



Smart Gardening Fact Sheet



THE ART AND SCIENCE OF BACKYARD COMPOSTING

Compost . . . because a rind is a terrible thing to waste!

INTRODUCTION

In nature, dead animals and plants breakdown slowly as a result of various natural biological and chemical processes collectively known as decomposition. In Smart Gardening, composting is a way to speed up natural decomposition by providing more controlled conditions. Composting is the result of understanding how these natural biological and chemical systems work.



THE HISTORY OF COMPOSTING

One of the earliest written references to compost use in agriculture appears on a set of clay tablets from the Akkadian Empire, nearly 4,500 years ago (2350 BCE). The Akkadian Empire was located in Mesopotamia, which literally means the land between the Tigris and Euphrates rivers and is now part of the country of Iraq.

These two rivers created an area called the Fertile Crescent, a rich agricultural area surrounded by deserts and mountains. About ten thousand years ago, the people of this region began the agricultural revolution by domesticating plants and animals and living in small villages, where they tended their crops.

Since this time, composting has been mentioned by virtually every major civilization. The Romans, Egyptians and Greeks all actively practiced composting, and there are references to composting in the Talmud, Bible and Koran. In the new world, archeological

excavations have produced indications that farmers from the Mayan civilization nearly 2,000 years ago actively practiced composting (the hieroglyphic languages of the New World recorded religious and military events, and thus don't provide any direct evidence).

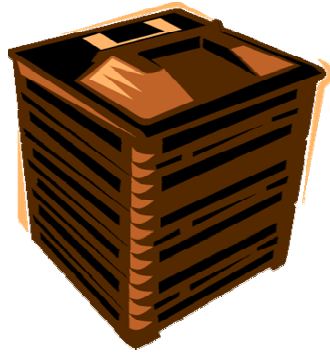
In more modern times, but particularly since the end of the Second World War, farming has increasingly been studied using the tools and approaches of science. Scientific farming heralded the advent of chemical fertilizers, pesticides and herbicides to increase crop yields. More traditional methods, such as using composted crop residues, didn't look very effective beside a bag of chemical fertilizer. For farmers in many areas of the world, the new chemical fertilizers replaced compost. Gradually, however, public interest in more traditional methods returned.



The publication of Rachel Carson's book "Silent Spring" in 1962 chronicling the devastating results of the wide-spread misuse of chemical pesticides and other contaminants resulted in a public outcry that resulted in the banning of many of the more dangerous types of these products. Many people began to rediscover the benefits of using what has come to be called "organic farming." One of the first publications in this arena was a book by Sir Albert Howard titled "An Agricultural Testament". Published in 1943, the book generated considerable interest in organic methods of agriculture and gardening. Today, even farmers who rely on expensive fertilizers recognize the value of compost for helping stimulate plant growth and in restoring depleted and lifeless soils.

BACKYARD COMPOSTING METHODS

Backyard composting is attractive to because it is a simple method of managing organic wastes at home. It also has the advantage of being readily adaptable to fit individual lifestyles, income, yard size, and overall ambition. Home composting can be performed by a variety of methods. Typically, these include: placing materials in open piles, burying materials in pits or trenches, enclosing materials in drums or bins (e.g., holding bins, turning bins, and worm bins). In order to heat up properly, compost piles should be at least one cubic yard in size. This provides the minimal insulation required to sustain the high temperatures in the center of the pile. Composting units or bins can either be commercial units, or can be simply constructed from inexpensive materials with little carpentry or masonry skills.



Another type of composting is called worm composting (also known as vermicomposting), can be done in bins or pits and is easily adapted for indoor or outdoor use. It can be ideal for persons with small yards or apartment dwellers who want to derive some of the benefits of composting and reduce solid waste. Worm bins are easy to build and are an excellent alternative to discarding food scraps. Vermicomposting involves placing redworms (not nightcrawlers or the field worms typically found in gardens) in a bin containing appropriate bedding materials, like shredded coconut fiber or newspaper, and garden soil.



Food scraps are then placed into the bin for the worms to eat. Once established in the bin, the worms (which consume half their body weight in food each day) will eat virtually any type of fruit or vegetable scraps that are put in the bin. Dairy and meat products should be avoided since they can attract scavengers and harmful insects. The finished compost makes an excellent potting soil and soil enhancer, and is actually an excellent fertilizer.

COMPOST AND ITS USES

Compost is an excellent soil conditioner. It improves the soil structure by binding soil particles together. This improves aeration and helps soil to retain water and nutrients. Compost also improves drainage in clay soils and water retention in sandy soils. Compost improves the buffering capacity of the soil and minimizes adverse effects to plants due to extreme shifts in soil pH. Adding compost to

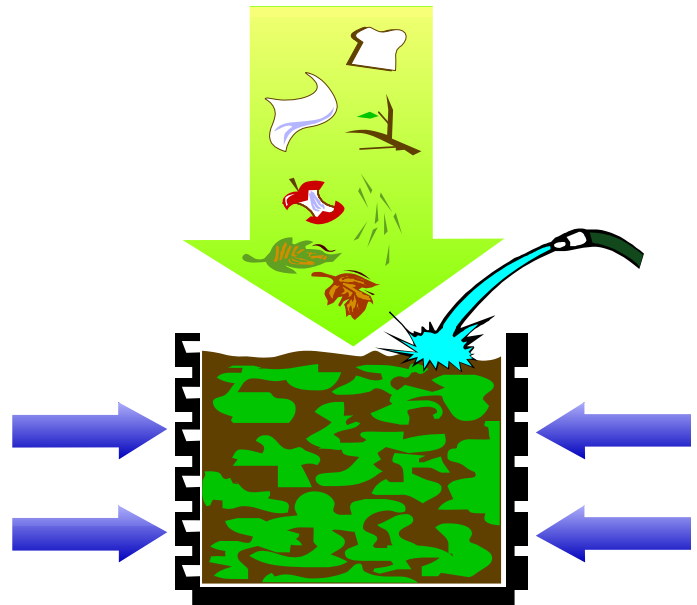
soil also attracts earthworms, which aerate the soil and add additional nutrients to the soil. Compost can help store some nutrients, releasing them slowly for more effective use by



surrounding plants. Although highly beneficial for soil, most composts are not good fertilizers.

MAKING GOOD COMPOST

A properly constructed compost pile represents a remarkably efficient biological and ecological system. It involves a diversity of species that emerge in response to changes in the nutritional and environmental conditions of the pile. However, it is imperative that a composting system be carefully constructed and maintained to exclude pests such as rodents, raccoons, and other vermin or pests.



Providing adequate sources of carbon and nitrogen is important since these elements are required by microorganisms for growth and cell division. Carbon also serves as an energy source for soil organisms. Nitrogen is used by organisms to make protein, enzymes, and new cell mass.

A balance between carbon and nitrogen results in optimal conditions, allowing the microbes to digest the waste material more efficiently. Food scraps and yard trimmings can be classified according to their carbon and nitrogen content as either Green or Brown. Green materials, such as fresh grass clippings, manure, garden plants, and kitchen scraps contain large amounts of

nitrogen. Brown materials, such as dried leaves and plants, branches, and woody materials have a high carbon content but are relatively low in nitrogen. A basic rule of thumb is to mix 50% green materials with 50% brown.

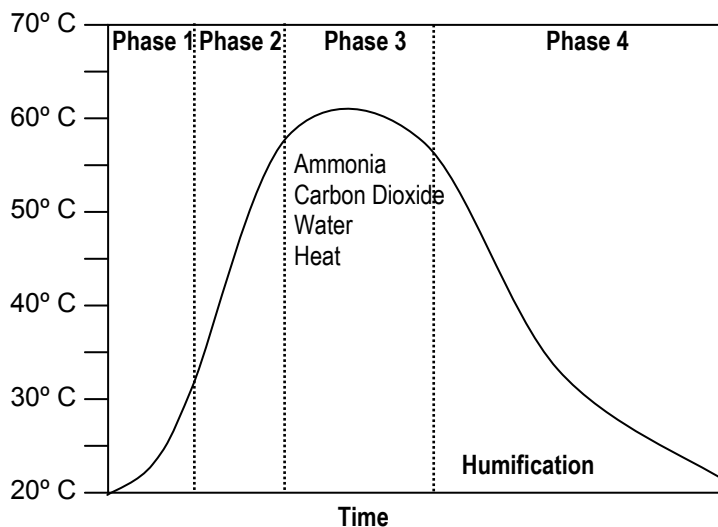
Table 1
Good Things to Compost

Greens	Browns
Grass clippings	Wood chips and sawdust
Garden trimmings	Shredded yard wastes
Green leaves	Pine and fir needles
Livestock manure	Straw and hay
Fruit and vegetable scraps	Dry grass and leaves
	Stale bread
	Nut shells
	Shredded paper
	Coffee grounds and filters

COMPOSTING PHASES

Composting is a complex, multi-phase process. Each phase in the composting process is different and is characterized by different consortia of organisms. The phases in composting include: (1) the initial or lag phase; (2) a moderate-temperature or mesophilic phase; (3) a high-temperature or thermophilic phase; and (4) the maturation or final phase as shown below.

Figure 1
Composting Phases



Phase 1 - Initial or Lag Phase

The initial lag phase occurs immediately after you place fresh yard waste into the compost pile. During this phase, the microbes are adjusting to the type of yard waste and initial conditions in your

compost pile. Decomposition begins during this phase, but the total populations of microbes are so small, very little heat is generated.

Phase 2 - Moderate Temperature or Mesophilic Phase

During the moderate-temperature, or mesophilic phase, decomposition proceeds and begins to accelerate. The population of microbes increases, but is dominated by those well adapted to low and moderate temperatures, the so-called mesophilic organisms. These microbes rapidly break down the soluble, easily degradable compounds such as simple sugars and carbohydrates. After these compounds are depleted, the microbes begin degrading more complex molecules such as cellulose, hemicellulose and protein. As these compounds are consumed, the microbes may excrete complex organic acids, which are generally consumed by other microbes. However, more of these complex organic acids are usually produced than can be initially consumed, causing excess organic acids to accumulate resulting in a drop in pH. This drop is usually temporary, unless something kills off the microbes that consume these organic acids. In most compost piles, these microbes do most of the work.

Phase 3 - High Temperature or Thermophilic Phase

As the consortia of microbes grows and metabolizes (eats) the yard wastes, they give off heat. If the temperature rises above approximately 40°C (104°F), the mesophilic microbes will be replaced by organisms better able to tolerate the higher temperatures. These organisms are collectively called thermophiles, which means "heat loving". Thermophiles are microbes that are very well adapted to extreme environments. Some scientists actually believe thermophiles may have been the first forms of life on Earth. These microbes are found throughout the world in dark, extremely hot, oxygen-free environments such as volcanic vents and hot springs. The Earth is thought to have been dominated by similar conditions 3.5 - 4 billion years ago, when life first began. The thermophiles in your compost bin have since adapted to an oxygen rich environment, but may be direct descendants of these first primitive life forms.

Allowing your compost pile to get hot is critical. Only when the pile gets hotter than 55°C (approximately 130°F) are most human and plant pathogens destroyed (a good thing). However, if the pile gets hotter than 65°C (above 150°F), most of the aerobic thermophiles will die. Another advantage of allowing your compost pile to get hot is that high temperatures also accelerate the breakdown of proteins, fats, and complex carbohydrates like cellulose and hemicellulose, the major structural molecules in plants. As the microbes exhaust their supplies of food, metabolic rates decrease and the temperature will gradually decrease.

Phase 4 - Maturation Phase

Once the temperature has reduced back into the mesophilic range, these microbes will begin to dominate again. The drop in temperature is the best indication that your compost pile has entered the maturation, or curing phase. In the curing phase, the remaining organic material becomes increasingly complex. These complex organic compounds resist further decomposition and are collectively referred to as humic acids, or humus.

CRITICAL COMPOSTING FACTORS

In much the same way that farmers improve crop yields by creating a favorable environment for their plants (balanced nutrients, water, and pest control), natural decomposition rates also can be accelerated by providing favorable conditions for bacterial growth and reproduction. The process of accelerating natural biological decomposition rates by controlling such factors as the moisture content, temperature, aeration (oxygen levels), particle size, size and shape of the compost pile, pH, and carbon to nitrogen ratios (C:N) is called composting.

Carbon - Nitrogen Ratio

Tea leaves and bags Carbon and nitrogen are both vital to cell growth. Carbon, which makes up approximately 50% of the total mass of microbial cells, serves as both the energy source and a basic cellular building block. Nitrogen is an essential element vital to a cells' ability to manufacture the proteins, nucleic acids, amino acids and enzymes necessary for cell structure, growth and function.

The C:N ratio represents the weight of carbon (not the number of atoms) to the weight of nitrogen. The target C:N ratio for composting is generally considered to be around 30:1, or 30 grams carbon for 1 gram of nitrogen. If C:N ratio is significantly higher than 30:1, the necessary nitrogen is not readily available and the metabolism of the microbes will slow down. To help obtain the nitrogen they need, the microbes will try to obtain it from the surrounding soil. This depletes soil nitrogen, reducing the amount available to plants. The depletion of surface soil nitrogen is why mulches are very effective for weed control. The surface soil lacks sufficient nitrogen for the seeds to germinate.

As composting proceeds, the C:N ratio gradually decreases from 30:1 to around 20:1 for the finished product. The C:N ratio constantly decreases because when carbon is consumed by microbes, 2/3 of the carbon is released as atmospheric carbon dioxide. The remaining 1/3 is incorporated along with nitrogen as microbial cell mass. In general, materials that are fresh and green tend to be higher in nitrogen, and those that are brown and dry are higher in carbon.

Table 2
Carbon - Nitrogen Ratios
of Common Compost Materials

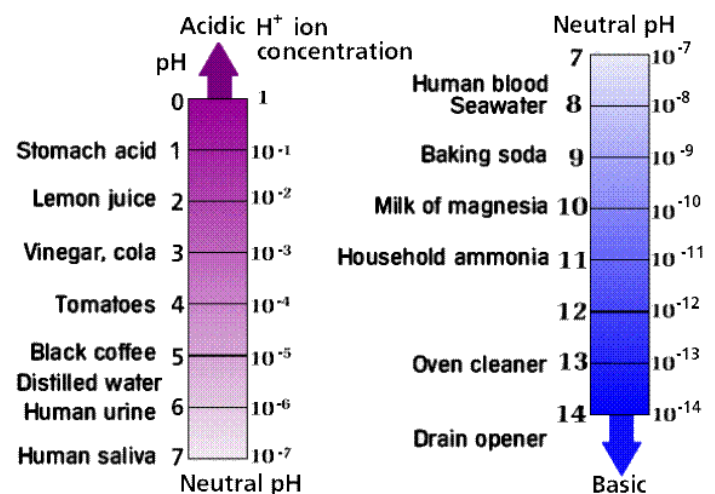
Materials High in Carbon	C/N Ratio	Materials High in Nitrogen	C/N Ratio
dry leaves	30:1 - 80:1	vegetable scraps	15:1 - 20:1
straw	40:1 - 100:1	coffee grounds	20:1
wood chips & sawdust	100:1 - 500:1	grass clippings	15:1 - 25:1
bark	100:1 - 250:1	manure	5:1 - 25:1
mixed paper	150:1 - 300:1		
newspaper & cardboard	560:1		

Since weighing everything you put in your compost pile is not practical, you should simply add half "browns" and half "greens". You should adjust the ratio you use up or down depending on the specific quantity and quality of yard waste materials you intend to use. We recommend remembering this adage, composting is half science and half art. The key is learning to use what you have as well as possible.

pH

One of the most important indicators of overall health in your compost pile is pH. What exactly is pH and what does it measure? Chemically, pH measures the strength of an acid or base and is defined as the negative log₁₀ of the hydrogen ion concentration.

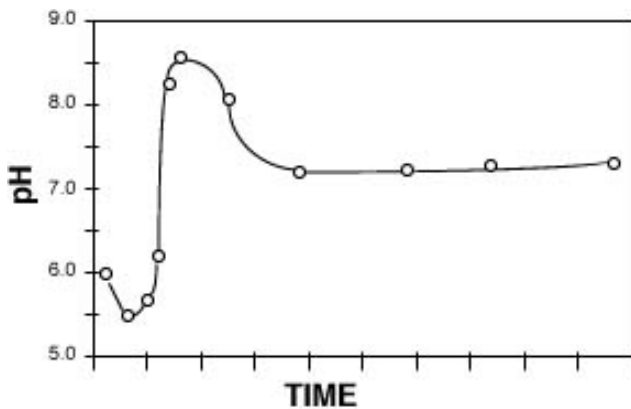
Figure 1
pH Scale



Generally, the pH of the yard wastes will drop to between 5.5 – 6.0 (or lower) during Phase II of composting. In fact, this drop in pH is a key indicator that a compost pile has moved from the initial, or lag, phase into the first stage of active microbial degradation. The drop in pH results from the activity of acid-forming bacteria that break down complex carbohydrate materials (polysaccharides and cellulose) into simpler organic acids.

The resulting drop in pH also encourages the growth of fungi and Actinomycetes, which are able to breakdown lignin under aerobic conditions. Bacteria and other microorganisms, as well as fungi and Actinomycetes, are all able, to varying degrees, to breakdown hemicellulose and cellulose.

Figure 2
pH vs. Time



The microorganisms that produce the acids can also utilize these organic acids as food once the most readily biodegradable materials have been consumed, typically within a few days. The net effect is that the pH will then begin to rise. The rise in pH typically continues until a level of 7.5 to 9.0 is reached, and the mass becomes alkaline. Attempts to control pH with sulfur compounds are difficult and costly. It is more important to manage aeration so that anaerobic conditions, typified by fermentation and odor formation, are controlled.

The reason pH is important in composting is that many types of microorganism, as well as higher order invertebrates, cannot survive highly acidic conditions. Fortunately, pH is generally controlled naturally (the process is called the carbonate buffering system), so you don't have become to concerned. One thing to keep in mind though, is that if you have to adjust pH by neutralizing acid or base conditions, salts are formed. If the salt concentration builds up, this can also have a detrimental effect on the health of your compost pile. It is common for the initial ingredients in a compost pile to be either slightly acidic (pH is less than 7) or slightly basic (pH is higher than 7), but finished compost generally

has a fairly neutral pH between 6.8 - 7.0. If the system becomes anaerobic, acid accumulation can quickly lower the pH to 4.5, severely limiting microbial activity. In such cases, aeration is generally enough to return the compost pH to acceptable ranges.

Aeration

Under normal conditions, composting is an aerobic process, which means that oxygen is essential for the metabolism and respiration of the microbes. The word aerobic derives from the Greek "aero" meaning air, and "bios" meaning life. Microbes use oxygen, rather than other oxidizing agents, because reactions are more energetic (19 times greater.) At the beginning of the compost process, the oxygen concentration in the pore spaces is about 15-20%, identical to the concentration in atmospheric air. The carbon dioxide concentration typically varies from 0.5-5.0%. As composting progresses, the oxygen concentration falls and the carbon dioxide concentration increases. Anaerobic (meaning without air) conditions will develop if the oxygen concentration drops below 5%. While anaerobic activity is characterized by undesirable odors, a small amount of this activity in the compost pile is acceptable and common. The compost pile acts as a bio-filter to trap and degrade the odorous compounds produced as a by-product of anaerobic decomposition. Some compost systems are able to maintain adequate oxygen passively, through natural diffusion and convection. Other systems require active aeration, provided by blowers or through turning or mixing the compost ingredients.

Moisture Content

Compost microbes need water. Because of this, decomposition occurs most rapidly in the thin liquid films found on the surfaces of the organic particles. About 50% moisture is optimal for composting. Too little moisture (<30%) inhibits bacterial activity. Too much moisture (>65%) chokes off diffusion of air into the pile, which can significantly slow decomposition and result in the production of odor in anaerobic pockets. To gauge moisture content, the compost mixture should feel damp to the touch with about as much moisture as a wrung-out sponge. Or use the "squeeze test": Take a handful of compost mixture and squeeze hard; If you get just a drop or two of water from the mixture, then moisture content is just right; If you get no water, then it's too dry; If you get a small stream, then it's too wet.

Particle Size

Microbial activity generally occurs on the surface of the organic particles. Therefore, decreasing particle size, through its effect of increasing surface area, will encourage microbial activity and increase the rate of decomposition. However, when particles are too small, they pack together too tightly, inhibiting the air circulation through the pile. This decreases the oxygen available to

microorganisms within the pile and ultimately decreases the rate of microbial activity. Particle size also affects the availability of carbon and nitrogen. Large wood chips, for example, provide a good bulking agent that helps to ensure aeration through the pile, but they provide less available carbon per mass than they would in the form of wood shavings or sawdust.

Size and Shape of the Compost Pile

A compost pile or windrow (a long row of compost) must be of sufficient size to prevent rapid dissipation of heat and moisture, yet small enough to allow good air circulation. The minimum dimension to keep sufficient heat in the pile is 3 feet x 3 feet x 3 feet (1 cubic yard). The maximum dimensions for a compost pile or windrow that will allow sufficient to allow air to diffuse to the center of the pile is generally estimated to be approximately 5 feet x 5 feet x any length. Some composting bins add insulation to adjust for smaller size and other composting systems use forced air to allow for piles or windrows of larger sizes.

APPROACHES TO COMPOSTING

There are nearly as many approaches to composting as there are people who practice it. Composting methods range from very complex, time-intensive approaches to very simple approaches which require very little time. The real beauty of composting is that no matter how many mistakes you make, you will probably still end up with a good compost you can use in your yard and garden. The real differences in the various approaches to composting are simply the amount of time and effort you are willing to invest. You can take a simple, hands-off approach (the so-called passive method of composting), which will require a year or two to make a finished compost. As an alternative, you can invest more time and effort and produce significantly more compost faster. The choice is yours.

Passive Composting Methods

Passive composting is only slightly more complicated than just piling dead plants together and letting them decompose. Passive composting is a low tech, low energy method to develop slightly more desirable conditions for microbial growth so that decomposition will speed up without too much extra work. The compost pile is built gradually; you add the plant materials as you get them, keeping in mind that a 50/50 balance of "greens" and "browns" is desirable. The only other thing you have to try to do is keep the pile moist. Since a passive pile doesn't get hot enough, care should also be taken not to include seeds that might sprout in your compost or diseased plants that might infect your garden.

The advantage of the passive method over the active method is that it requires less work on your part. There is no turning required. The disadvantage to the passive approach is that it takes longer to get finished compost (6-12 months vs. 1-3 months for the active approach. For some, the "passive approach" to composting, sometimes called "cold composting", is sufficient for their needs. Passive composting may suit your needs if:

- You don't need a lot of compost,
- You don't want to spend a lot of time monitoring and adjusting the conditions in your compost pile;
- You aren't in a hurry to make your compost; or
- You don't have access to a lot of raw material.

A pile of leaves left to itself will often take a long time to compost. But if you keep in mind the following guidelines, the passive approach can be used to give you finished compost within a reasonable time.

- Place your composting bin in a convenient location. Since you will be adding material to your passive compost pile frequently, make sure it's easily accessible.
- Make sure your composting bin is within easy reach of the garden hose since your passive pile will require you to water it many times because of the long composting period.
- Your pile should be about 50% "greens" and 50% "browns", as noted previously. It's helpful to keep a bag of leaves, shredded newspaper or other "browns" near your bin to cover your kitchen scraps and mix with your lawn clippings; and
- Avoid adding any seeds and do not add material from sick or diseased plants.
- Continue to add material to your passive compost bin until it is nearly full. This may take a while, since as the material composts, its volume decreases.
- After you stop adding ingredients to your passive compost pile, continue to monitor its Moisture level keeping it about as wet as a damp sponge (At this point, while you're waiting for this pile to mature, it's nice to have a second bin around to deposit any new stuff).

In several weeks to a few months, the original materials used in the pile should no longer be identifiable. The compost should be a nice uniform brown color and smell like good rich earth. Your compost is now finished and ready for use in your garden.

Active Composting Methods

The active approach differs from the passive approach only in the level of assistance you need to provide to make the process

happen faster. Generally, the compost materials are added all at once. This is because a compost pile needs to be a certain size to retain heat well enough for the thermophilic bacteria to kick in. Once the pile has been hot for 3 - 5 days, the pile is physically turned, which aerates it, and water is added. The pile will then generally heat back up again. This general approach is repeated a few of times until the pile becomes compost. This generally takes 2 - 4 months, although with practice, you could create finished compost in as little as 4 - 6 weeks.

Because of the high temperatures, most plant materials can be composted. You should still avoid adding obviously sick or diseased plants. The beauty of the active approach is that you can have beautiful brown compost in just a few weeks. Although the active approach does require more work than the passive approach, the difference is slight, and the results, finished compost, are ready much sooner. The general method is as follows:

1. Collect a 50/50 mix of "browns" and "greens", enough to build a 3' x 3' x 3' or larger pile. Active composting is a "hot" method and a minimum bulk is necessary for your pile to retain enough heat to get above 150°F. The C:N ratio can be adjusted up or down depending on the quantity and quality of the materials at hand.
2. Size reduction is critical to creating compost quickly. Try to shred large materials to a minimum of 1/2" in size. Since many materials are relatively dry, it's usually helpful to soak your browns in water prior to building the pile. This step is particularly helpful in the dry southern California climate. Typical composting times can be cut in half.
3. To build the pile, mix 50% "browns" with 50% "greens" thoroughly with water until your bin is full. Most commercial composting bins include a cover to help retain heat and water during the dry season and to prevent the wind from blowing material around the yard. If the bin isn't equipped with a cover, flattened cardboard boxes work well and it's a good way to recycle the cardboard. Just lay the cardboard on top of the pile and soak it thoroughly to weight it down.
4. Temperature is the most accurate way to tell when to turn the pile. Normally, within 24 to 48 hours, a new pile will reach temperatures of about 140 - 150°F and will sustain this temperature for several days. After a minimum of 3 - 5 days, turn the pile using a pitchfork or shovel, being careful to break up any clumps. You should also be careful to rotate the material from the outside into the inside of the pile. Turning the pile is also a great time to water the pile or bin again. When you're done, just cover the pile or bin, and do the process

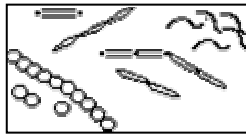
again. This process should be repeated approximately 6 - 8 times, or until the compost is finished.

5. You can tell when compost is finished by simply looking at it and smelling it. The compost should be dark and crumbly, smell like fresh turned earth, and very little of the original material should be identifiable. Other indicators include a relatively constant temperature, usually no more than 8 - 10°F above ambient air temperature, even after turning the pile and the pH should be close to 7 (neutral).

COMPOSTING MICROORGANISMS

In composting, most of the decomposition that takes place is due to the action of microorganisms. These microorganisms are extremely varied and include many types of bacteria, fungi and actinomycetes, as well as more complex microorganisms.

Bacteria



Bacteria are the smallest and the most numerous living organisms in a compost pile, accounting for 80% - 90% of the total population. Bacteria are responsible for most of the decomposition and heat generation in compost. Bacteria are a diverse group of microorganisms, utilizing a broad range of enzymes to chemically break down a variety of organic materials.

Bacteria don't generally need to be added to the compost pile. They are present virtually everywhere and enter the pile on every piece of organic matter. Good compost will have on the order of a 1 billion bacteria per teaspoon. Most of these individuals are beneficial to plant growth, and do not cause disease.

Different types of bacteria prefer different temperatures. Low temperature bacteria, called psychrophiles, are well adapted to low temperatures ranging from 40°F, down to below 0°F (the freezing point of water). Moderate temperature bacteria, called mesophiles, typically predominate at temperatures between 40°F - 95°F. In most compost piles these moderate temperature bacteria do most of the work.

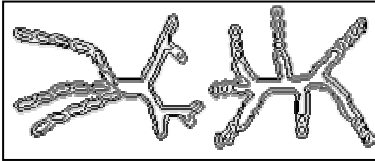
In an active compost pile, mesophilic bacteria usually start the decomposition process, but are soon replaced by high temperature bacteria, called thermophiles. Thermophilic bacteria generally predominate at temperatures above 100°F.

The species diversity of bacterial is fairly high at low and moderate temperatures up to about 90°F - 95°F, but decreases steadily as the temperature rises above 150°F. The normal maximum temperature in a compost pile will rise to between 140°F - 160°F.

As the amount of simple substrates becomes limited, the number of bacteria will begin to decline. As the total population of bacteria falls, the amount of heat generated by their metabolism decreases.

When the temperature of the compost pile finally cools to below about 100°F, mesophilic bacteria will again predominate. The numbers and types of mesophilic microbes that recolonize compost as it matures will depend on the type and numbers of spores and other organisms present in the compost, as well as in the immediate environment. In general, the longer the curing or maturation phase, the more diverse the microbial community it supports.

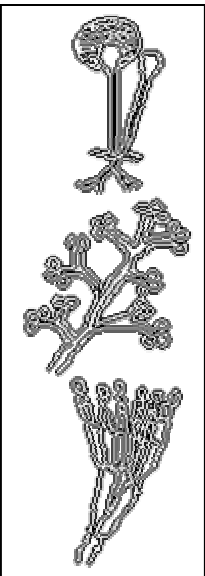
Actinomycetes



The characteristic rich, earthy smell of compost is due primarily to a group of organisms called actinomycetes. Actinomycetes

are a fungus-like bacteria that form long, thread-like branched filaments that look like gray spider webs stretching through the compost. Different species of actinomycetes predominate during each phase of the composting process (the mesophilic, thermophilic, and maturation phases) but are most easily seen early in the process, primarily in the outer 1 - 2 inches of the pile. Actinomycetes are the primary decomposers of high lignin-containing plant materials like bark, newspaper and woody stems.

Fungi



Fungi is the name for a family of simple organisms that lack photosynthetic pigment and includes molds and yeasts. Next to bacteria, fungi are one of the most efficient decomposers of organic material. In a compost pile, fungi are critical because, like actinomycetes, fungi can break down complex organic substrates containing cellulose, hemicellulose and lignin. By breaking complex substrates into simpler compounds, fungi allow bacteria to continue the decomposition process once most of the cellulose has been exhausted. They spread and grow vigorously by producing many cells and filaments, and they can attack organic residues that are too dry, acidic, or low in nitrogen for bacterial decomposition. Various species of fungi are common during both mesophilic and thermophilic phases of composting.

Most fungi prefer to live in the outer 1 - 2 feet of the compost pile when temperatures are high. Compost molds can grow both as unseen filaments and as gray or white fuzzy colonies (*Aspergillus fumigatus*) on the compost surface.

COMPOSTING INVERTEBRATES

Invertebrates are also very active in helping to degrade complex organic material into simpler organic molecules. These organisms co-exist with the microbes (and in some cases rely on the microbes as a food source) and are essential to a healthy compost pile. Much larger than the microbes, but fewer in number, complex invertebrate organisms such as mites, springtails, sowbugs, centipedes, millipedes, ants, beetles, green fruit beetle larvae, and worms break down large organic materials into smaller pieces. This process increases the amount of exposed surface area in the compost and helps transport and transplant microbes throughout the compost pile. In short, the invertebrates are the movers and shakers of the compost pile.

Ants



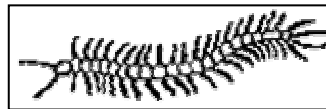
Most species of ants live in highly organized colonies. They are generally very small, but all have six legs and articulated antennae. In the compost pile, ants feed on fungi, seeds, sweets, and other insects. The compost pile also provides shelter for nests. They will remain, however, only while the pile is relatively cool. Ants may benefit the compost heap by moving minerals (especially phosphorus and potassium) around and by bringing fungi and other organisms into their nests. Lots of ants in the compost pile may sometimes indicate that the pile is too dry. Ants can be a major problem in the garden, though. They tend to encourage and sometimes even protect sap-sucking insects like aphids, which produce a sweet, sugary sap called honeydew, which some ants eat. The small brown ants common in Southern California are generally Argentine ants, an invader species which has displaced many native species.

Beetles



The most common beetles in compost are the rove beetle, ground beetle and feather-winged beetle. Feather-winged beetles feed on fungal spores, while the larger rove and ground beetles prey on other insects.

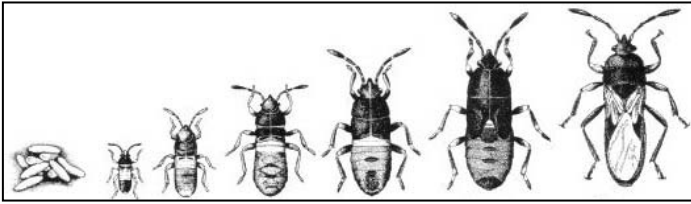
Centipedes



Centipedes are fast moving predators found mostly in the top few inches of the compost heap.

They have formidable claws behind their head which possess poison glands that paralyze small red worms, insect larvae, newly hatched earthworms, and arthropods - mainly insects and spiders.

Chinch Bugs



Chinch bugs damage turf grasses by sucking the juices from blades of grass while allowing a toxic saliva to enter the grass plant, disrupting its water conducting system which causes it to wilt and die. Chinch bugs move in an outward pattern from the center of the dead area of grass. They are most commonly found in drought stressed lawns. If left untreated they can cause significant damage. An adult chinch bug is approximately 6mm long, black with skinny white wing covers. The nymphs (young) are bright red with a white band across their backs. They can be seen by parting the grass where the green lawn meets the brown lawn or by using the flotation monitoring method. Even lawn care professionals sometimes mistake chinch bug damage for other types of damage such as fungal diseases. This can be a costly error. Properly identify the pest before you treat.

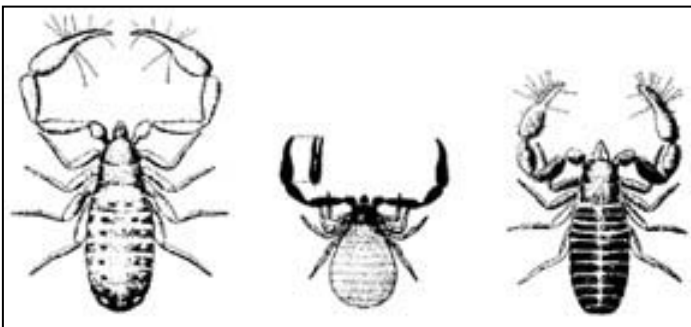
Cutworms



Cutworm is a common name for one of the many types of hairless caterpillar larvae of several species of night flying

moths. They come in various shapes, sizes and colors and may be up to 2 inches in length. Most feed only at night, but be found during the day curled up into a characteristic "C" shape. Cutworms may be mistaken from Green Fruit Beetle Larvae, but Cutworms lack noticeable legs. Cutworms feed on seedlings, grass stalks, and newly transplanted garden vegetables and flowers. Cutworms are voracious eaters, and will attack virtually any type of plant. Common in lawns, they cause small patches of sod to turn brown and die as the Cutworms eat the grass blades near the ground.

Pseudoscorpions



Pseudoscorpions are a common predator in most composting bins. They are not true scorpions as they lack a tail and are completely harmless to humans. They are close relatives to spiders.

A Pseudoscorpion is typically between 1/16 to 1/8 inch (2 to 8 mm) long. They usually have a pair of large pincerlike claws (pedipalps) that project forward from the front of the body. There is no curved upward stinger from the rear tip of the abdomen as found in true scorpions.

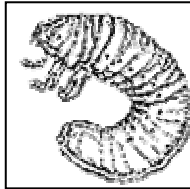
The body color ranges from yellowish-tan to dark-brown, with the paired claws sometimes black. Some have 2 or 4 eyes while others have none. Legs are 5-segmented.

Pseudoscorpions are rather common, but are rarely seen due to their secretive habits and small size. They have the habit of attaching themselves (not as parasites) to the legs and appendages of flies, beetles and other insects, which permits them to "hitchhike" into new areas.

The pincer-like pedipalps contain well-developed venom glands and ducts. The poison is used solely to capture small insects (their prey). They do not bite. They have silk gland openings on their jaws, and use silk to make chambers for overwintering, molting or brooding. Adults may live for 2 to 3 years and are active in the spring, summer and autumn, overwintering in silken cocoons.

Pseudoscorpions are considered beneficial to humans since they are aggressive feeders (predators) on clothes moth larvae, carpet beetle larvae, booklice, ants, mites, small flies and even small earthworms.

Fruit Beetle Larvae



In the late summer and early fall, Fruit Beetles (a large metallic green beetle) lay their eggs in compost piles and other decomposing plant litter. The larvae are fairly large (about 2 inches), C-shaped, pale translucent white with dark brown heads. Because of their large size, the larvae can be disconcerting

when found in the pile. Don't worry, the larvae are beneficial for the pile, breaking down large materials. Although the larvae do not damage plants in your garden, the mature beetles do eat soft fruits such as overripe peaches, plums and figs. You should note that the Green Fruit beetle is not the same bug as the Japanese beetle, a smaller and more noxious garden pest not often found locally. The Green Fruit Beetle larvae are not harmful, and you don't need to remove them from your composting pile.

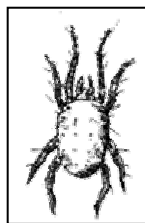
Millipedes



Millipedes are similar to Centipedes, except that they're non-predatory,

usually dark, and have two pairs of legs per body segment (and subsequently, usually slower than the fast moving centipedes). They feed mainly on decaying plant tissue but will eat insect carcasses and excrement. They break up, consume and process raw plant material, leaving droppings that in turn feed Bacteria and Fungi.

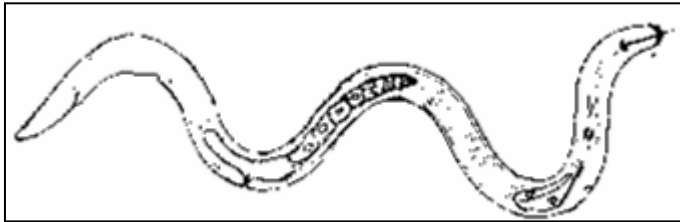
Mites



Mites are the second most common invertebrate found in a compost pile. They have eight leg-like jointed appendages. Some can be seen with the naked eye and others are microscopic. Some can be seen hitching rides on the back of other, faster moving invertebrates such as sow bugs, millipedes and beetles. Some scavenge on leaves, rotten wood, and other organic debris. Some species eat fungi, yet

others are predators and feed on nematodes, eggs, insect larvae and other mites and springtails. Some are both free living and parasitic. One very common compost mite is globular in appearance, with bristling hairs on its back and red-orange in color.

Nematodes

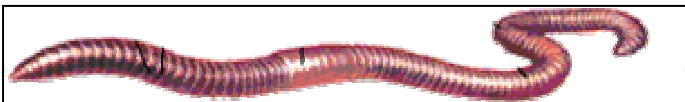


Nematodes are simple worms consisting of little more than an elongated stomach and reproduction system inside a resistant outer skin. Most nematodes are so small, between 400 micrometers to 5 mm long, that a microscope is needed to see them. Their small size, resistant outer skin, and ability to adapt to severe and changing environments have made nematodes one of the most abundant types of animals on earth.

Most nematodes feed on bacteria, fungi, and other soil organisms. Others are parasitic, obtaining their food from animals (such as the dog heartworm), humans (such as the pinworm), and plants. Agricultural cultivation, such as gardening, encourages an increase in parasitic nematodes that feed on the plants being grown.

Occasionally, new kinds of plant parasitic nematodes may be introduced into a field by contaminated plant parts, soil on farm equipment and irrigation water. Nematodes which parasitize plants may cause yield losses by themselves or they may join with other soil-borne organisms such as viruses, fungi, and bacteria, to promote disease development in plants. Most often, nematode feeding reduces the flow of water and nutrients into the plant, increasing the plant's susceptibility to other stress factors such as heat, water, and nutritional deficiencies.

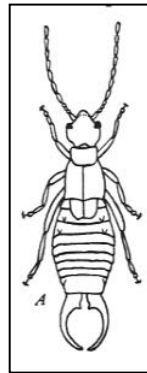
Earthworms



Earthworms are among the largest of all of the various invertebrates that can be found in a composting bin. Earthworms do much of the decomposition work. During the daylight hours, they're constantly tunneling and feeding on decaying organic matter. Their tunneling aerates the compost and enables water, nutrients and oxygen to filter down. Earthworm castings are one of the richest soil amendments you can add to your soil. Earthworms take in soil and organic matter, which passed down through the digestive system. The soil acts like grinding stones, helping break up the organic material. Plant acids are neutralized by secretions of calcium carbonate from calciferous glands near the worm's gizzard. Digestive intestinal juices rich in hormones, enzymes, and other fermenting substances continue the breakdown process as the organic material moves through the digestive tract. The matter passes out of the worm's body in the form of castings, which are one of the richest and finest quality organic fertilizers. Fresh worm castings are

markedly higher in bacteria, organic material, and available nitrogen, calcium, magnesium, phosphorus and potassium levels are generally higher than the surrounding soil.

Earwigs



The European earwig is commonly found in backyard composting bins. It is an elongated, flat insect, reddish-brown to black in color, and 1/2 to 1 1/4 inches in length. The earwig is easily identified by forceps-like appendages (cerci) found at the base of its abdomen. These forceps are used primarily for defense and during courtship. The name "earwig" originated from the widespread superstition that the insects purposely crawl into the ears of sleeping persons and bore into their brains. In fact, other than an occasional pinch, earwigs can't harm people.

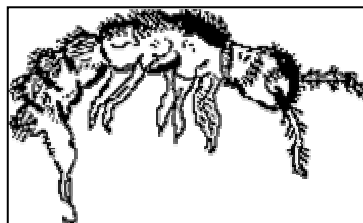
Earwigs are primarily scavengers of dead insects and rotted plant materials but may also feed on live plants. They are a natural enemy of some mites and aphids. Earwigs can become a problem in the garden, feeding on the roots and leaves of flowers, vegetables and shrubs. Common targets include marigolds, dahlias, zinnias, roses, lettuce, and strawberries. They may also feed on corn tassels and blossoms, reducing kernel set. Plants defoliated overnight, in the absence of pests in daylight or the telltale signs (slimy trails) of slugs, may have been attacked by earwigs.

Sowbugs/Pillbugs



Sowbugs and pill bugs are not insects but small, soil-dwelling crustaceans. Looking like little tiny armadillos, sowbugs move slowly while grazing on decaying vegetation. Sowbugs and pillbugs may become a problem if garden plants remain damp so that the outer cells begin decaying. This is particularly common in situations where homeowners over-water plants, leaving them to lie damp on the ground. However, sowbugs and pillbugs are blamed for more damage than they actually do because they are often found with plants that were initially damaged by other pests. The only significant difference between sowbugs and pillbugs are the two small tail-like appendages which prevent a sowbug from curling up into a little ball like a pillbug.

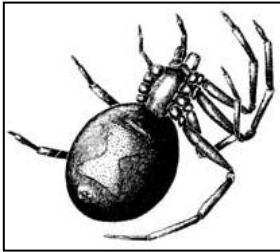
Springtails



Springtails are very small (0.05 inches) wingless insects and can be distinguished by their ability to jump when disturbed. They run in and around the particles in the compost and have a small spring-like structure under the belly that catapults them into the air when the spring catch is triggered.

Springtails, along with nematodes and mites, are the most numerous invertebrates in the compost pile. Springtails feed primarily on fungi, decomposing plants, nematodes and droppings of other arthropods.

Spiders



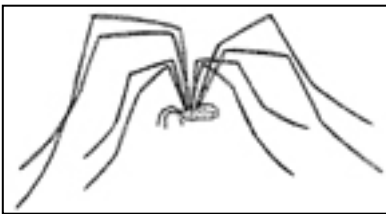
Spiders have eight legs (four pairs), vary in size, shape and color, and lack wings and antennae. Their body regions consist of two parts; a cephalothorax (fused head with thorax) and an abdomen. Most spiders have eight eyes, some only six and several have fewer or none. All have a pair of jaw-like structures (chelicerae)

which are a hollow claw-like fang through which venom can be ejected. The tip of the abdomen has silk spinning glands. Young spiders (spiderlings) resemble adults except for their smaller size and coloration. Males are usually smaller than females.

Virtually all spiders are all predators. They all feed on meat, usually in the form of other invertebrates. All spiders are venomous, but very few are capable of biting or causing harm to humans. The only species usually considered dangerous to people in Southern California that may be found in a composting bin or pile is the Black Widow. It is worth noting, however, that if a person is allergic to the venom, almost any spider can be dangerous.

Spiders are attracted by ready sources of food, such as the wide array of invertebrates commonly found in a composting bin. Always check for spiders in and around your compost bin or pile using your eyes before sticking in your hand. Always wear gloves when working with your compost.

Daddy-longlegs or Harvestman



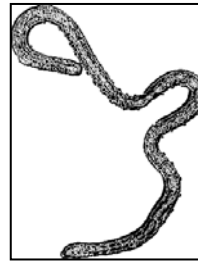
Most of the creatures people commonly refer to as “Daddy-longlegs” are actually distant cousins of spiders and are more closely related to mites and ticks. Daddy-longlegs, also known as Harvestmen,

and are members of the class Arachnida, but belong to the Order Opiliones. They make their living by eating decomposing vegetative and animal matter, although are opportunist predators if they can get away with it. They do not have venom glands, fangs or any other mechanism for chemically subduing their food.

There is a family of spiders called Pholcidae, also known as “Daddy long-legs” spiders. These spiders hang inverted in a messy, irregular, tangled web. These webs are constructed in dark places such as composting bins and are also known as cellar spiders. The web has no adhesive properties but the irregular structure traps insects, making escape difficult. When the spider is threatened by a touch to the web or when too large a prey hits the web, the spider becomes invisible by vibrating rapidly and becoming blurred. When off their webs, pholcids walk with an unsteady, bobbing action.

Certain species of these seemingly benign spiders invade webs of other spiders and eat the host, the eggs or the prey. In some cases the spider vibrates the web of other spiders, mimicking the prey to lure the host of the web closer.

White Worms (*Enchytraeids*)



You will often find many tiny white worm-like creatures, usually less than $\frac{1}{4}$ ” – $\frac{1}{2}$ ” in size (10-20 mm) on the food in your worm bin. These could be mistaken for baby worms, but are actually a distant relative of earthworms called Enchytraeids. Also called “Potworms” or “White Worms”, Enchytraeids will not

harm your composting worms, and actually help eat and decompose the organic matter in your worm composting bin, too. In a worm composting bin, Enchytraeids can reach densities of 250,000 individuals per cubic meter of bin volume. These very simple creatures prefer acid soils, and large numbers of them may be an indication that your worm bin is acidic. They feed primarily on soil bacteria and fungi, but also eat dead organic material and small feces. They have no enzymes for digesting complex polysaccharides, and thus do not digest the organic matter they ingest. They are good for your compost system and harmless to you, your worms and plants.