteria, fungi and actinomycetes, are the most numerous organisms in the bin. They enzymatically break down and soften the raw organic matter to a state that the worms can digest.

Microscopic protozoa, nematodes: These diverse microscopic organisms are secondary decomposers that feed on bacteria.

Springtails (Colembola): Open any healthy worm bin and you'll see tiny white specks hopping around amid the decomposing material. Those specks are hardworking springtails. These tiny wingless insects are important primary decomposers of organic matter and the excrement of other animals.



Sow or pill bugs (Isopoda): The same "rollypolly" crustaceans you see in the backyard compost bin inhabit worm bins. Technically, the two belong to different species and the pill bugs roll up when threatened and sow bugs do not. They shred and consume tough woody, high celluose materials, making them easier for the worms to digest.

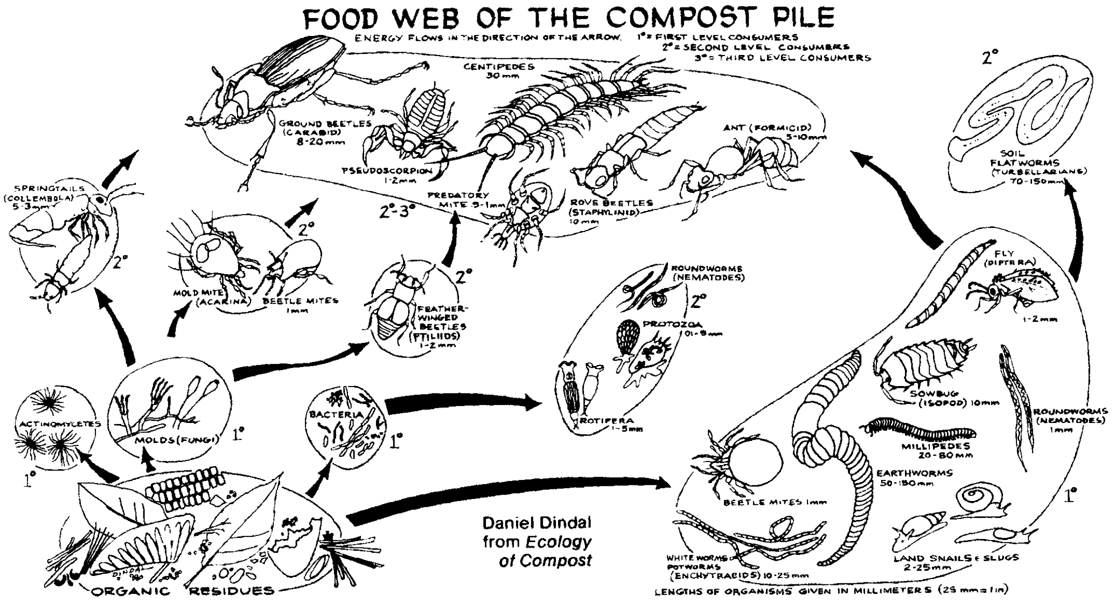
Mites (Acarina): Many different mite species inhabit a worm bin. Mites are tiny, spider-like insects that range in color from brown to red, to glossy white. By and large they are beneficial to a worm bin, but sometimes their populations can become so large that they stress the worms.

Pot Worms (Enchytraeids): Pot worms are tiny, threadlike, segmented white worms that are barely visible to the naked eye. Many people mistake them for baby redworms. They are beneficial and usually appear in a worm bins with a lot of finished vermicompost. As an added bonus, pot worms are prized as tropical fish food and some worm growers culture this species of worm as pet food.

Millipedes (Diploda) and Centipedes (Chilopoda): Millipedes and centipedes are often confused. Both are long, tubular creatures with many legs, but the similarity ends there. Millipedes have two legs per body segment and roll up when disturbed. They are gentle, SLOW moving, beneficial decomposers of organic matter.

Centipedes (below) are FAST moving predators that prey on beneficial insects and worms. Centipedes are venomous, they DO NOT benefit a worm bin and should be killed or removed from the bin if possible.

Figure 5-3. Compost Food Web (From Dindal 1971, *Ecology of Compost*).



Fruit Flies (Diptera): Although many home vermicomposters can tell long tales of fruit fly woe, these tiny flies and their larvae are actually voracious decomposers. Although they are distasteful to humans, they pose no health threat and are beneficial to the worm bin. Methods to control fruit flies will be discussed in Section C: Troubleshooting a Worm Bin.

Fungus gnats (Diptera): These tiny, black flies feed on fungi and are similar in appearance to fruit flies. Methods to control fungus gnats will be discussed in Section C: Troubleshooting a Worm Bin.

What is that rich, brown, crumbly material in my worm bin?

The end product harvested from a worm bin is called vermicompost. ***Vermicompost is a "dark mixture of worm castings, organic material, and bedding in various stages of decomposition, plus living earthworms, cocoons and other organisms present"*** (ref. Appelhof, *Worms Eat My Garbage*, p.110). Every harvest produces vermicompost with varying amounts of worm castings.

Worm castings are "deposits that moved through the digestive tract of the worm" (ref. Appelhof, *Worms Eat My Garbage,* p.110), or to put it bluntly, worm manure. Worms are, in many ways, a small version of a cow, in that the bacteria and fungi in a worm's gut digest the food for the worm. The digestive tract of the worm is an amazing "bioreactor". The worms "ingest sand, silt, clay, dead plant material, bacteria, fungi, protozoa, nematodes, the odd insect larva, microarthropods and so forth. Inside the gut of the worm, conditions are perfect (good moisture and we believe, well aerated) for the bacteria and fungi to speed up their growth processes and decompose more organic matter" (ref. Soil Food Web [Online], Available at www.soilfoodweb.com/). As organic matter passes through the worm's gut, it undergoes "chemical changes, deodorization and neutralization, so that the resultant ***castings are a practically neutral humus, rich in water-soluble plant food, immediately available for plant nutrition***" (ref. Barrett, *Harnessing the Earthworm* p.9). Worm castings contain as much as 40% more humus than is normally found in the top six inches of soil. In addition, worm castings are alive with thousands of beneficial bacteria and fungi. These organisms literally cover the root and leaf surfaces of plants, making them resistant to pathogenic attack.

How does Vermicompost differ from Yard Waste Compost?

Humus is a complex system of large molecules whose composition varies depending on the unique combination of simple building blocks that make up each sample. Humus provides color, structure, porosity, drainage and moisture holding capacity to the soil. Although both finished compost and vermicompost are considered humus and there is a great deal of overlap between the two, they differ in several important ways.

Chemical Composition of Vermicompost

- **pH:** Like yard waste compost, vermicompost is considered almost pH neutral. Both vermicompost and backyard compost act as buffers in the soil, helping maintain a steady acid-base balance.

- **N-P-K:** Although ***N-P-K*** levels [percentage of Nitrogen (N), Phosphorus (P) and Potassium (K)] vary with feedstock**,** vermicompost in general is richer in nutrients than yard waste compost. As the worms digest and excrete organic matter, they concentrate nitrogen and other nutrients in their castings. Because castings pack more nutrients into a smaller volume, the nutrient percentages rise. N-P-K levels as high as 4-3-4 have been reported (Holcombe, *Casting Call*, 3(2), p.2), but an N-P-K of 1-1-1 is probably more typical. As far as plants are concerned, the amount of nitrogen is not as important as the chemical form of that nitrogen. The nitrogen in vermicompost is nitrate nitrogen, a form more available to plant roots than the ammonium nitrogen found in backyard compost (ref. Subler, *BioCycle*, 39(7), p.64).

- **Micronutrients**: Like yard waste compost, vermicompost also contains bioavailable magnesium, calcium, sodium, iron, manganese, copper, zinc and boron. All these trace nutrients are necessary for plant growth.

- **Heavy metals:** Humus of any kind has the capacity to bind toxic heavy metals and prevent plants from absorbing them. Because vermicompost is rich in humus, it plays an important role in soil detoxification.

Biological Composition of Vermicompost

The real value of vermicompost lies in its teeming microbial life. Studies done by Dr. Clive Edwards and his associates at the Ohio State University show that "vermicomposts were clearly distinguishable from [yard waste] composts, in that they had significantly greater cumulative microbial activity than the composts" and that "there are distinct differences between microbial communities found in vermicomposts and composts" (ref. Subler, *BioCycle* 39(7), p.63-66). They attribute their findings to the metabolic differences between the thermophilic bacteria that dominate the backyard system and the bacteria that line the guts of the worms. The microbes found in vermicompost are thought to play important roles in plant growth and disease resistance.

In addition to beneficial microbes, vermicompost is thought to "contain hormone-like compounds that accelerate plant growth" (ref. Dominquez, *BioCycle* 38(4), p.57-59).

Pathogen/Weed Seed Content of Vermicompost

In a yard waste compost pile, sustained high temperatures effectively kill most plant pathogens and weeds. As you know, vermicompost does NOT go through a thermophilic phase, and you may fear that vermicompost may contain pathogens and weeds. Although little data is available, preliminary studies show that many weed seeds and pathogens (including human disease pathogens) are destroyed as they pass through the worm's digestive tract. Worms "ingest the root-feeding nematodes, the pathogenic bacteria and fungi and the small size weed seeds. What they don't consume gets released from their bodies as fecal material, but in that material, pathogens, root-feeding nematodes and weed seeds have a very difficult time surviving the burst of growth of other organisms" (ref. Ingham, *BioCycle*, 39(11), p.18).

In summary, vermicompost is a storehouse of plant nutrients, growth stimulators and beneficial microbes. It is vital to soil porosity, it aids in moisture retention and it contributes to soil structure. A "gardener's gold," vermicompost truly brings life to sand, silt and clay.

Using Vermicompost

- **Seed Beds:** Spreading a little vermicompost into a prepared seed row will provide germinating seeds and seedlings with nutrients and beneficial microbes.

- **Top Dressing:** Vermicompost can be used to top-dress plants. To top-dress, simply sprinkle vermicompost about ¼" deep around the base of each plant out to the drip line (ref. Appelhof, *Worms Eat My Garbage*, p.118). Vermicompost is rich in available plant nutrients and a little goes a long way. Unfortunately, you will rarely have enough vermicompost to top dress all your plants. Make sure to gently work the vermicompost into the soil with a garden fork so that it does not dry out on the soil surface. ***Completely dry worm compost is impossible to re-wet, low in microbial life and will not release its nutrients into the soil.***

- **Transplanting:** When transplanting vegetable, flower or ornamental plant seedlings, simply toss a handful of vermicompost into the prepared hole; then add the seedling, soil and water.

- **Potting Media:** Vermicompost can be used to supply up to ¼ the volume of potting media.

- **Vermicompost Tea:** Like backyard compost, vermicompost can be extracted to make a microbially rich tea. Because the mix of organisms in vermicompost differs from that present in backyard compost, the resulting tea will differ.

Vermicompost
Bins & Systems

Objectives

1. Become familiar with both low and hi-tech worm bin systems.
2. Be able to set up a simple worm bin.
3. Understand the pros and cons of various harvesting methods.
4. Know how to troubleshoot common problems.

Terms Defined in this Chapter:

Bedding
Continuous Flow System
Dump and Sort
Forced Screening
Harvest
Harvesting
Hi-tech vermicomposting system
Lateral Movement System
Layer feeding
Leachate
Migration Method
Pocket feeding
Quick and Dirty
Self-Screening
Simple bin
Stacking Tray System
Top feeding
Worm bin
Worm crawl
Worm fork

Study Materials

Recommending a Vermicomposting System

Composting worms are oxygen-breathing animals that require a moist, dark, temperate, vibration-free environment and a ready source of decaying organic matter. Their human companions prefer a small, attractive, convenient, odor-free, inexpensive, low maintenance system. The best vermicomposting systems are designed to mimic the redworm's ideal natural environment in a way that appeals to humans. Although open systems and windrows can be managed to encourage worms, home vermicomposting systems are easier to maintain if they are housed in a bin. ***"A worm bin is any container that corrals the worms and the composting activity"*** (see Worm Digest No. 23). As you will learn, systems can be as simple as a plastic box or as complex as an entrepreneurial builder can conceive.

As a Master Composter/Recyclers, we should become familiar enough with the common worm bin systems to recommend the system best suited to the individual's needs. Many people see their first worm bin at one of our workshops or fair booths and are intrigued by the concept, but need more information to get started. To help ensure that they have a positive first experience, we must assess their needs and level of knowledge. The most important questions to ask a prospective vermicomposter are:

1. How much food waste do you generate each week?
2. Do you want a system that will handle all your food waste?
3. Where would you like to place your system? Are aesthetics a concern?
4. Would you prefer one large bin or several smaller ones?

5. Are you a do-it-yourselfer or would you prefer to buy a ready-made system?
6. Is cost a factor?
7. Would you like hands-on contact with the worms or prefer to keep your distance?
8. How much work are you willing to do to maintain and harvest the bin?
9. What would you like to do with the finished vermicompost?

Many novices will not have ready answers to these questions and may need more information. Feel free to direct them to our Wormshops and to Mary Appelhof's *Worms Eat My Garbage.*

How Big a Bin?

The right size bin is vital to successful vermicomposting. Bin size is important to both the worms and their humans. Because *Eisenia fetida* are epigeic worms (surface feeding), the bin should be fairly shallow, ***no more than 18"-24" deep***. In addition, a successful worm bin must support enough worms to handle a family's food waste. The number of pounds of food waste/week determines the correct bin size. The easiest way to determine how much food waste is generated is to weigh it. Simply weigh your scraps every day or save them for a week and weigh the accumulated waste. For even more accuracy, weigh food wastes for several weeks and determine a weekly average. ***One square foot of bin surface area is required for each pound of food waste/week.*** A typical, non-vegetarian family of four produces about 6 pounds of food scraps per week and would need 6 square feet of bin surface area. As you will see in Section 8, adequate surface area can be obtained in several creative ways.

Where to Put a Worm Bin

Once a prospective vermicomposter knows how big a bin they'll need, the next step is to decide where to place it. It is important to consider many factors when locating a bin. These include:

- **Convenience/Appearance:** Because compostable food wastes are generated almost daily, it is important to locate a worm bin near the waste source. One of the real advantages to vermicomposting is its flexibility. Worm bins can be successfully managed indoors, in garages, in basements and outdoors. Most systems are attractive, and some connoisseurs even build furniture-quality bins designed for living room use!

- **Temperature Control:** Although *E. fetida* can tolerate a fairly wide temperature range, they are happiest between 65° and 75°F. In other words, worms thrive in the same temperature range as we do. In cold climates, worm bins can be kept indoors, or in a basement or garage. Although large outdoor bins tend to be self-insulating, during extremely cold weather, covering them with blankets, Styrofoam panels or hay bales can further insulate them. In hot weather, it is important to keep a worm bin wet (approximately 70% moisture). A wet bin will maintain its temperature through evaporation.

- **Vibration Control:** All worms are sensitive to vibration and will attempt to flee from its source. If they cannot flee, they will panic and eventually die of neural shock. No worm bin should be placed near an air conditioning compressor, clothes dryer, or any other source of vibration.

- **Aeration:** Worms are oxygen-breathing animals. Any worm bin must provide a system of airflow and be placed in an area free of toxic fumes.

- **Predator Control:** Any outdoor system must be protected from dogs, cats, birds, rodents and amphibian predators. A heavy bottom and top cover are usually adequate.

Which Bin is Best?

After deciding upon size and location, it's time to select a bin system. Before the early 1990s, virtually all bins were homemade wooden or plastic bins. Since then, consumer demand has fueled the creative fires of several entrepreneurs and their efforts have produced impressive hi-tech products.

Simple Bin Systems

Simple bins are by far the most commonly used. They appeal to the novice and expert alike. All low-tech vermicomposting systems share the same basic characteristics and are bedded, fed and harvested in the same ways. ***Virtually any opaque, non-toxic material can be used to build a worm bin.*** *Eisenia fetida* is exquisitely sensitive to light and will die if exposed for more than about 20 minutes. It is vital that an opaque material is used for the bin and that the system is covered. Wood and plastic are the most common materials used and simple systems can be homemade or purchased commercially.

Simple Plastic Bins

Probably the most common and widely used worm bins are plastic. Plastic bins are ***cheap and readily available***. Because they are usually ***small and neat***, they will fit anywhere and can be easily moved. In addition, plastic is inherently ***resistant to moisture and will not decompose***. A popular homemade bin can be made by retrofitting a 14-33 gallon plastic storage container with the ***Worm World-Insert Kit***. This kit is available through Beaver River Associates (see handout entitled "Worm bin sources") and consists of two air vents, a plastic tube and spigot, Styrofoam base material and a series of screens. This is the bin we use in the Master Composter/Recycler Wormshops.

Of course, any plastic bin can be used to make a serviceable worm bin. Obviously, one should avoid re-using any plastic container that previously held pesticides or other toxic chemicals. Simple plastic worm bins are also available commercially. They include the *Worm-a-Way*, *A Worm Friendly Habitat*, the *Worm Factory*, and *Worm's World Home Vermicomposting Units*. For in-depth reviews of each of these commercial systems, see Worm Digest No. 23.

Despite their many advantages, most simple plastic bins are too small to handle an entire family's wastes. Many people solve this problem by owning several small bins. Finally, unlike wood, ***plastic bins require careful attention to aeration and have a tendency to become too wet***.

Simple Wooden Bins

A popular alternative to a plastic worm bin is a simple homemade wooden bin. Wood has many advantages. First, ***wooden bins "breathe."*** Because it is naturally porous, wood facilitates the movement of oxygen and moisture. Secondly, wooden bins are ***easy to build.*** Only minimal woodworking skills and tools are required. Building plans for building a wooden bin are available free through the MCR Program. Chapter 3 of Mary Appelhof's book, *Worms Eat My Garbage,* also gives detailed construction directions. Wooden bins are usually built from cheap plywood or recycled wood (Please note: do not use any sort of chemically treated wood to build a worm bin. The chemical additives used to extend the outdoor life of wood are very toxic to worms). Finally, ***one of the real advantages of wooden systems is their flexibility***. The dimensions of the bin can be altered to suit the homeowner as long as the depth never exceeds 18-24 inches.

Like plastic bins, wooden bins have some drawbacks. The most serious is their ***relatively short life***. Wood is an organic material and it will eventually decompose along with its contents. The average outdoor wooden bin lasts approximately 3-5 years. In addition, wooden bins are ***heavy and difficult to move****.*

High-tech Vermicomposting Systems

Hi-tech systems are generally designed to reduce or eliminate the labor and time-intensive work of separating the worms from the finished vermicompost. Hi-tech systems can be divided into three basic types: **Stacking Tray Systems** like the *Can-O-Worms* and the *Wriggly Ranch*, **Continuous Flow Systems** like the *Earth Factory* and the *Eliminator*, and **Lateral Movement Systems** like, the *Worm-A-Roo*. Each has advantages and disadvantages. Please refer to Worm Digest, No. 23 for in-depth reviews of each system.

Handy Tools and Gadgets

Besides a bin, no tools are really required for vermicomposting. However, a few handy additions will make vermicomposting more convenient. These include:

- **Two food waste collecting containers with lids** (great use for those large yogurt and cottage cheese containers). Unless you dump your food wastes every day, these covered containers will contain the mess and reduce the likelihood of a fruit fly invasion.

- **A three pronged *worm-fork* or dull garden fork**. Forks are very handy for feeding, monitoring and harvesting a bin. Worm forks have flattened blades that are less likely to impale the worms. They are available through worm bin manufacturers. A dull 3-prong garden fork also works well, and a small garden shovel will do in a pinch.

- **A compost screen** may be used to break up clumps of finished vermicompost and generate a uniformly sized end product.

Creating a Worm Friendly Habitat in Your Bin

No matter which bin is selected, it is important to create a healthy worm habitat. Preparing and placing appropriate ***bedding*** into the worm bin is the first step. Bedding refers to the ***non-food waste, fibrous material placed in a worm bin***. Bedding is required for several reasons. First, bedding aids in aeration. Food wastes tend to be wet and soft, leading to compaction and anaerobic conditions. Fibrous bedding materials such as shredded dried leaves, shredded cardboard or paper, coir fiber and straw help maintain pore space for oxygen penetration. Usually, two or more of these materials are combined to vary particle size and ensure they don't compact. Second, food wastes tend to have high nitrogen content, and must be balanced with a carbon source in order to encourage rapid microbial decomposition. Remember, worms have no teeth and can only consume the softened, partially rotted remains of microbial decomposition.

The type, amount and technique for adding bedding to a worm bin varies with the bin type.

- **Bedding a Simple Wooden or Plastic Bin:** The ideal moisture level for *E. fetida* is 65%-85%. Any bedding material must be moistened with water until a handful of it feels a little wetter than a wrung out sponge i.e., a few drops of water fall when the material is squeezed. Most bedding materials can be soaked in water briefly before they are added to a bin, but straw must be soaked overnight to ensure adequate hydration. Simple bins are bedded by mixing enough damp bedding material to fill approximately 2/3 the bin capacity.

- **Bedding a Hi-Tech Worm Bin:** All hi-tech systems come with detailed bedding instructions. Please see Worm Digest No. 23 for details.

Worms: Where to find them and how many?

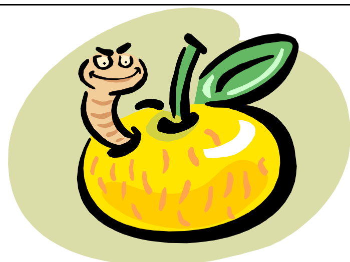
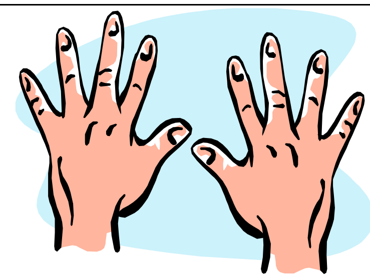
After the bedding has been selected and the moisture level is correct, it is time to add the worms. How many worms are needed to start a bin? Theoretically, two worms would eventually populate an entire bin, but the ***average home system requires at least 500-1000 worms to quickly jump-start the system***. If well fed, the starter worms will reproduce rapidly and quickly populate the entire bin.

Several free and low cost worm sources are available. In addition, many commercially available vermicomposting systems include the worms in the purchase price. Worms can be obtained from a friend with a worm bin, from the manure pile of a nearby farm or from commercial worm growers. Remember, KNOW YOUR WORMS! ***It is vital to use Eisenia fetida (or a combination of E. fetida and E. andrei) in a vermicomposting system***. Worms are usually sold by weight. **One pound of *E. fetid*a is equivalent to approximately 1000 worms.** Worms are usually shipped in moist peat moss or vermicompost and should be added to a prepared worm bin immediately upon receipt. Adding the worms is as simple as upending the container over the bedding and dumping out the worms! They will quickly make themselves at home.

Local worm sources are listed on the flier entitled "Redworm Sources" that is included in this section.

Food: What to Feed Your Worms and What NOT to Feed Your Worms
Composting worms are amazing creatures that, *in nature*, eat ANYTHING that was once living.

Table 13. What to Feed and What Not to Feed Your Worm Bin.

 **DO FEED** YOUR WORM BIN	 **DO NOT FEED** YOUR WORM BIN
Vegetable peelings, scraps (free of cooking oils)	Meat
Fruit peels, scraps*	Fat
Cereal (no milk)	Bones
Coffee grounds, tea (filters, bags and all!)	Fish
Egg shells	Whole eggs
Maple syrup, molasses (yes, you can add the pancakes your kids won't eat)	Oils including margarine, cooking oil, lard, grease
Bread, muffins, pizza crusts (free of cheese, butter or margarine)	Dairy products including milk, butter, cheese, whole eggs
Paper napkins, paper plates, tissues	Pet or human feces
All those moldy "science experiments" in the back of the refrigerator	Non-biodegradable materials like the rubber bands encircling green onions and asparagus

*Please note: large quantities of citrus rinds may be toxic to worms; add in moderation.

Natural foods include decaying plant materials, dead animals, and animal feces. As former Worm Digest editor Kelly Slocum says, "Our forests would be knee-deep in animal carcasses without worms and their voracious appetites!" Unfortunately, foods acceptable in the forest are not acceptable in a home worm bin. Remember that a worm bin is a controlled system living in a human world without the checks and balances of nature. A few simple rules will keep the worms happy and your bin safe and odor-free. Table 13 is a guideline for feeding your worm bin. The feeding categories are general and include many specific foods.

Several books, including *Worms Eat My Garbage* discuss adding small amounts of meat and cheese. Although an experienced vermicomposter may successfully compost meat, we do not recommend this practice. Meat, fats, oils and dairy products attract flies and vermin, tend to degrade anaerobically and stink. Pet and human feces may contain pathogens and never belong in a worm bin.

Food: How to Feed Your Worms

There are two main methods to feed a worm bin: ***pocket feeding*** and ***top or layer feeding.*** Pocket feeding is the most commonly used method for low-tech simple bins. Many of the hi-tech bins employ top or layer feeding techniques.

- **Pocket feeding:** For pocket feeding, the bin is bedded to a depth of 12”-18”. At each feeding, a small hole or pocket is dug into the bedding and the food deposited within. The pocket is then covered with a bit of bedding. Each time the system is fed, a pocket is dug into a new area. No new bedding is added, only feed stock. In this way, food, in varying states of decay, is eventually spread throughout the system. The worms then work in all layers of material. ***The greatest advantage of pocket feeding is its simplicity. It requires no addition of material besides food and is in essence a “throw and go” system***. The only drawback to pocket feeding is that, because worms are working in all layers of the system, it is more laborious to separate them from the finished compost at harvest time.

- **Top or layer feeding:** Although it can be used in any system**,** top feeding is primarily used in hi-tech systems**.** Using the top feeding method involves bedding the bin to a depth of 2”-8” (some systems require specialized bedding for first layer), layering 1-2” of food waste on top and covering with 1-2” more bedding. Each time the system is fed, the procedure is repeated. When done correctly, the worms consume all the food in each level as they work their way up to the freshest food. ***In top or layer feeding, the worms stay near the surface making them easy to separate from the finished vermicompost at harvest time.*** On the down side, one must have a handy stock of bedding material to add at each feeding and some hi-tech systems require specialized bedding.

Harvesting a Simple Worm Bin

You’ve carefully selected and bedded your bins, the worms are happy and healthy and you’re diverting all your vegetable and fruit scraps from the waste stream. After a couple months, you notice an accumulation of a rich, moist, dark brown, soil-like material. Only the newest food scraps are recognizable and the bedding is disappearing quickly. After about 4-6 months, the bin takes on a delicious, earthy aroma and the brown material is beginning to fill the bin. The time has come to reap your reward. Yes, it’s time to harvest the bin.

The term ***harvesting refers to the separation and removal of the worms from the finished vermicompost***. The methods outlined below apply ONLY to simple, low-tech vermicomposting systems. The pros and cons of each method are outlined in Table 14. Hi-tech commercial systems are designed to be “self-harvesting” and come with detailed instructions. Please see Worm Digest No. 23 for a description of each system.

- **Quick and Dirty Method:** Remove 2/3 of the contents of the worm bin and use it, worms and all, in the garden. Rebed the bin and allow the remaining worms to repopulate the bin.

- **Dump and Sort Method**: Dump the entire contents of the worm bin onto a tarp under bright light or in the sun. Mound the material into several small cone shaped piles. Because the worms are photophobic, they will dive down in the piles to avoid the light. Scrape the material from the top of the piles until you expose the worms and wait for them to move down through the material again. Keep scraping off the tops of the vermicompost piles until there is nothing but worms left. Re-bed the bin, replace the worms and operate as normal.

- **Migration Method:** Scrape as much finished material as possible to one side of the bin. Fill the empty side with new bedding and operate the bin as you normally would, feeding ONLY the freshly bedded side. In approximately 4 weeks the worms will leave the finished material and migrate to the freshly bedded side. At that time, remove the finished compost and fill the space with new bedding and continue operating as normal.

- **Forced Screening Method:** Spread the entire contents of the finished worm bin onto a ¼" to ½" mesh screen. Hold the screen over a wheelbarrow and shine a bright light directly over the material. The worms, in an effort to avoid the light will dive down into the material and fall through the screen. When there are no more worms falling from the bottom of the screen, remove the screen and retrieve the worms from the wheelbarrow. Place the worms into a freshly bedded bin.

- **Self-Screening Method:** Cut a piece of window screening larger than the surface area of the worm bin. Lay this screen on top of the finished material with the excess length laying flat against the sides of the bin. Re-bed the bin on top of the screening and feed as normal. The young worms will easily crawl up through the screen seeking the food in the upper part of the system. Mature worms will have to work at squeezing through the small holes and will remain in the lower layer of material. They will continue feeding until they have converted all the food into finished castings. Once they have consumed all available food beneath the screen, they will go through the effort to squeeze through the screen (remember worms are 75% water and are very flexible) into the upper layer. This process takes about 4 MONTHS. After that time, the screen and the upper layer of worms and organic matter can be lifted out and set aside. The finished compost on the bottom can then be removed and the top materials and fresh bedding put back into the bin. Operate the bin as normal from this point until the next harvest. At that time, simply lay the screen on top of the nearly finished material and feed above.

Storing Vermicompost

Once vermicompost is harvested, it can be stored in an ***aerated container*** for several months. Aeration is important, because the harvested material will continue to slowly decompose after it is removed from the worm bin. A few worms may remain in the harvested material and babies may hatch from harvested cocoons. Lack of oxygen will kill the worms and the material will become anaerobic, foul smelling and toxic.

It is important to make sure that vermicompost stays moist (no drier than commercial potting soil) because once it dries out completely it is impossible to re-wet. In addition, moisture nourishes the beneficial microbes that are an important component of vermicompost.

Table 5-3. Pros and Cons of Worm Bin Harvesting Methods.

Worm Bin Harvesting Method	Pros	Cons
Quick and Dirty	Fast, easy, no sorting.	Many worms, cocoons and unfinished organic matter lost. Must reduce feeding load until system repopulates.
Dump and Sort	Very few worms lost.	Slow, labor-intensive, tedious. Difficult to dump large, heavy bins. Cocoons generally lost in finished compost.
Migration	Relatively easy. Few worms and cocoons lost.	Slow. Must take care to feed on one side only. Reduces usable worm bin area by half.
Forced Screening	Fast.	Rough separation. Cocoons generally lost in finished compost.
Self-Screening	Very little human labor involved. Virtually no worms or cocoons lost.	Slow. Reduces usable worm bin area by half.

Tricks of the Trade: Troubleshooting a Worm Bin

Most worm bins are low maintenance and virtually trouble-free, but occasionally, a bin runs into trouble. One of the prime symptoms of an unhealthy bin is ***worm crawl***. Worm crawl refers to the action taken by worms desperately trying to escape adverse conditions. The most common causes of worm crawl are excess moisture, excess vibration, low oxygen levels and anaerobic conditions. Other problems are more a nuisance to humans than a danger to the worms. A few tips will solve the most common problems.

Q: My worm bin seems too wet (or dry), what can I do?

A: A handful of material from a healthy bin will feel a little wetter than a wrung out sponge. A few drops of water should fall. If it is too wet, oxygen levels may drop to the point that anaerobic organisms and their associated toxins and odors predominate. Although worms can survive under water providing it is *well oxygenated*, extremely wet bins can become so compacted and oxygen starved that the worms die. At the other extreme, a bin can become too dry to sustain the worms. It is important to check the system regularly to ensure adequate moisture. If a bin gets too wet, one can either drain the excess liquid or add fresh dry bedding to absorb the excess. If a bin dries out, simply add water or wet feed items like melon.

Q: Why does my worm bin develop unpleasant odors sometimes?

A: Although worms are phenomenal eaters, people sometimes generate more food waste than their bin can handle. An **overfed bin** may become anaerobic and develop nasty odors. The simplest way to handle the problem is temporarily stop feeding the bin, turn the existing materials in the bin to aerate them and then add fresh bedding. In the meantime, you can add your food scraps to your backyard compost bin or remove some of the worms and bedding from the main bin and start a temporary bin with the new scraps until the original bin recovers.

Q: Help! I'm being attacked by an army of fruit flies.

A: Although they drive humans insane, your worms are not bothered by fruit flies. If a bin is kept outdoors, fruit flies are merely a nuisance, but they present a real problem for indoor bins. Fruit fly larvae are often present on bananas and other tropical fruits. These larvae hatch in the rich environment of your worm bin and once a few hatchlings mature, they multiply rapidly. One of the best solutions is prevention. First, it is important to bury all food wastes and cover the top of the bedding with a few sheets of damp newspaper or cardboard (a great use for old pizza boxes). Another great suggestion is to freeze all scraps before adding them (thawed, of course) to the bin. The frigid temperature kills the fruit fly larvae. For the hunters among us, Mary Appelhof suggests several ingenious fruit fly traps in Chapter 9 of *Worms Eat My Garbage.*

Q: There are tiny flies in my worm bin that don't seem like fruit flies, what are they?

A: Probably Fungus gnats. Fungus gnats may be more than a nuisance. These tiny flies resemble fruit flies and they feed on the fungi growing in worm bins. Unfortunately, they also feed on plant roots and can be a problem in homes with indoor bins and prized houseplants. The best defense is prevention. Keep the bedding covered with several sheets of damp newspaper or cardboard and limit the amount of food added to the bin.

Q: I'm mixing browns and greens in my worm bin, why doesn't it get hot?

A: Good question! Although your worm bin operates in much the same way as a backyard compost bin, the system is designed to favor earthworms. ***The main reasons worm bins do not usually become thermophilic are their relatively small size and their high moisture content.*** Home size worm bins are too small to hold much heat. Whatever heat is generated is usually rapidly dissipated through the bin walls or cooled by the evaporative properties of the bin's moisture. A home worm bin can become too hot if it is overfed. Vast excesses of organic matter will support rapid bacterial growth and can become thermophilic. Commercial vermicomposters are plagued by temperature regulation problems. Their huge bins must be carefully fed and monitored to ensure they do not become hot enough to kill the worms.

Q: Is there any danger in handling the worms or vermicompost?

A: For most healthy people, a worm bin poses no danger**.** A worm bin will tend to grow a lot of fungus, so sensitive and immunosuppressed individuals may need to exercise caution.

Q: Do the worms keep reproducing forever in the bin? What happens when there are too many?

A: A worm bin is a self-regulating ecosystem. Available food, oxygen and predators regulate worm reproduction rates in nature and in the worm bin.