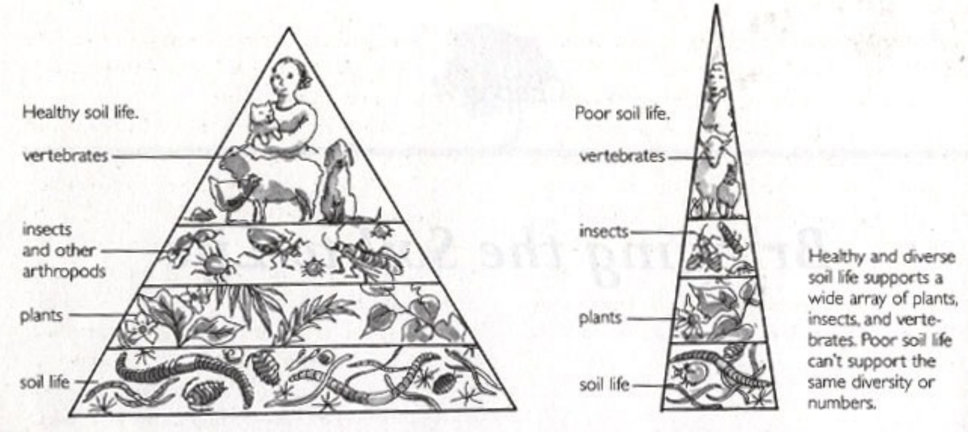


From Gaia's Garden by Toby Hemingway

What is compost really?

A COMPOSTIFESTO

By K. Semilla

At first glace, Compost is simply the deliberate recycling and transformation of organic "wastes" from our kitchens, gardens, and bathrooms into rich humus-building soil. More than that, it is a challenge to the industrial paradigm that promotes a linear product-consumption-waste pattern. Humans are not consumers by nature. It is a false concept created by a capitalist profit system that values greed and property over the good of all. The concept that humans are inherently destructive to the Earth is utterly untrue. In reality, humans are a part of nature. Humans have the capacity to function sustainably as part of a larger ecosystem. We have the ability to enrich and evolve our soils and environments, rather than destroy them. We have the ability to act as bioaccumulators, promoting diversity and abundance rather than waste and consumption. Nature does not create waste. Waste is a human-made concept. Waste is the forceful disruption of the natural cycles of growth and decay that repeat endlessly. In truth, our waste is simply another species food—microbes, plants, and animals all depend on it. To think that once organic materials are unfit for human consumption, they become useless, is a hopelessly narrow and speciest mindset. It needs to change, and only when it does will we find peace. Composting is the acknowledgment that every piece of life has a need and a place and a function. Nature does not create waste. No child of the soil, whether it is a fallen leaf or a dead worm or coffee grounds or a banana peel, or a factory raised chicken or a troubled teenage, deserves to be called waste. That is why we compost. Compost is the one and only magical natural process that transforms kitchen scraps and poop into soil again, ready to feed and shelter everyone, season after season. It is more than a physical and environmental transformation—it is social, cultural, and spiritual detoxification! Compost re-turns the suffering, the uselessness, the WASTE of this world, into nothing short of BLACK GOLD!

SUGGESTED READINGS

Books:

The Permaculture Handbook by Peter Bane. Real nice and comprehensive manual on permaculture.

Gaia's Garden by Toby Hemingway. A really great introduction to practical permaculture technique. Written for climates that are a bit more temperate with a lot of rainfall (IE the Pacific Northwest/Cascadia region)

The Humanure Handbook by Joseph Jenkins. The best, most well-researched, comprehensive, and hilarious manual on composting human shit I've ever seen. Actually, one of the only books I've ever seen about this.

Worms Eat My Garbage by Mary Appelhof and Mary Frances Fenton. Seriously epic and useful manual on worm composting.

Toolbox for Sustainable City Living by Scott Kellogg and Stacey Pettigrew. These two were co-founders of the legendary Rhizome Collective in Austin, TX. The book is an extremely practical rundown of how to obtain, grow, and deal with life's necessities in an urban environment: food, water, waste, energy, bioremediation. Illustrations by Juan Martinez of the Beehive Collective are great too.

Pedagogy of the Oppressed by Paolo Friere "education must begin with the solution of the teacher-student contradiction, by reconciling the poles of the contradiction so that both are simultaneously students and teachers." (chapter 2)

Web Sites:

http://compost.css.cornell.edu/ Cornell University developed a bunch of useful research and info on composting. Then they made this site for you

http://www.permies.com/ awesome collection of forums and information relating to permaculture and DIY growing

http://zinelibrary.info/ This wonderful site has a huge database of printable zines (like this one) for free.

http://thiscouldbeagarden.org/ stories of urban gardening projects and radical communities around the US. ((compiled by the person who made this zine… :0))) a disposal strategy applied to fields as "biosolids" with tight regulations to prevent environmental damage. The water that carried the poop to the treatment plant is zapped with chlorine and allowed to go back into the river. Overall, the modern sewage system is doomed. It cannot be saved. It takes two incredibly valuable resources--water and soil fertility--and with all the elegance of modern convenience and efficiency, turns both into trash.

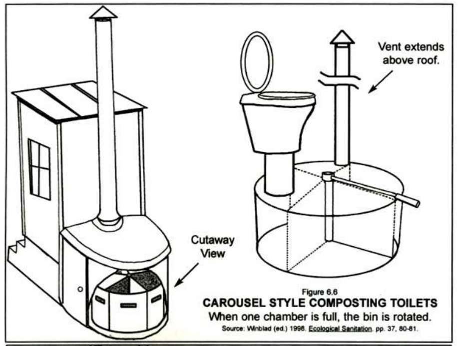
Cow and chicken poop are already recognized as valuable soil amendments. Yet humans are still scared to deal with their own back end. In fact, human poop is the cream of the crop in terms of nitrogen content. It is entirely possible and plausible to compost and re-use our poopy pearls in a small-scale, sustainable, soil-enriching way. Instead of praying to the porcelain altar every time nature calls, why not save and conserve that resource? Why not take responsibility for our own shit?

Table 3.5

COMPARISONS OF DIFFERENT TYPES OF MANURES

Manure	% Moisture	% N	% Phos	% K
Human	66-80	5-7	3-5.4	1.0-2.5
Cattle	80	1.67	1.11	0.56
Horse	75	2.29	1.25	1.38
Sheep	68	3.75	1.87	1.25
Pig	82	3.75	1.87	1.25
Hen	56	6.27	5.92	3.27
Pigeon	52	5.68	5.74	3.23
Sewage	---	5-10	2.5-4.5	3.0-4.5

Source: Gotaas, Harold B. (1956). Composting - Sanitary Disposal and Reclamation of Organic Wastes, pp. 35, 37, 40. World Health Organization, Monograph Series Number 31. Geneva.



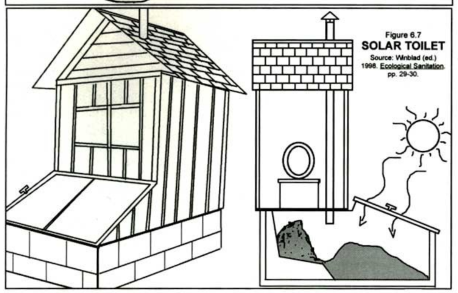


Table 3.3

COMPOSITION OF HUMANURE

FECAL MATERIAL

0.3-0.6 pounds/person/day (135-270 grams), wet weight

Organic Matter (dry wt.)	88-97%
Moisture Content	66-80%
Nitrogen	5-7%
Phosphorous	3-5.4%
Potassium	1-2.5%
Carbon	40-55%
Calcium	4-5%
C/N Ratio	5-10

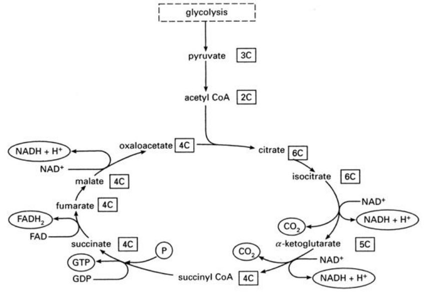
URINE

1.75-2.25 pints per person per day (1.0-1.3 liters)

Moisture	93-96%
Nitrogen	15-19%
Phosphorous	2.5-5%
Potassium	3 -4.5%
Carbon	11-17%
Calcium	4.5-6%

Source: Gotaas, Composting, (1956), p. 35.

Images/ charts are from The Humanure Handbook by J. Jenkins



CONTENTS

Compostifesto……………………………………………………………...2

Basic soil science and fertility…………………..……………………4

Compost Theory…………………………………………………………..7

Compost Chemistry …………………………………………………..8

Compost Physics……………………………………………………….…..12

Compost Biology………………………………………………………….13

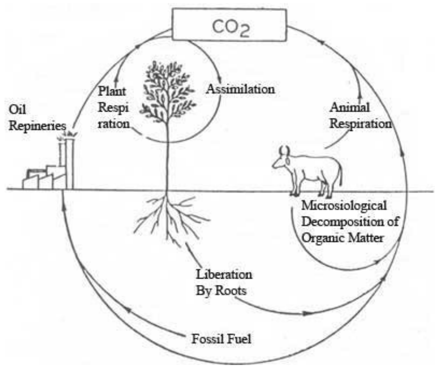
How-To Guide for Thermophilic Composting…………….……..15

About Dairy and Meat in the compost……………………………...17

Others Modes of composting……………………………………………18

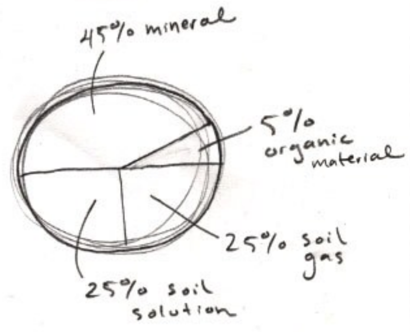
Poop………………………………….…………………………………………25

Suggested Reading……………………………………..…………………27

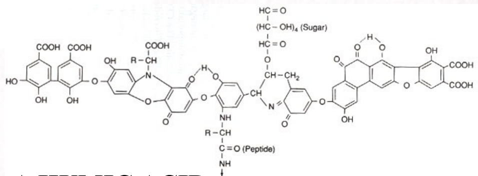


Basic Soil Science.

Soil is basically the combined residue of years of geologic weathering and organic buildup. Soils take thousands of years to fully form, and the process is a factor of time, climate, biological activity, topography, parent material, and human activity. Here's a basic rundown of soil components….



MINERAL. (49-45%) The mineral portion of soil is the sand (particles .05-2 mm in size), silt (.002-.05 mm), and clay (<.002 mm). The exact composition of mineral depends on geologic parent material, but is generally made of silica, aluminum, oxygen, and hydroxyl atoms arranged in sheets of tetra– or octahedrons. Soil particles usually have a permanent negative charge, so they attract and hold positive cations like Ca+, Mg+, Na+, ect. Its ability to hold cations is called its Cation Exchange Capacity (CEC).



A HUMIC ACID.

ORGANIC. Organic matter is the combined total biomass of soil organisms, undecomposed litter, actively decomposing organic residues, and stabilized organic matter. The exact structure of stabilized organic material, or humus, is not known, but a proposed model is shown at left. The organic fraction, although small, is extremely important. Organic matter improves the physical structure of soil by gluing particles together. It increases nutrient holding capacity, and when microbes degrade it, nutrients are released for plant uptake.

SOIL SOLUTION. (Up to 50%) Water with nutrients dissolved within.

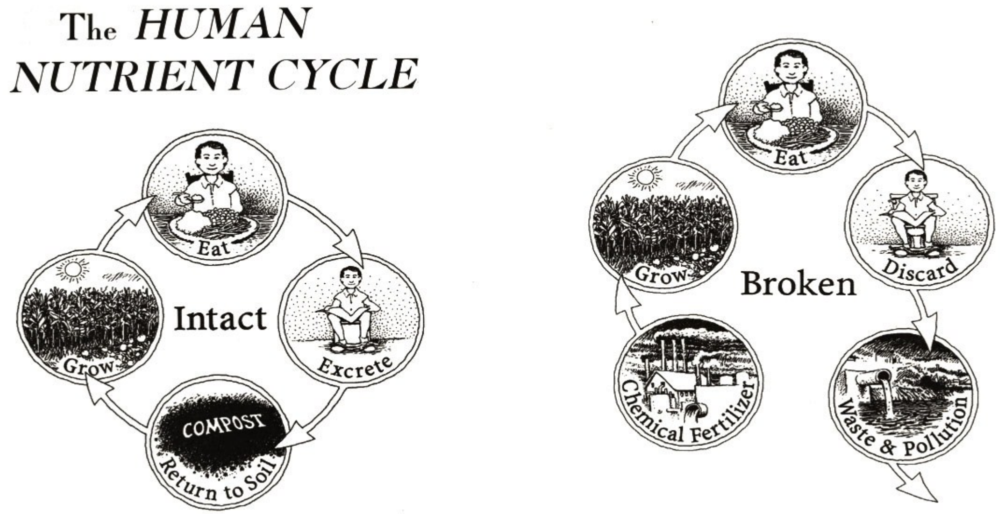
SOIL GAS. (Up to 50%) Often lower in oxygen and higher in CO2 than the atmosphere, due to the activity of microbes.

FROM MY PILE TO YOURS……

Poop is great. It is high in nitrogen, phosphorous, and potassium--the very nutrients that are most limiting for plants. It is rich in microbial life, which stimulates and activates compost life. It can even be argued that soil is essentially the collective stabilized poop from thousands of years of biological and geological activity. Without poop, we would be nothing.

Many people are concerned about poop because of its potential to harbor dangerous bacteria. Indeed, these fecal-borne pathogens can include nasty things like E. Coli, Salmonella, nausea-causing Vibrio species, Tetanus (Clostridium tetani), Botulism, parasitic worms, and more. Even people who are healthy themselves can be carriers of infectious poop bugs. In certain parts of Asia, they apply raw human poop (called "night soil") directly to the fields, which has caused epidemics. Recent scares of salmonella on spinach were caused by use of raw cow manure as a fertilizer. This is why poop needs to be COMPOSTED. Pathogens are used to the cushy pampered life in someone's intestines and are entirely incapable of surviving in the soil, due to heat, lack of resources, and competition from native microbes. Composting poop thermophilically and allowing it to cure for at least a year is pretty much guaranteed to render it safe and sickness-free.

Human poop represents possibly the most disrespected, most broken part of the waste loop. Food is harvested from the soil, but the by-product of that very same food is not allowed to return. Instead, we mix it with clean drinking water and flush it away, where it is collected at the waste water treatment plant and allowed to concentrate in great volumes. Poop breaks down best in small, localized piles, exposed to oxygen and microbes. Collecting it in a gigantic vat at the plant creates anaerobic conditions, keeping it from decomposing properly, and producing a lot of methane (recognized by the EPA to be 20 times more potent than CO2 as a greenhouse gas). Furthermore, the nature of the sewage system is that innocent poop gets mixed up with industrial waste such as heavy metals, solvents, chemicals, biocides, and whatever else people pour down their drains. Once contaminated, the poop is forever damned. It ends up being desiccated and as



Sheet Mulching/Bed Compost/Lasagna Gardening

In a forest, the leaves and pine needles fall onto the surface of the earth, right? And animals come and leave their droppings, trees fall over and die, and over time the mushrooms and bacteria eat these things and they become soil. If you dig down into the forest soil, you will see layers: the most decomposed material is on the bottom, the freshest and least decomposed on the top. The soil is being created in layers.

Sheet mulching is a similar process which is used in areas that have very poor soil. Unlike regular mulching, it is a lot thicker, and it is not done at the same time that plants are growing there.
Sheet mulching is when we intentionally create layers of organic matter in our farms and gardens in order to build the soil. Unlike nature, we add the specific ingredients all at once, and keep it watered so that it will break down very fast and give us fertile soil. Over the course of one year (or even just one winter) you can have dramatically improved topsoil for your garden.

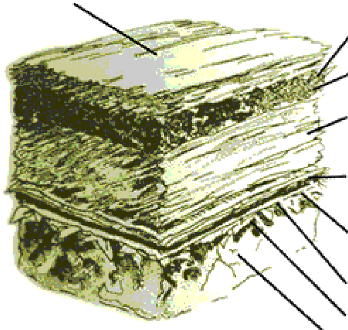
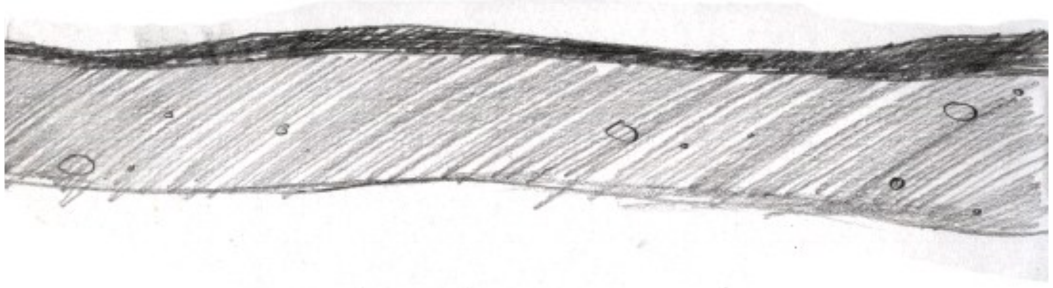


Image: from Gaia's Garden by T. Hemingway

It works like this: In the fall, we dig the existing soil a little bit. Then, we layer organic material on top of it. It is just like regular composting: You need a balance of nitrogren and carbon, and having many different sources of those nutrients will give you more balanced soil. The cardboard at the bottom serves as a weed barrier, while the leaves or fabric at the top prevent it from drying out.

Once built, leave the bed alone for 4-6 months, but keep it watered as best you can. In the winter, water during warm spells and let it freeze otherwise. This will help it break down into amazing, wonderful soil!
It is normal for the bed to seem to "shrink' a little bit. This is because the material is decomposing.

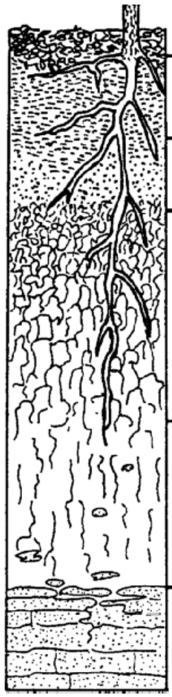
In the spring, uncover it! Viola—it is now soil! If it does not look properly broken down, you need to give it more time. If it looks dry, give it more water.



Methods of Classifying and Describing Soil:
By Texture: % Sand, Silt, and Clay.
By Color: Color depends on chemical composition. Red soilds are usually high in oxidized iron, for example. The darker the color, the more organic carbon it has (generally)
By pH: Soil ranges in pH from 5.5 (very acidic tropical conditions) to 8.5 (Dry, carbonate-rich soil). Colorado soils are usually very alkaline, with pH from 7.5-8. Acidic soils will range from 6-7 in pH. Even .1 amount of difference on the pH scale will have a huge impact on the nature of your soil, so you need a better measurement than just litmus paper.

STOP TREATING YOUR SOIL LIKE DIRT!!!
Soil is NOT the same as dirt. Dirt implies a substance, a commodity than can be scraped up, moved around, or otherwise exploited. Soil, on the other hand, is a living system. It takes thousands of years to form properly, determined by climate, vegetation, topography, native geologic material, and human activity. The soil is home to many. It provides food, water, shelter, and heat. Plants, bacteria, fungi, and animals all depend on it, and all these creatures have specific needs and relationships to one another. Within the soil is a complex web of creatures breathing, eating, dying, and making love, releasing nutrients and taking them up. Soil is full of drama and emotion, dirt is boring and inert. Soil is alive, dirt is dead! Which would you rather have?

Soil Profile



Nitrogen-Phosphorous-Potassium

On bags of commercial fertilizer, there will always be a guaranteed analysis of the N-P-K content. This is required by law. In commercial industrial agriculture, nutrients are synthesized (with fossil energy) and applied to the soil for direct plant uptake. Plants cannot take up large molecules like proteins and fats—they need smaller molecules to pass through their root membranes. Plants take up nitrogen as NO_2, NO_3, and NH_4 to a smaller degree. They take up Phosphorous as H_2PO_4, HPO_4, or PO_4. Potassium as K^+, Sulfur as SO_4, and trace elements as Ca^+, Mg^+, Cu^{++}, Zn^{++}, MoO_4^{--}, Cl^-, and so forth.

In a natural ecosystem, fertility inputs to the soil do not occur in these forms. Plants rely entirely on microbes to break down organic molecules, transform the constituents into plant-available nutrients, and release those nutrients into the soil solution.

THE DESTRUCTIVE CYCLE OF SYNTHETIC FERTILIZATION.

Nitrogen, phosphorous, and other nutrients in nature never get added to a soil system on their own—always in the form of organic materials, which are mostly carbon. When synthetic fertilizer is added to a field or garden, it upsets the nutrient balance of the soil ecosystem. Bacteria and fungi, suddenly overwhelmed with an influx of raw nitrogen or phosphorous, grow out of control, burning up all the soil carbon as food and releasing it into the atmosphere as CO_2. Eventually, having exhausted all the organic carbon in their soil home, they decline and die off. The soil is left with less organic material, less diverse microbial populations, and less ability to convert organic residues into plant nutrients. The soil, drained of carbon, loses its ability to retain water and other nutrients, loses its ability to maintain structure, and is more susceptible to erosion. For it to continue to support plant growth, it needs more synthetic chemicals, and the cycle continues. The soil becomes nothing more than a medium for supporting plant roots. It loses its life, its soul, its soil-ness…

A second way to remove the worms is to build a small harvester frame of 2 x 4s with a 3/16-inch mesh bottom. Place the worm compost on the frame and sift the worms out. Larger pieces of compost can be returned to a new batch of bedding and worms.

The compost also can be placed in small piles on a tarp in the sun (or under bright lights inside). Because worms don't like light, they will wiggle to the bottoms of the piles. After waiting 10 minutes, remove the upper inch or more of finished compost from each pile until you run into the worms. Allow the worms to again wiggle to the bottom of the pile and repeat the process. Combine whats left of the small piles into one big pile and again repeat the process. You should eventually end up with a pile of finished compost and a ball of worms. The worms can be added back to a new bin of bedding and food waste. Larger worms also can be used as bait for fishing.

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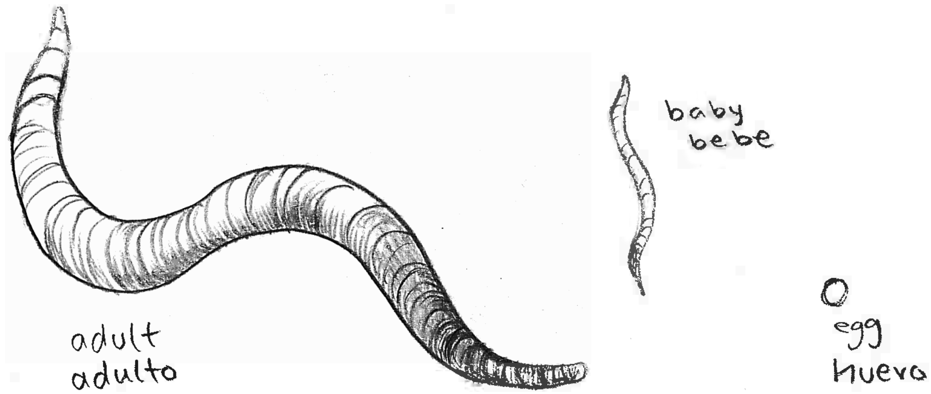


The bedding material should be thoroughly moistened (about the consistency of a damp sponge) before adding the worms. Fill the bin three-quarters full of moist bedding, lifting it gently afterwards to create air space for the worms to breathe and to control odors.

ADDING THE WORMS

Under optimum conditions, redworms can eat their own weight in food scraps and bedding in one day. On the average, however, it takes approximately 2 pounds of earthworms (approximately 2,000 breeders) to recycle a pound of food waste in 24 hours. The same quantity of worms requires about 4 cubic feet of bin to process the food waste and bedding(1 cubic foot of worm bin/500 worms).

Composting worms can be purchased from dealers listed in the ad sections of many garden magazines. Some dealers sell worms as pit-run worms, which consist of worms of all ages and sizes. Add worms to the top of the moist bedding when they arrive. The worms will disappear into the bedding within a few minutes.

ADDING FOOD WASTE

Earthworms eat all kinds of food and yard wastes, including coffee grounds, tea bags, vegetable and fruit waste, pulverized egg shells, grass clippings, manure, and sewage sludge. Avoid bones, dairy products, and meats that may attract pests, and garlic, onions, and spicy foods. Limited amounts of citrus can be added, but too much can make the compost too acidic. The compost should be kept at a pH of 6.5 if possible, with upper and lower limits at 7.0 and 6.0, respectively. Overly acidic compost can be corrected by adding crushed eggshells.

Avoid adding chemicals (including insecticides), metals, plastics, glass, soaps, pet manures, and oleanders or other poisonous plants, or plants sprayed with insecticides to the worm bin.

Food wastes should be added to the bin by pulling back the bedding material and burying it. Be sure to cover it well to avoid attracting flies and other pests. Successive loads of waste should be buried at different locations in the bin to keep the food wastes from accumulating. Grinding or blending the food waste in a food processor speeds the composting time considerably.

CONTROLLING TEMPERATURE AND MOISTURE IN THE BIN

Redworms can survive a wide range of temperatures (40-80°F), but they reproduce and process food waste at an optimum bedding temperature range of 55-77°F. The worms should never be allowed to freeze. Bins kept outside may have to be insulated with straw in the winter to keep the worms from freezing. Portable bins can be kept by a hot water heater in the garage during the winter to keep them warm.

The bin contents should be kept moist but not soaked. Do not allow rainfall to run off a roof into the bin. This could cause the worms to drown. A straw covering may be needed in exposed sites to keep the bin from drying out during hot summer weather.

MAINTAINING THE BIN

Food scraps can be continually added to the bin for up to 2 to 3 months, or until you notice the bedding material disappear. When the bedding disappears, harvest the worms and finished compost, then refill the bins with new bedding material.

Overloading the bin with food wastes can result in foul odors. If you notice these odors, stop adding the waste until the worms have a chance to catch up. Overly moist food waste and bedding also cause odors. To relieve this problem, fluff up the bedding to add air and check the drainage holes. As a general rule of thumb, keep the bedding material moist, but never soggy. Make sure the food waste is buried properly in the bedding. Exposed food wastes can attract fruit flies, house flies, and other pests. Keeping the bin covered with straw or moist burlap also deters these pests.

Garden centipedes can be a problem in the worm bin, especially outside. These predators should be destroyed. Overly wet beds also can attract the earthworm mite, which may cause the worms to stop eating.

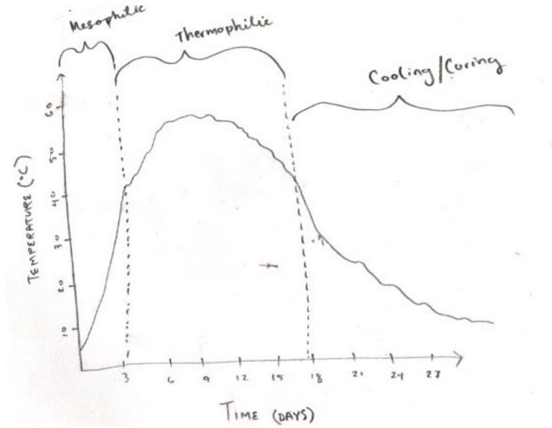
HARVESTING THE COMPOST AND WORMS

There are three basic ways to separate the worms from the finished compost. One way involves moving the finished compost and worms over to one side of the bin and adding new bedding material and food waste to the other side. Worms in the finished compost should move over to the new bedding with the fresh food waste. The finished compost can then be removed.

COMPOST THEORY

This Zine focuses on thermophilic composting, which literally means "Heat-Loving" This method is one of the most-used, easiest, and most effective. The heat given off by a compost pile is a result of the metabolic processes of millions of microbes in a furious feeding frenzy. Most of these microbes are found naturally in all soils and food wastes, and given the right conditions, will perform nothing short of alchemy. To promote the growth of these organisms, all we need to to is add the right ingredients of food, water, and oxygen in the correct ratio, and let nature do the rest.

The process of thermophilic composting can be classified into three stages, each of which supports a different community of microorganisms.



1) Mesophilic Stage: Rapid growth of mesophilic bacteria and breakdown of easiest to eat compounds like simple sugars and starches.

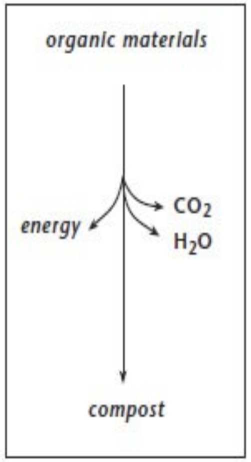
2) Thermophilic stage: As the pile heats, mesophilic bacteria become less competitive and are replaced by thermophilic organisms. They feast on the fats, proteins, celluloses and hemicelluloses in the pile, which are the main constituents of plant matter. The larger the pile, the more food there is for the bacteria, who will reach a greater critical mass and thus, more heat. It can get gets super hot, up to 60 degrees C. Most harmful pathogens are killed at 55 degrees C, so in general, it is great to get compost above this temperature. Temps above 65 will kill the beneficial bacteria.

2) Cooling/Curing stage: As the thermophiles eat up the abundance of food, they begin to decline. At this time, less heat-tolerant organisms gain a foothold—such as fungi, mesophilic bacteria, higher-ordered microbes like protozoa and nematodes, and invertebrate animals. During this stage, these microbes break down the more recalcitrant substances like lignin. They also eat each other, creating a rich soil food web, releasing and transforming nutrients along the way. Over time, the organic matter in the pile is stabilized as humus and nutrients are freed up for plant uptake.

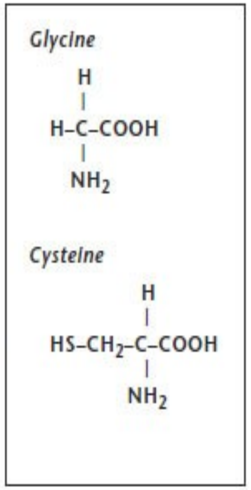
From "Composting in the Classroom" by the Cornell Waste Management Institute, 1996:

COMPOST CHEMISTRY

Many chemical changes occur during composting, either relatively rapidly in thermophilic systems or more slowly in worm bins or other systems that do not heat up (Figure 1–3). In all of these compost systems, chemical breakdown is triggered by the action of enzymes produced by microorganisms. Bacteria and fungi secrete enzymes that break down complex organic compounds, and then they absorb the simpler compounds into their cells. The enzymes catalyze reactions in which sugars, starches, proteins, and other organic compounds are oxidized, ultimately producing carbon dioxide, water, energy, and compounds resistant to further decomposition. The enzymes are specialized, such as cellulase to break down cellulose, amylase for starches, and protease for proteins. The more complex the original molecule, the more extensive the enzyme system required to break it down. Lignins, large polymers that cement cellulose fibers together in wood, are among the slowest compounds to decompose because their complex structure is highly resistant to enzyme attack.



As organic matter decomposes, nutrients such as nitrogen, phosphorus, and potassium are released and recycled in various chemical forms through the microorganisms and invertebrates that make up the compost food web. Proteins decompose into amino acids such as glycine or cysteine. These nitrogen- and sulfur-containing compounds then further decompose, yielding simple inorganic ions such as ammonium (NH_4^+), nitrate (NO_3^-), and sulfate (SO_4^{2-}) that become available for uptake by plants or microorganisms.



Not all compounds get fully broken down into simple ions. Microbes also link some of the chemical breakdown products together into long, intricate chains called polymers. These resist further decomposition and become part of the complex organic mixture called humus, the end product of composting.

In thermophilic composting, any soluble sugars in the original mixture are almost immediately taken up by bacteria and other microorganisms. The resulting explosive microbial growth causes the temperature to rise. During the thermophilic phase, more complex compounds such as proteins, fats, and cellulose get broken down by heat-tolerant microbes. Eventually, these compounds become depleted, the temperature drops, and the long process of maturation begins. During this final phase, complex polymers continue slowly to break down. Those most resistant to decay become incorporated into humus.

***Research Possibility:** How well do human nutrition concepts apply to compost microorganisms? For example, will the microbes get a "sugar high," demonstrated by a quick, high temperature peak when fed sugary foods, compared with a longer but lower peak for more complex carbohydrates?*

Finished vermicompost should have a rich, earthly smell if properly processed by worms. Vermicompost can be used in potting soil mixes for house plants and as a top dressing for lawns. Screened vermicompost combined with potting soil mixes make an excellent medium for starting young seedlings. Vermicompost also makes an excellent mulch and soil conditioner for the home garden.

ANATOMY OF EARTHWORMS

The earthworm has a long, rounded body with a pointed head and slightly flattened posterior. Rings that surround the moist, soft body allow the earthworm to twist and turn, especially since it has no backbone. With no true legs, bristles (setae) on the body move back and forth, allowing the earthworm to crawl.

The earthworm breathes through its skin. Food is ingested through the mouth into a stomach (crop). Later the food passes through the gizzard, where it is ground up by ingested stones. After passing through the intestine for digestion, whats left is eliminated.

Earthworms are hermaphrodites, which means they have both male and female sex organs, but they require another earthworm to mate. The wide band (clitellum) that surrounds a mature breeding earthworm secretes mucus (albumin) after mating. Sperm from another worm is stored in sacs. As the mucus slides over the worm, it encases the sperm and eggs inside. After slipping free from the worm, both ends seal, forming a lemon-shape cocoon approximately 1/8 inch long. Two or more baby worms will hatch from one end of the cocoon in approximately 3 weeks. Baby worms are whitish to almost transparent and are 1/2 to 1 inch long. Redworms take 4 to 6 weeks to become sexually mature.

HOW TO CONSTRUCT A WORM BIN

Bins can be made of wood or plastic, or from recycled containers like old bathtubs, barrels, or trunks. They also can be located inside or outside, depending on your preferences and circumstances.

As red wigglers tend to be surface feeders, bins should be no more than 8 to 12 inches deep. Bedding and food wastes tend to pack down in deeper bins, forcing air out. Resulting anaerobic conditions can cause foul odors and death of the worms.

The length and width of the bin will depend on whether it is to be stationary or portable. It also depends on the amount of food waste your family produces each week. A good rule of thumb is to provide one square foot of surface area per pound of waste in your bin.

Wooden bins have the advantage that they're more absorbent and provide better insulation. Do not use redwood or other highly aromatic woods that may kill the worms. Plastic tends to keep the compost too moist. Plastic, however, tends to be less messy and easier to maintain. Be sure containers are well cleaned and have never stored pesticides or other chemicals. Drilling air/drainage holes (1/4- to 1/2-inch diameter) in the bottom and sides of the bin will ensure good water drainage and air circulation. Place the bin on bricks or wooden blocks in a tray to catch excess water that drains from the bin. The resulting compost tea can be used as a liquid fertilizer around the home landscape.

Each bin should have a cover to conserve moisture and exclude light. Worms prefer darkness. Bins can be covered with a straw mulch or moist burlap to ensure darkness while providing good air ventilation. Outside bins may require a lid to exclude scavengers and other unwanted pests.

Outdoor bins should be insulated from the cold to protect the worms. One option is to dig a rectangular hole 12 inches deep and line the sides with wooden planks. The bottomless box can then be filled with appropriate bedding material, food wastes, and worms. Food wastes can be continually added as they accumulate. The pile should be kept damp and dark for optimum worm activity. During the winter, soil can be piled against the edges of the bin and straw placed on top to protect the worms from cold weather. Do not add food waste to outdoor bins during the winter because this could expose the worms to freezing weather.

BEDDING MATERIALS

Bedding for bins can be made from shredded newspapers (non-glossy), computer paper, or cardboard; shredded leaves, straw, hay, or dead plants; sawdust; peat moss; or compost or aged (or composted) manure. Peat moss should be soaked for 24 hours in water, then lightly wrung out to ensure it is sufficiently moist. Grass clippings should be allowed to age before use because they may decompose too quickly, causing the compost to heat up. Bedding materials high in cellulose are best because they help aerate the bin so the worms can breathe. Varying the bedding material provides a richer source of nutrients. Some soil or sand can be added to help provide grit for the worms digestive systems. Allow the bedding material to set for several days to make sure it doesn't heat up (and allow to cool before adding worms).

Vermicomposting

Cooperative Extension Service
College of Agriculture and Home Economics

Guide H-164

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This publication is scheduled to be updated and reissued 3/04.

Yard and food waste make up a major component of solid waste in most municipalities throughout the United States. Although much of this organic waste can be recycled in the backyard using traditional aerobic backyard composting techniques, these techniques are not appropriate for apartment dwellers and are often inconvenient, particularly during bad weather in the winter.[1]

Vermicomposting, or composting with earthworms, is an excellent technique for recycling food waste in the apartment as well as composting yard wastes in the backyard. Worm bins located near a hot water heater in the garage during the winter will save many a trip through the snow to the backyard compost bin. Letting worms recycle your food waste also saves your back, because you don't have to turn over the compost to keep it aerated.

TYPES OF EARTHWORM

The most common types of earthworms used for vermicomposting are brandling worms (*Eisenia foetida*) and redworms or red wigglers (*Lumbricus rubellus*). Often found in aged manure piles, they generally have alternating red and buff-colored stripes. They are not to be confused with the common garden or field earthworm (*Allolobophora caliginosa* and other species).

Although the garden earthworm occasionally feeds on the bottom of a compost pile, they prefer ordinary soil. An acre of land can have as many as 500,000 earthworms, which can recycle as much as 5 tons of soil or more per year.

Redworms and brandling worms, however, prefer the compost or manure environment. Passing through the gut of the earthworm, recycled organic wastes are excreted as castings, or worm manure, an organic material rich in nutrients that looks like fine-textured soil.

WHAT IS VERICOMPOSTING?

Vermicompost contains not only worm castings, but also bedding materials and organic wastes at various stages of decomposition. It also contains worms at various stages of development and other microorganisms associated with the composting processing.

Earthworm castings in the home garden often contain 5 to 11 times more nitrogen, phosphorous, and potassium as the surrounding soil. Secretions in the intestinal tracts of earthworms, along with soil passing through the earthworms, make nutrients more concentrated and available for plant uptake, including micronutrients.

Redworms in vermicompost act in a similar fashion, breaking down food wastes and other organic residues into nutrient-rich compost. Nutrients in vermicompost are often much higher than traditional garden compost (see table 1).

Table 1. Chemical characteristics of garden compost and vermicompost, 1994.

Parameter*	Garden compost[1]	Vermicompost[2]
pH	7.80	6.80
EC (mmhos/cm)**	3.60	11.70
Total Kjeldahl nitrogen(%)***	0.80	1.94
Nitrate nitrogen (ppm)****	156.50	902.20
Phosphorous (%)	0.35	0.47
Potassium (%)	0.48	0.70
Calcium (%)	2.27	4.40
Sodium (%)	< .01	0.02
Magnesium (%)	0.57	0.46
Iron (ppm)	11690.00	7563.00
Zinc (ppm)	128.00	278.00
Manganese (ppm)	414.00	475.00
Copper (ppm)	17.00	27.00
Boron (ppm)	25.00	34.00
Aluminum (ppm)	7380.00	7012.00

[1]Albuquerque sample [2]Tijeras sample

*Units- ppm=parts per million mmhos/cm=millimhos per centimeter

** EC = electrical conductivity is a measure (millimhos per centimeter) of the relative salinity of soil or the amount of soluble salts it contains.

*** Kjeldahl nitrogen = is a measure of the total percentage of nitrogen in the sample including that in the organic matter.

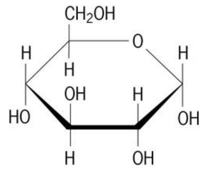
**** Nitrate nitrogen = that nitrogen in the sample that is immediately available for plant uptake by the roots.

[1]For more information on composting, see Backyard Composting (nmsu) Extension Guide H-110). Request this publication by calling (505) 646-3228. You can download this and other publications from our World Wide Web site at http://www.cahe.nmsu.edu. Click on Resources, then Gardeners.

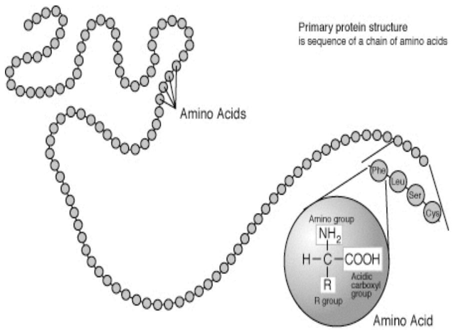
Constituents of Organic "Wastes"

(ordered most to least digestible by microbes)

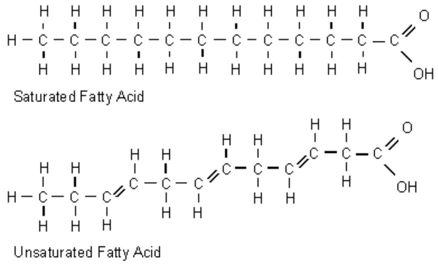
1) Simple Sugars and Starches. Glucose is shown. Starch is a bunch of glucoses linked together.



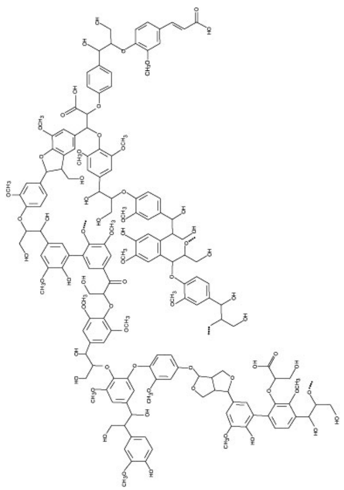
2) Proteins. Are long chains of nitrogen-rich amino acids. Shown is the primary structure of a generic protein. The secondard and tertierty structures of the protein are when it is then "pleated" folded over and over on itself and linked together with peptide and hydrogen bonds.



3) Fats.
Long-chain hydrocarbons make up the "fatty acids" which are a huge component of cell membranes.



5) Lignin. Found in wood.
WHOA.



4) Cellulose/Hemicellulose/Chitin. Are major components of plant cell walls. They are impossible to break down in human digestive systems, but lots of other critters find them tasty! Below: Cellulose

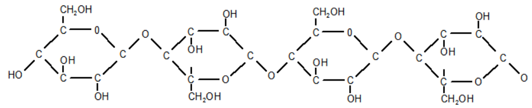
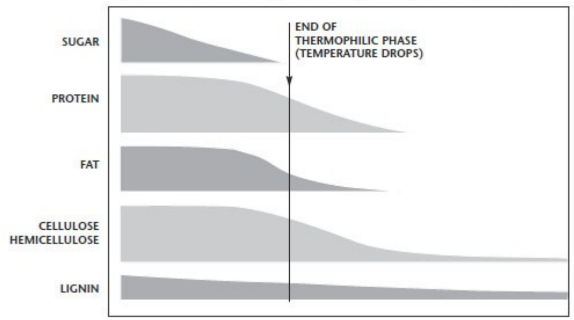


Fig. 9.5: Persistance in the compost pile!

Figure 1–3. Chemical Decomposition during Thermophilic Composting.



C:N

Of the many elements required for microbial decomposition, carbon and nitrogen are the most important. Carbon provides both an energy source and the basic building block making up about 50 percent of the mass of microbial cells. Nitrogen is a crucial component of the proteins, nucleic acids, amino acids, enzymes and co-enzymes necessary for cell growth and function.

To provide optimal amounts of these two crucial elements, you can use the carbon-to-nitrogen (C/N) ratio for each of your compost ingredients. The ideal C/N ratio for composting is generally considered to be around 30:1, or 30 parts carbon for each part nitrogen by weight. Why 30:1? At lower ratios, nitrogen will be supplied in excess and will be lost as ammonia gas, causing undesirable odors. Higher ratios mean that there is not sufficient nitrogen for optimal growth of the microbial populations, so the compost will remain relatively cool and degradation will proceed at a slow rate.

Table 3.2

CARBON/NITROGEN RATIOS

Material	%N	C/N Ratio
Activated Sldg.	5-6	6
Amaranth	3.6	11
Apple Pomace	1.1	13
Blood	10-14	3
Bread	2.10	---
Cabbage	3.6	12
Cardboard	0.10	400-563
Coffee Grnds.	---	20
Cow Manure	2.4	19
Corn Cobs	0.6	56-123
Corn Stalks	0.6-0.8	60-73
Cottonseed Ml.	7.7	7
Cranberry Plant	0.9	61
Farm Manure	2.25	14
Fern	1.15	43
Fish Scrap	10.6	3.6
Fruit	1.4	40
Garbage (Raw)	2.15	15-25
Grass Clippings	2.4	12-19
Hardwood Bark	0.241	223
Hardwoods (Avg)	0.09	560
Hay (General)	2.10	---
Hay (legume)	2.5	16
Hen Manure	8	6-15
Horse Manure	1.6	25-30
Humanure	5-7	5-10
Leaves	0.9	54
Lettuce	3.7	---
Meat Scraps	5.1	---
Mussel Resid.	3.6	2.2
Mustard	1.5	26
Newsprint	.06-.14	398-852
Oat Straw	1.05	48
Olive Husks	1.2-1.5	30-35
Onion	2.65	15
Paper	---	100-800
Pepper	2.6	15
Pig Manure	3.1	14
Potato Tops	1.5	25
Poultry Carcasses	2.4	5
Purslane	4.5	8
Raw Sawdust	0.11	511
Red Clover	1.8	27
Rice Hulls	0.3	121
Rotted Sawdust	0.25	200-500
Seaweed	1.9	19
Sewage Sludge	2-6.9	5-16
Sheep Manure	2.7	16
Shrimp Residues	9.5	3.4
Slaughter Waste	7-10	2-4
Softwood Bark	0.14	496
Softwoods (Avg.)	0.09	641
Soybean Meal	7.2-7.6	4-6
Straw (General)	0.7	80
Straw (Oat)	0.9	60
Straw (Wheat)	0.4	80-127
Telephone Books	0.7	772
Timothy Hay	0.85	58
Tomato	3.3	12
Turkey Litter	2.6	16
Turnip Tops	2.3	19
Urine	15-18	0.8
Vegetable Prod.	2.7	19
Water Hyacinth	---	20-30
Wheat Straw	0.3	128-150
Whole Carrot	1.6	27
Whole Turnip	1.0	44

Table 3.1

NITROGEN LOSS AND CARBON/NITROGEN RATIO

Initial C/N Ratio	Nitrogen Loss (%)
20.0	38.8
20.5	48.1
22.0	14.8
30.0	0.5
35.0	0.5
76.0	-8.0

Source: Gotaas, Composting, 1956, p. 92

Sources: Gotaas, Harold B. (1956). Composting - Sanitary Disposal and Reclamation of Organic Wastes (p.44). World Health Organization, Monograph Series Number 31. Geneva. and Rynk, Robert, ed. (1992). On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service. Ph: (607) 255-7654. pp. 106-113. Some data from Biocycle, Journal of Composting and Recycling, July 1998, p.18, 61, 62; and January 1998, p.20.

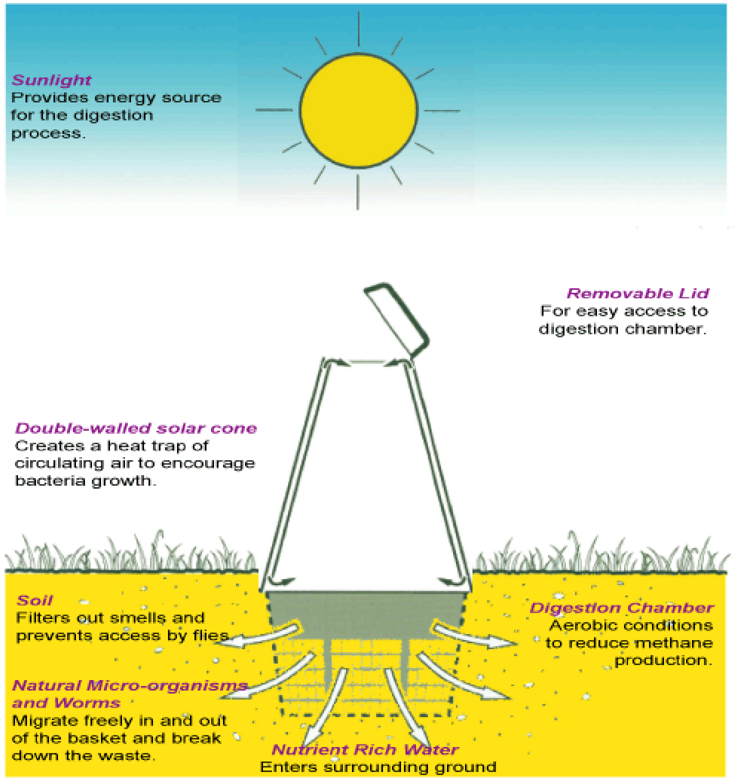
34 *The Humanure Handbook — Chapter Three: Microhusbandry*

In general, materials that are green and moist tend to be high in nitrogen, and those that are brown and dry are high in carbon. High nitrogen materials include grass clippings, plant cuttings, and fruit and vegetable scraps. Brown or woody materials such as autumn leaves, wood chips, sawdust, and shredded paper are high in carbon. You can calculate the C/N ratio of your compost mixture, or you can estimate optimal conditions simply by using a combination of materials that are high in carbon and others that are high in nitrogen.

As composting proceeds, the

Green Cones

Green cones are becoming quite popular especially in public areas. It is a durable plastic cone thing with a basket on the bottom, that is put into the ground and equipped with a tight fitting lid. Food waste is put inside, but because of the design, no large animals can get in to eat it. At it rots, small insects tunnel into the basket from underground and eat it, carrying the organic material into the rest of the surrounding soil. So, it enriches the soil from underground, and you barely had to do anything. Win-Win! Downside: you don't get any compost to put on your garden, expensive to buy and made of plastic.

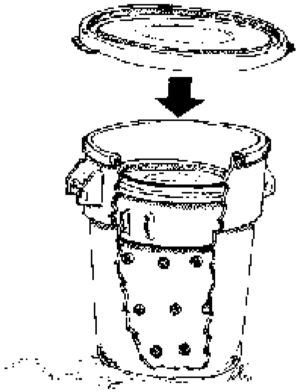


Alternative Methods

Container Composting/Bioreactors/Earth Tubs

These are containers that are used to both collect and compost organic materials. It's useful for places that don't have the land or space to house a traditional pile, or for people who are wary or unsure about keeping a pile. People in apartments and dorms use these to great effect. Institutions like schools, corporate offices, and municipal governments often use things like this because they are squeamish about odors or possibility of messiness. Appearances are important when dealing with the authorities….

Can be made out of a bucket, trash can, cooler, ect, They are often used for indoor systems, so need careful management of oxygen content and controlled ingredients (for sure no meat or dairy, which might cause odors).



This is a bioreactor made from a 35 and a 20 gallon trash can. Source: Cornell U

Goucher College in Maryland has a bunch of these all over campus.

This is an indoor system from Japan using a special microorganism strain called Bokashi. The food wastes are inoculated with the Bokashi strains, and they ferment and decompose it into compost right in that little container. Google it!

There are also really large-scale mechanical bioreactos that large instutions use, which cost thousands or millions of dollars.

C/N ratio gradually decreases from 30:1 to 10-15:1 for the finished product. This occurs because each time that organic compounds are consumed by microorganisms, two-thirds of the carbon is given off as carbon dioxide. The remaining third is incorporated along with nitrogen into microbial cells, then later released for further use once those cells die.

Although attaining a C/N ratio of roughly 30:1 is a useful goal in planning composting operations, this ratio may need to be adjusted according to the bioavailability of the materials in question. Most of the nitrogen in compostable materials is readily available. Some of the carbon, however, may be bound up in compounds that are highly resistant to biological degradation. Newspaper, for example, is slower than other types of paper to break down because it is made up of cellulose fibers sheathed in lignin, a highly resistant compound found in wood. Corn stalks and straw are similarly slow to break down because they are made up of a resistant form of cellulose. Although all of these materials can still be composted, their relatively slow rates of decomposition mean that not all of their carbon will be readily available to microorganisms, so a higher initial C/N ratio can be planned. Particle size also is a relevant consideration; although the same amount of carbon is contained in comparable masses of wood chips and sawdust, the larger surface area in the sawdust makes its carbon more readily available for microbial use.

Oxygen

Another essential ingredient for successful composting is oxygen. As microorganisms oxidize carbon for energy, oxygen is used up and carbon dioxide is produced. Without sufficient oxygen, the process will become anaerobic and produce undesirable odors, including the rotten-egg smell of hydrogen sulfide gas.

So, how much oxygen is sufficient to maintain aerobic conditions? Although the atmosphere is 21% oxygen, aerobic microbes can survive at concentrations as low as 5%. Oxygen concentrations greater than 10% are considered optimal for maintaining aerobic composting. 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.

Nutrient Balance

Adequate phosphorus, potassium, and trace minerals (calcium, iron, boron, copper, etc.) are essential to microbial metabolism. Normally these nutrients are not limiting because they are present in ample concentration in the compost source materials.

pH

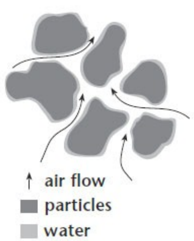
A pH between 5.5 and 8.5 is optimal for compost microorganisms. As bacteria and fungi digest organic matter, they release organic acids. In the early stages of composting, these acids often accumulate. The resulting drop in pH encourages the growth of fungi and the breakdown of lignin and cellulose. Usually the organic acids become further broken down during the composting process. If the system becomes anaerobic, however, acid accumulation can lower the pH to 4.5, severely limiting microbial activity. In such cases, aeration usually is sufficient to return the compost pH to acceptable ranges.

COMPOST PHYSICS.

COMPOST PHYSICS.

Pile Size: For thermophilic piles, it needs to be large enough to get up to a good heat, retain that heat and also moisture, but small enough to allow good air circulation. Generally, 1-2 m3 (or 1-2 cubic yards) is a good size for free-standing compost piles. Piles can be contained by a wooden, wire, or brick structure to protect them from wind.

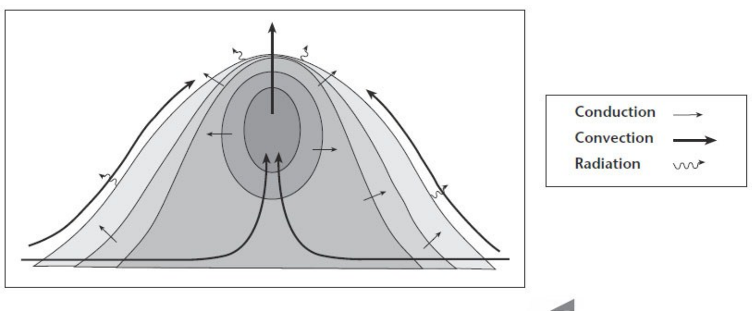
Moisture. It needs to be moist enough to support microbial growth, but not so moist as to make the pile anaerobic. Generally, 50-60% moisture is good. More than this, it will start to stink from anaerobic pockets and nutrients will leach out of the pile. Less than this, the microbes will die from thirst. To test, get a handful of compost. If water is dripping out of it, there's too much. Squeeze it. If water comes out like a wet sponge, it's just right.

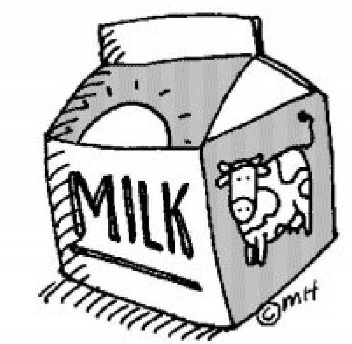


Aeration.
Oxygen levels in a compost pile can initially be around 15-20% (the same as air). Over time, due to microbial respiraton, oxygen levels in the pile decrease rapidly. 10% oxygen is a good amounts for microbes to behave optimally. If consumption rates exceed that of diffusion rates into the pile, the pile will become anaerobic. To combat this, make sure that when you are building the pile, add plenty of bulky carbon-rich material, and turn the pile when needed. (if it starts to smell). Adding tubing (PVC is often used—although it is one of the most toxic plastics available) with holes drilled into it is helpful.

Heat Flow.
Piles should be insulated with a layer of leaves to keep heat in. It is possible to get too hot—Monitoring with a thermometer is good; if it gets above 65 degrees C, turn the pile.

Figure 1–5. Three Mechanisms of Heat Loss from a Thermophilic Compost Pile.





DAIRY DEBATE.

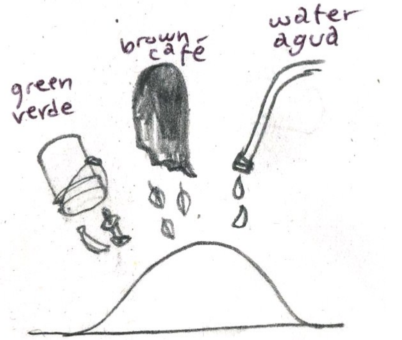
Most sources will tell you not to add meat, dairy, or random grease to the pile. The truth is that in a hot compost system, these compounds will actually break down just fine. Dairy and meat contain hydrophobic (water-repelling) long-chain fatty acids that do not mix easily with the rest of the ingredients in a pile, but tend to stick together in globs, which can cause anaerobic conditions. It can take some time for bacteria to eat through that glob, but eventually, they will devour it fully. Keep in mind that nature does not regularly produce or release animal fats in mass quantities, only humans do with their factory farms and oil mills. If large quantities of oil is added, it could smell a little weird. Be aware of this and don't feed oil to your indoor tub composting system. If you're worried about pathogens, make sure the pile cures for at least 6 months to be safe.

Some people discourage greasy components because they attract rodents and other critters! The horror! To think we could be feeding, nurturing, or otherwise living in symbiosis with the animal kingdom!! The activity of burrowing creatures can actually be a great aerator of a compost pile.

Be aware that you should NOT feed dairy, meat, or grease to a worm bin—their digestive systems cannot handle those compounds. But there's no reason to toss them in the landfill.

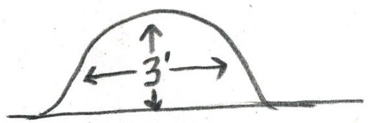
Troubleshooting

SYMPTOMS	PROBLEMS	SOLUTIONS
The heap is wet and smells like rotten eggs.	–Not enough air; pile too wet.	Turn it; add coarse, dry wastes such as straw or corn stalks.
The center is dry and contains tough, woody wastes.	–Not enough water in pile. –Too woody.	Turn and moisten; add fresh green wastes; chop or shred.
The heap is damp and warm right in the middle, but nowhere else.	–Pile is too small, or too dry.	Collect more material and mix into a new pile; moisten.
The heap is damp and sweet-smelling, but will not heat up.	–Lack of nitrogen in pile. –Compost is done!	Mix in fresh grass clippings or nitrogen fertilizer.



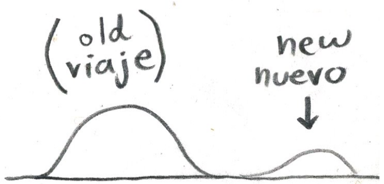
3) MIX THE INGREDIENTS. Just mix it! You can either keep adding small amounts to the pile (called "continuous" composting), or save up the organic matter and make a pile to cook all at once (called "batch" composting)

4) When the pile is three feet tall and wide, **STOP ADDING TO IT.** Let it continue on its decomposition journey. Start a new pile for your new stuff.



5) WATCH IT! water your compost occasionally, be aware of its smell, possibly take its temperature if you are interested.

6) Give it time and let nature do its magic.

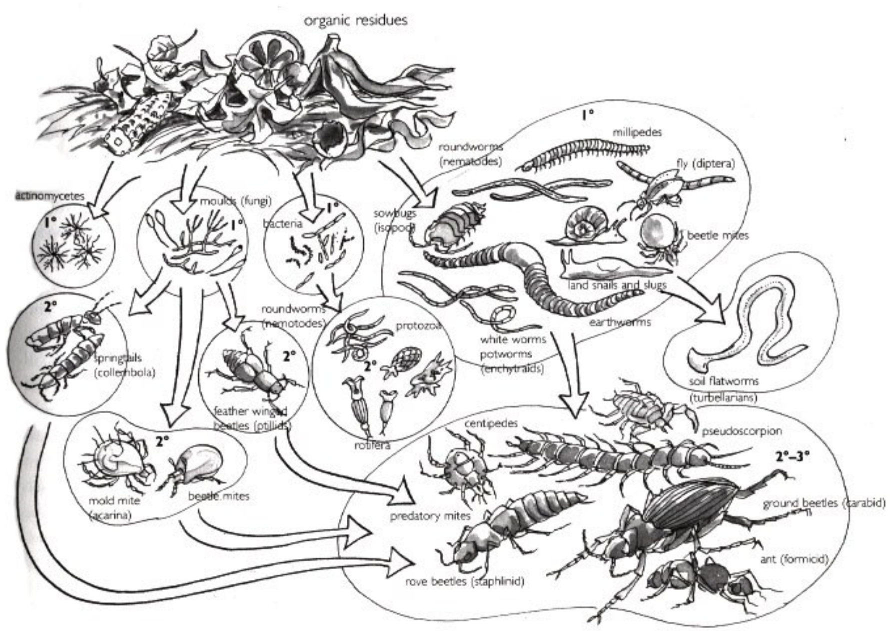


7) After 3-6 months, check up on it. You might want to "turn" the compost (dig it with a shovel and stir it up). This adds oxygen and ensures that all parts of the pile are decomposing.

8) How do you know when it's ready?
There is no exact way to determine this. The speed of decomposition depends on many factors such as heat and moisture. After the temperature drops, the pile gets colonized by mesophilic bacteria and insects, the organic matter begins to stabilize, it turns a black color and a crumbly consistency, there are no recognizable bits of food, and it is done. This can take 5 months to 1 year. If you got it to be hot, all the pathogens (if there were any) have probably died during the thermophilic phase. Test it out and go by your own judgment.

9) What to use it for? Till it into your soil, top-dress plants and trees with it, make compost tea and spray your plants for both fertility and pest resistance, give it to your mom, etc., etc..

COMPOST BIOLOGY.



The soil food web. 1°=primary decomposers; 2°=secondary; 3°=tertiary.

Image from Gaia's Garden
By T. Hemingway

TYPES OF MICROBES IN THE PILE.

A. Bacteria.

There are literally thousands of species of bacteria Unlike plants and animals, definitions between bacterial species are vague and can even change over the bacterium's lifespan, if it decides it wants to aquire or secrete a plasmid of DNA. The scientific community can't really even decide what a bacterial "species" is exactly, and have generally agreed it means that two species with 95% matching DNA classify as the same. The easiest way to scientifically classify bacteria is by their metabolisms—that is, what they eat and poop out. Here are some basic approximations.

Aerobic: Uses oxygen and Water as its electron acceptor, carbon sources as its food, and releases CO2. Aerobic bacteria are the preferred population for your compost pile—they don't smell that bad, they release CO2 gas, and are effective at degrading organic molecules into plant nutrients.

Anaerobic: Anything that doesn't use oxygen. This includes fermentors, who release Carbon Dioxide, alcohols, and organic acids. It also include the sulfur respirers, who use SO4 as their elecron acceptor, giving off H2S, which smells like rotting eggs. Methanogens are another anaerobe—they consume CO2 and produce methane gas. Stinky compost is characteristic of anaerobic conditions.

B. **ACTINOMYCETES**
The characteristic earthy smell of soil is caused by actinomycetes, a type of bacteria that forms chains or filaments. In composting, actinomycetes play an important role in degrading complex organic molecules such as cellulose, lignin, chitin, and proteins. Although they do not compete well for the simple carbohydrates that are plentiful in the initial stages of composting, their enzymes enable them to chemically break down resistant debris, such as woody stems, bark, and newspaper, that are relatively unavailable to most other forms of bacteria and fungi. Some species of actinomycetes appear during the thermophilic phase, and others become important during the cooler curing phase, when only the most resistant compounds remain. Actinomycetes thrive under warm, well-aerated conditions and neutral or slightly alkaline pH. Actinomycetes form long, threadlike branched filaments that look like gray spider webs stretching through compost. These filaments are most commonly seen toward the end of the composting process, in the outer 10 to 15 cm of the pile. Sometimes they appear as circular colonies that gradually expand in diameter.

B. FUNGI. Are eukaryotic, aerobic organisms that digest food by secreting enzymes onto their preferred dinner and then absorb the resulting nutrient slurry. They include the unicellular yeasts, the molds, and the fruiting mushrooms that many find so delicious (or poisonous). They can be primary or secondary decomposers, meaning they eat pure woody lignin stuffs or already half-composted stuff, respectively. They can be mycorrhizal, meaning they associate with plant roots and help that plant take up water and nutrients. Fungi have the unique ability to span long distances in the soil, their mycelial tendrils reaching across pore spaces, transporting water and nutrients to where they are needed. Fungi are mesophilic and are strict anaerobes.

C. Micro and mesofauna. Includes protozoa, nematodes, soil mites. These guys feast on primary decomposers like bacteria and fungi, as well as organic residues.

D. **Invertebrae.** All manner of higher-ordered insects and worms. Includes earthworms, spiders, pillbugs, mollusks (snails and slugs), mites, ants, milli and centipedes, flies and bees, beetles, butterflies, and many more.

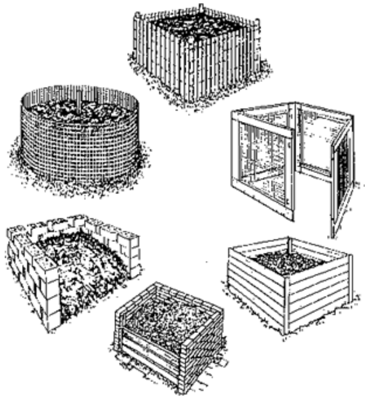
COMPOST 101.

(step-by-step)

1) Location, Location.

Your pile should be in a secluded part of your yard where it won't be disturbed by pets. Sunniness is good but not extremely vital as the pile will make its own heat. You could build a containment around it from wood or wire, to protect from wind, but it's not necessary.

2) Get the Recipe Right



BROWN STUFF

50-70% OF VOLUME
(leaves, hay, woody dry matter) "Browns" are rich in carbon and carbohydrates, giving energy to composting microorganisms. It is good to moisten browns as you add them, or use browns to absorb excess moisture.

GREEN STUFF

30-50% OF VOLUME
(grass, garbage, manure) "Greens" are fresh, damp materials that quickly decompose on their own. Their nitrogen is key in protein for the microbes. "Greens" are also the source of most odors. They should be mixed in completely or in layers with "browns" (always cover food scraps!) Otherwise, greens can collapse in volume, lose air, and putrefy.

BLACK STUFF

0-5% OF VOLUME
"Blacks" are the inoculant, like yeast in bread, which starts the process. Dark soil or finished compost contains millions of soil organisms to add to your pile. This isn't always necessary—bacteria are everywhere. They are ubiquitous. Combine any green and brown material, and it will get hot and decompose. But like a good beer or sourdough, sometimes you want to be consistent.