Basics of Composting

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General Definition of Composting

Transformation of raw organic materials into biologically-stable, humus-rich substances suitable for growing plants.

NOSB Compost definition
(§205.2)

"The product of a managed process through which microorganisms break down plant and animal materials into more available forms suitable for application to the soil. Compost must be produced through a process that combines plant and animal materials with an initial C:N ratio of between 25:1 and 40:1. Producers using an in-vessel or static aerated pile system must maintain the composting materials at a temperature between 131°F and 170°F for three days. Producers using a windrow system must maintain the composting materials at a temperature between 131°F and 170°F for 15 days, during which time, the materials must be turned a minimum of five times."

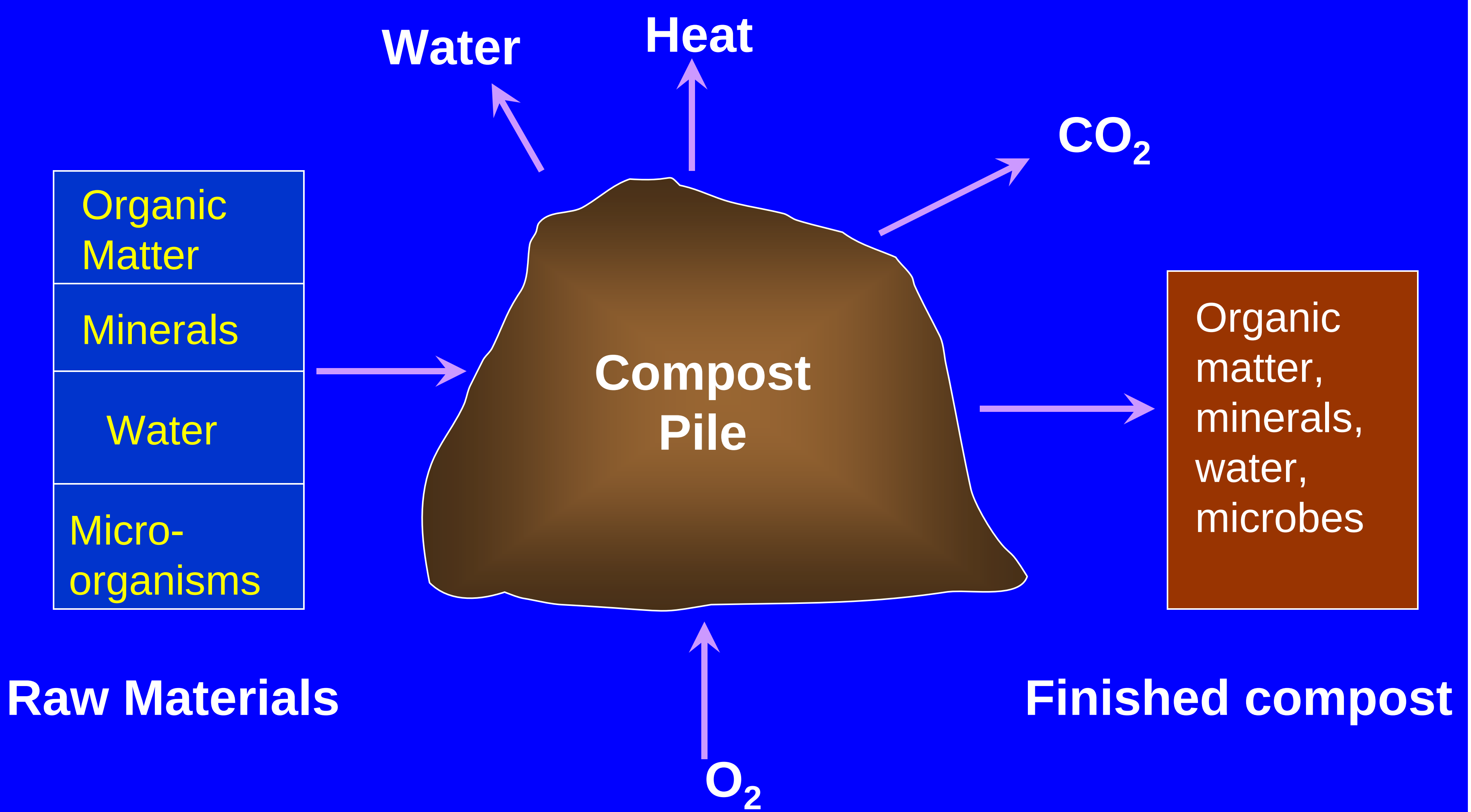
Compost cannot contain:

- Any synthetic substance not included on the National List (OMRI)
- Sewage sludge (biosolids)

Compost Task Force Modifications

- If compost achieves 131ºF for 3 days and pile mixed/managed to ensure all of feedstocks achieve this temp., it's OK
- Vermicompost acceptable
- Compost and vermicompost teas still under review; not acceptable at present.

The Composting Process



Three most important factors for making good compost are:

1) chemical makeup of raw ingredients or feedstocks

2) physical size and shape of feedstocks and porosity of the pile

3) population of organisms involved in composting process

Composting is a BIOLOGICAL process:

Take the microbes’ point of view when setting up conditions for efficient composting

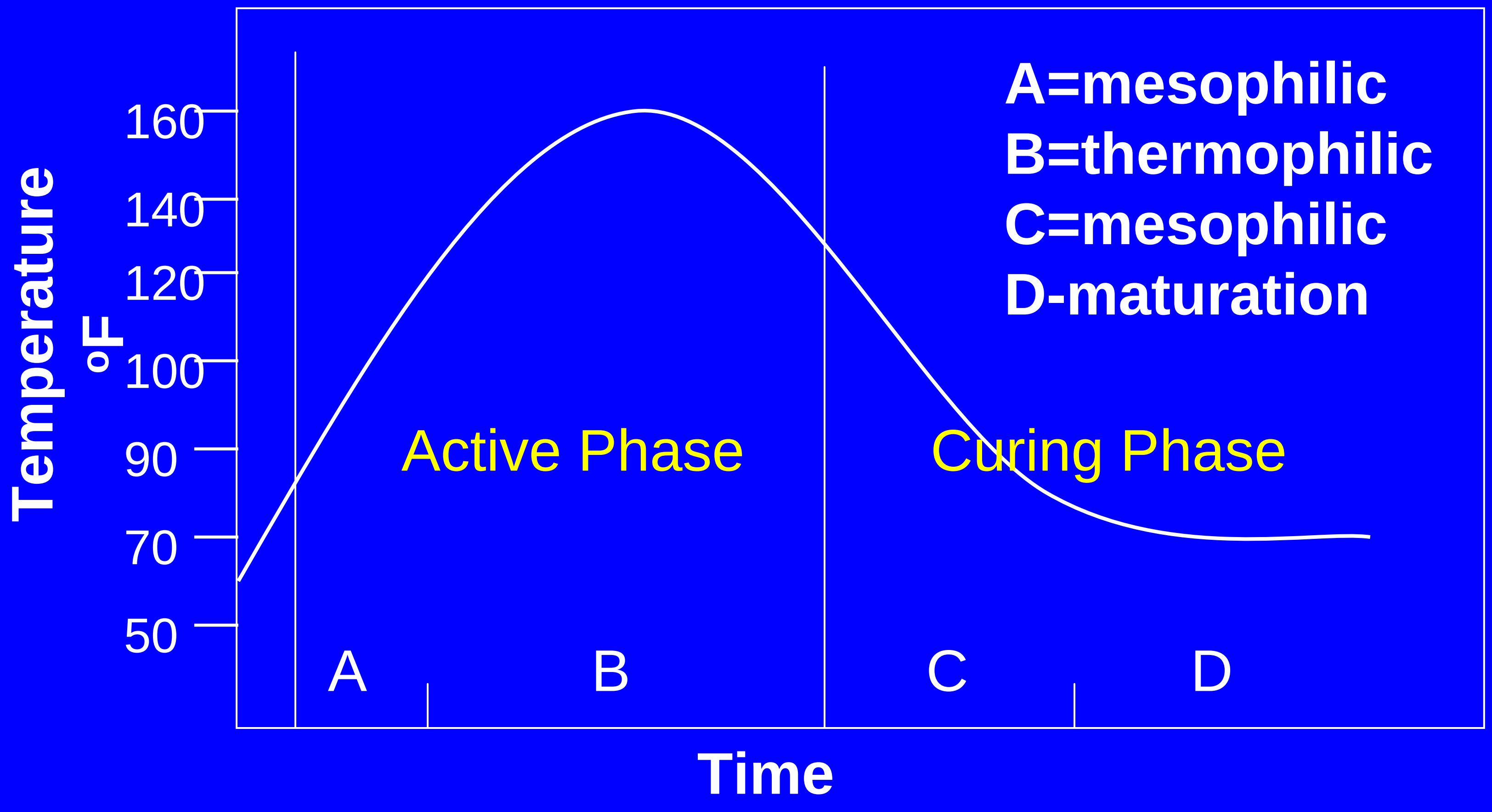
Microbes break down organic compounds to:

- Obtain energy to carry on life processes
- Acquire nutrients (N, P, K) to sustain populations

Compost "Happens"

- Aerobically (with oxygen) or anaerobically when organic materials are mixed and piled together
- Aerobic composting is most efficient and least offensive form of decomposition
- Heat generated is by-product of microbial break down of organic matter

Temperature Changes in an Aerobic Compost Pile



Who are the microbes?

- Mesophiles-moderate temperature (80-113ºF) organisms begin the process
- Thermophiles-high temperature (130-150ºF) organisms take over during active phase
- Mesophiles recolonize pile during curing phase (actinomycetes, beneficial microbes)

Pathogens

- Coliform bacteria and Salmonella are most common.
- Moist heat more effective in killing pathogens than dry heat.
- More pathogens killed at acid or alkaline pH than at neutral (7) pH.
- US EPA requires minimum of 3 days at 130^{o}F to kill pathogens.

Microbial Food Quality

Carbon compounds

- carbohydrates
- cellulose
- hemicellulose
- chitin
- lignin
- fats, oils

Ease with which compounds are broken down:

carbohydrates > hemicellulose > fats/oils > cellulose = chitin > lignin

Fruit, vegetable wastes easily degraded because contain mostly sugars and starches

Leaves, stems, nut shells, bark, tree trunks more difficult because contain cellulose, hemicellulose and lignin

Nitrogen

- Amino Acids
- Proteins
- Sources include:
  - green plant tissue (grass clippings, green leaves & stems, fruits, vegetables)
  - animal wastes (meat, feathers, hair, hides, blood, intestinal matter, urine, fecal matter).

Index of Feedstock quality: Carbon:Nitrogen (C:N) Ratio

- Supply of total carbon relative to total nitrogen
- If amount of C relative to N is too high, slows composting process
- If C:N ratio is too low, more likely to lose N as ammonia gas

C:N ratio considered a threshold phenomenon relative to microbial activity:

- C:N > 20:1 results in net N immobilization (tie up)
- C:N < 20:1 results in net N mineralization (release)
- **Ideal starting range for composting 25:1-35:1**

Rules of thumb:

Green materials have lower C:N ratios than woody materials or dead leaves.

Animal wastes more N rich than plant wastes.

Combine high C:N materials with low C:N materials in ratios of 2-3:1

Feedstock C:N Ratios

Materials High in Carbon	C:N Ratio
Fall leaves	30-80
Straw	40-100
Wood chips or sawdust	100-500
Bark	100-130
Mixed paper	150-200
Newspaper or cardboard	560
Materials High in Nitrogen	C:N Ratio
Vegetable wastes	15-20
Coffee grounds	20
Grass clippings	15-25
Manure	5-25

Environmental Factors Affecting Composting

Oxygen content

- Since most efficient composting is aerobic, need O_2.
- Atmospheric O_2 concentration: 21%.
- O_2 levels in compost air shouldn't go < ~5% for aerobic composting; 10% optimal.
- As pile heats up, more O_2 will be consumed.

Rapidly degrading substrates

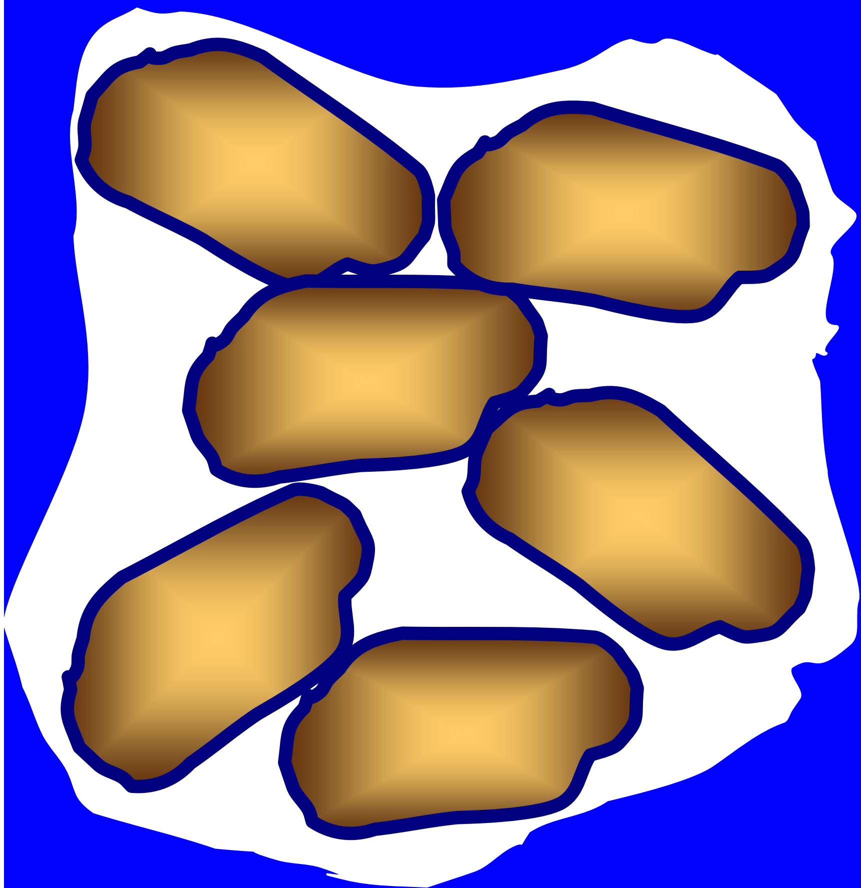
- Include grass clippings, food processing wastes.
- Usually have low C:N ratios, high available C compounds, high moisture, small particle size.
- Consume O_2 faster than it can be replenished.
- Need to blend with dry, high C feedstocks immediately

Moisture content

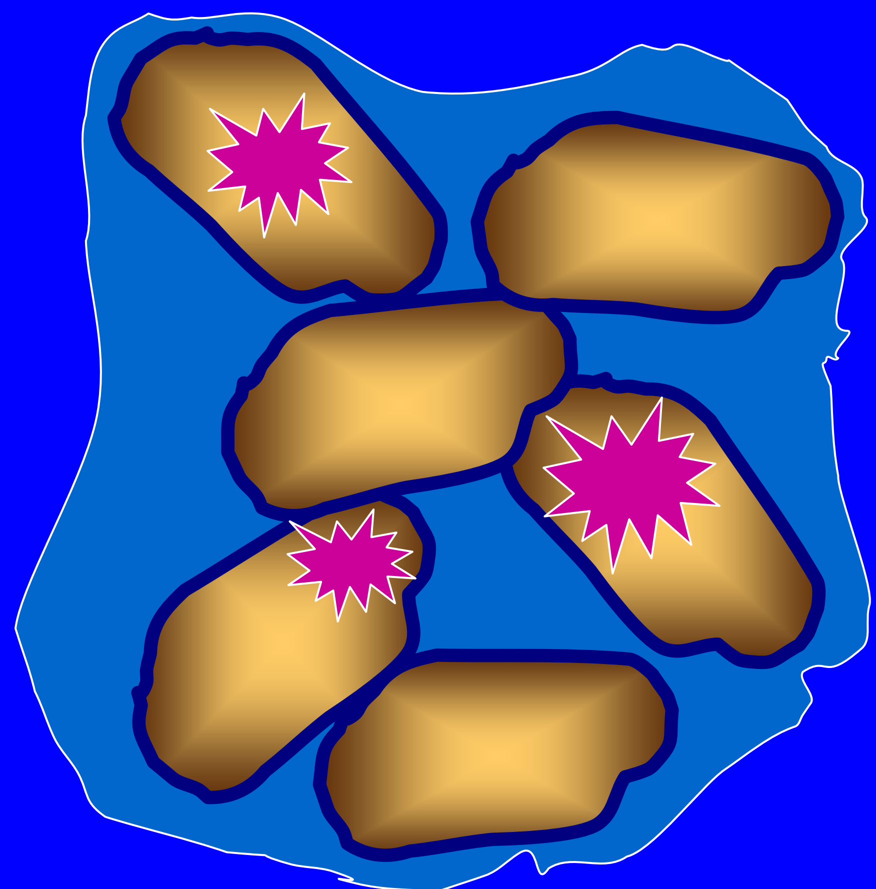
- Optimal range 45-60% by weight.
- Low moisture impedes composting process because
  - microbes need water
  - Can cause spontaneous combustion if temperature increases
  - Moisture content < 30% creates dust problems.

Adapted from T. Richard

Water content effects on aeration



Adequate moisture with air-filled pores



Excessive moisture with water-filled pores

Moisture cont'd

- Moisture content > 60% means pore spaces filled with water rather than air.
- Insufficient O_2 $\longrightarrow$ anaerobic conditions.
- Dry, high-carbon feedstocks often used as bulking (drying) agents with wet feedstocks.

Temperature

- Higher temperatures result in faster breakdown of organic materials.
- Excessively high temperatures (> 170 ^{o}F) can inhibit microbial activity.
- Moisture moderates wide swings in temperature.
- Once compost pile no longer heats to thermophilic range, goes into curing phase.

pH: Measure of acidity or alkalinity

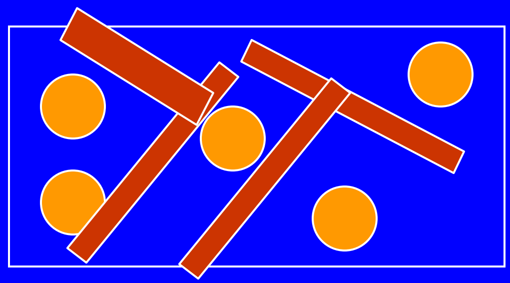
- Ideal range 5.8-7.2
- If pH exceeds 7.5 can promote ammonia gas loss
- Certain feedstocks can increase or lower pH
- Production of organic acids and anaerobic conditions can lower pH < 4.5, limiting microbial activity

Particle size

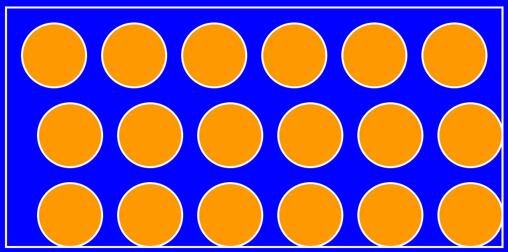
- Particle size regulates microbial access to food.
- Smaller particles have more surface area than large particles; easy access.
- HOWEVER, v. fine particles produce small pores; restricted air flow could lead to anaerobic conditions.
- Wood chips create porosity, but carbon isn't available to microbes.

Adapted from T. Richard

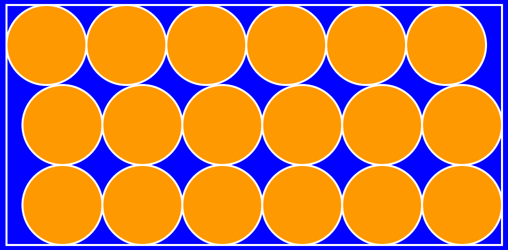
Porosity effects on aeration



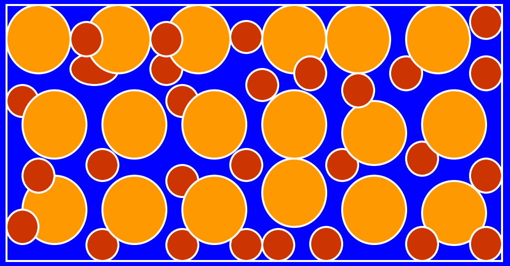
Loosely packed, well structured



Loosely packed, uniform particle size



Tightly packed, uniform particle size

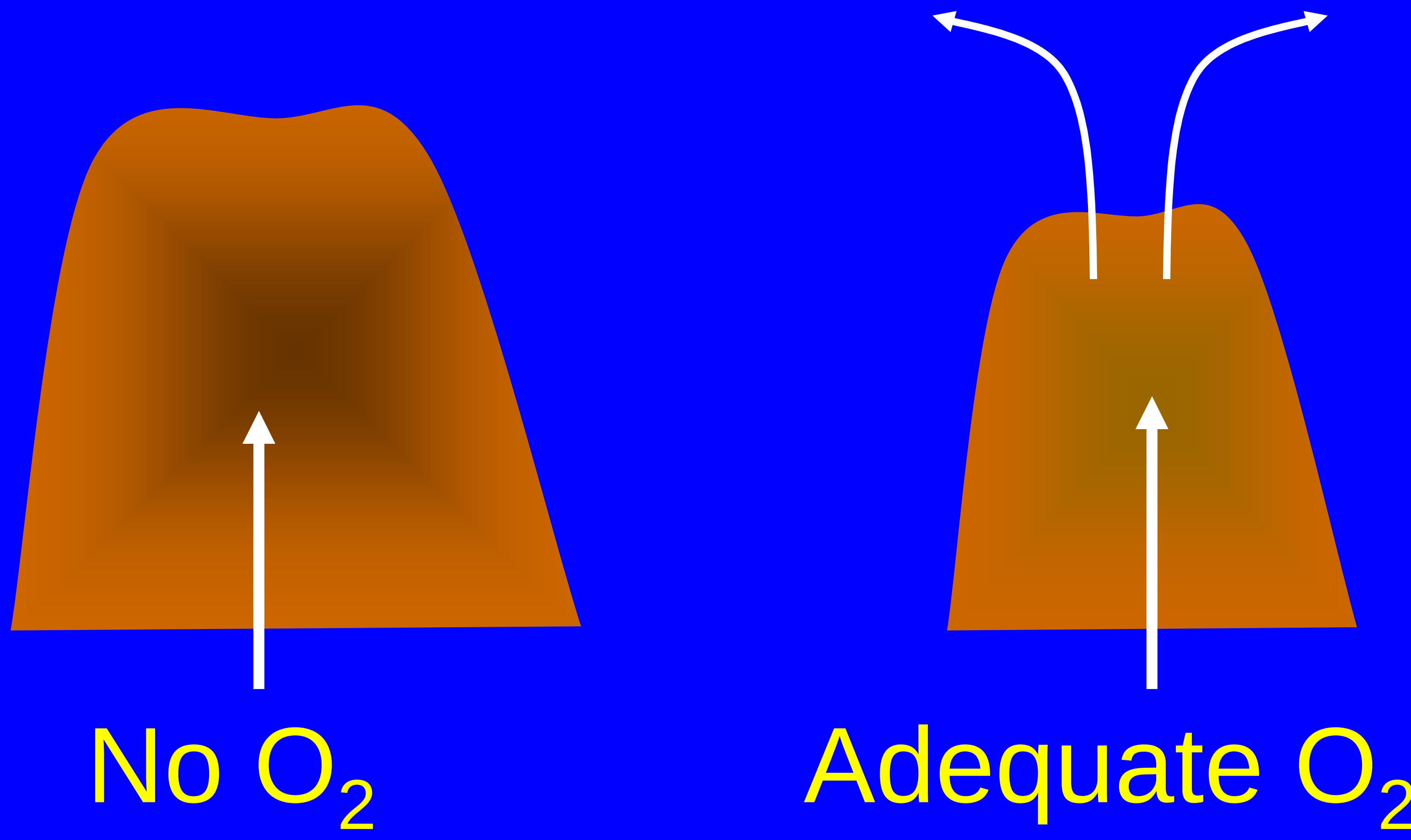


Tightly packed, mixed particle sizes

Pile Size/Shape

- Pile size will affect O_2 content and temperature.
  - Small piles maintain higher internal O_2 concentrations than large piles.
  - Large piles retain higher temperatures than small piles.

Air Flow and Pile Size



Odor Management 101

Where do odors originate?

- Incoming feedstocks
- Stockpiled feedstocks
- Poorly aerated compost piles
- Standing pools of water around compost windrows
- Water retention ponds

Most odors are by-products of anaerobic respiration

- Sulfur compounds (hydrogen sulfide)
- Volatile fatty acids (butyric acid)
- Aromatic compounds (terpene)
- Amines (putrescine)

- Ammonia can be formed under both anaerobic AND aerobic conditions

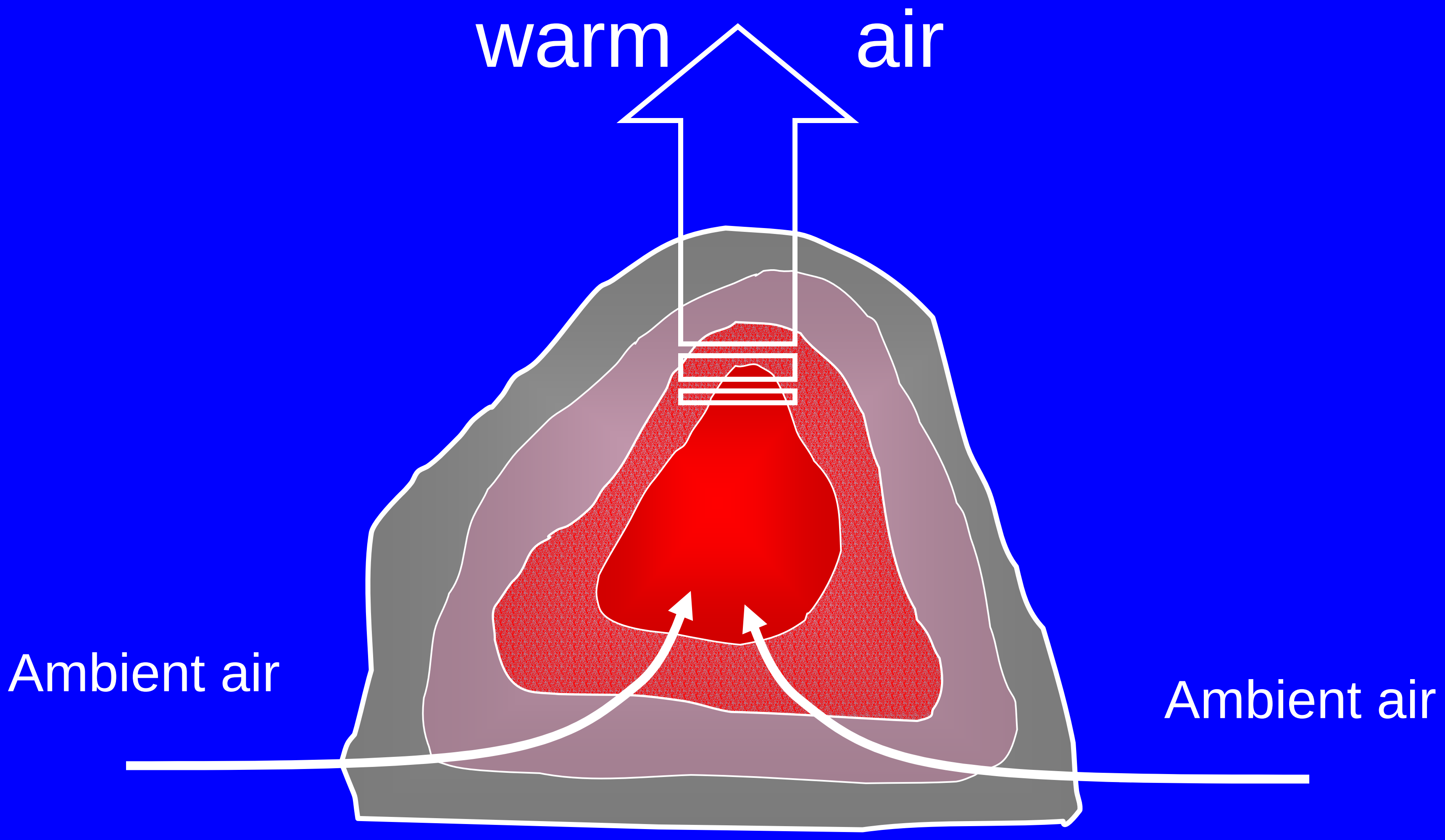
How do anaerobic compounds form?

- Under conditions that restrict the entry of oxygen into either feedstocks, compost piles or standing water bodies.
  - High moisture content
  - Inadequate porosity
  - Rapidly degrading substrate
  - Excessive pile size

How to get aerobic bacteria breathing oxygen again

- Mix wet feedstocks with coarse dry bulking agents.
- Create adequate porosity in compost piles by increasing number and sizes of pores (wood chips).
- Build piles to maximize convective air flow.
- Once aerobic conditions re-established, bacteria will “eat” odorous compounds.

Convective aeration



Ammonia Odors

- Ammonia odors formed independent of O_2 status of feedstocks or piles.
- N-rich feedstocks usually have low C:N ratios.
- If N is in excess of microbial needs, susceptible to gaseous loss.
- Ammonia loss is exacerbated by pH >7.5.

How do you minimize Ammonia Losses?

- Set pile C:N well above 10:1 (25-35:1)
- Keep pile pH below 7.5

Summary: Requirements for Aerobic, Thermophilic Composting

Parameter	Reasonable Range	Preferred Range
C:N Ratio	20:1-40:1	25:1-30:1
% Moisture	40-65%	50-60%
O_2 Conc.	> 5%	~10%
Particle size	<3 inches	<2 inches
pH	5.5-9.0	6.5-8.0
Temperature	120-160 ^oF	130-150 ^oF

Feed the microbes and let them do the work for you!