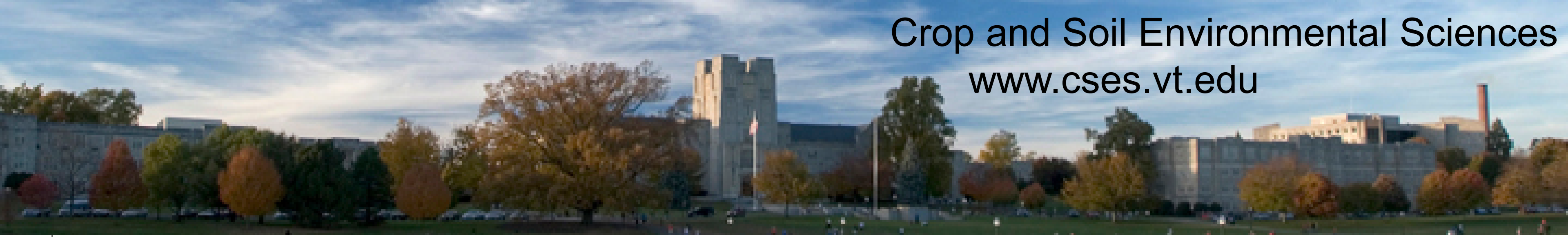

Science of Composting

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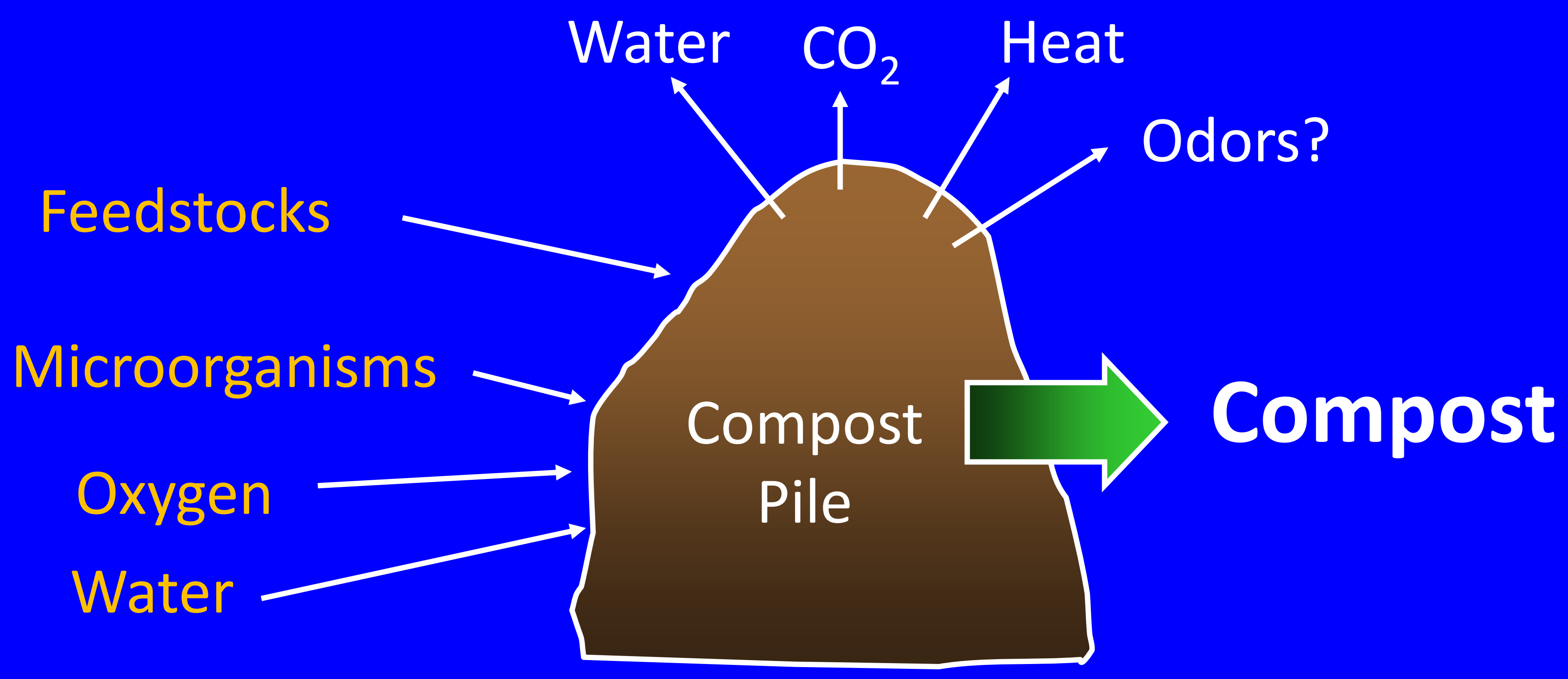
Confined Animal Manure Managers Workshop

January 16, 2020

VirginiaTech
Invent the Future

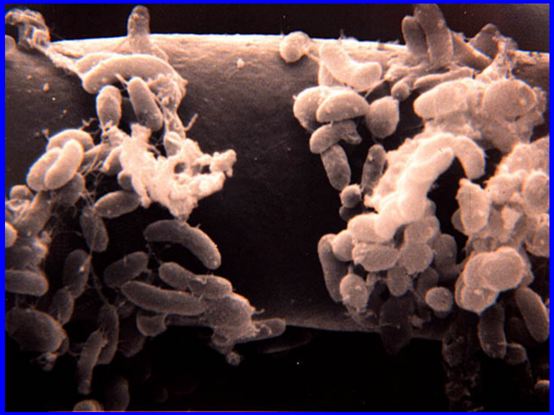
The Composting Process



Why Does Composting Happen?

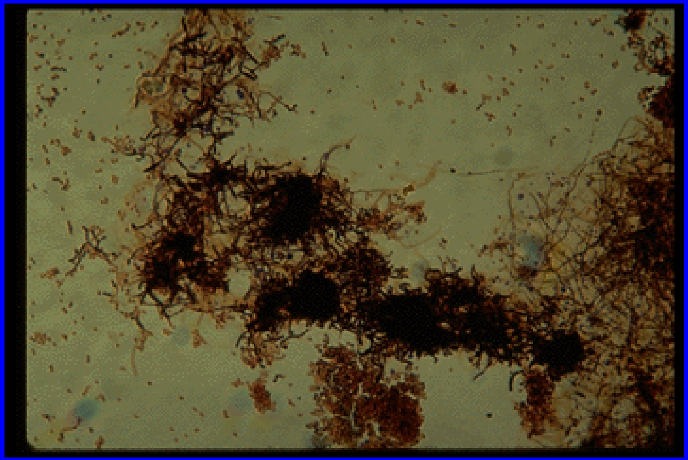
- Microbes consume feedstocks to obtain energy & nutrients
- Their activity creates heat
- Heat gets trapped in pile
  - Accelerates process

Bacteria



- Single-celled rod (bacilli), sphere (cocci) or spiral (spirilla)
- 80-90% of organisms in compost
- Earliest and fastest decomposers
  - Most nutritionally diverse
  - tolerant of low oxygen
- Thermophiles survive unfavorable conditions by forming thick-walled spores (endospores) that are resistant to heat, cold, dryness, and lack of food

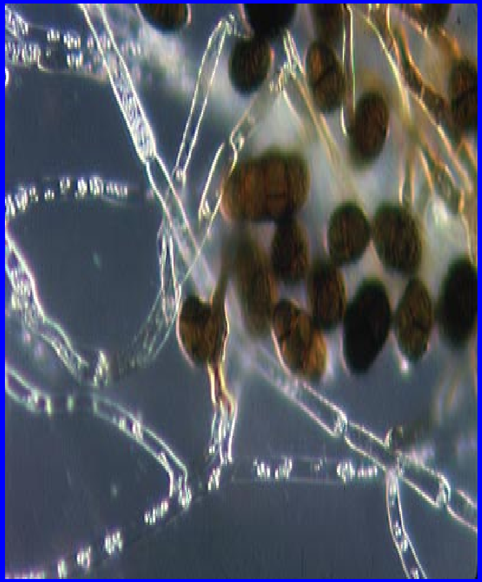
Actinomycetes



- Classified as bacteria, but resemble & function like fungi
- Earthy soil smell
- Degrade complex organic compounds like cellulose and lignin commonly found in woody stems and newspaper, and chiten and proteins via powerful enzymes
- Appear during thermophilic and cooler curing phase
- Form long, thread-like branched filaments that look like gray spider webs

Fungi

- Include molds and yeasts
- More tolerant of low moisture and pH, but less tolerant of low oxygen than bacteria
- Function during mesophilic and thermophilic phases
- Most efficient woody decomposers



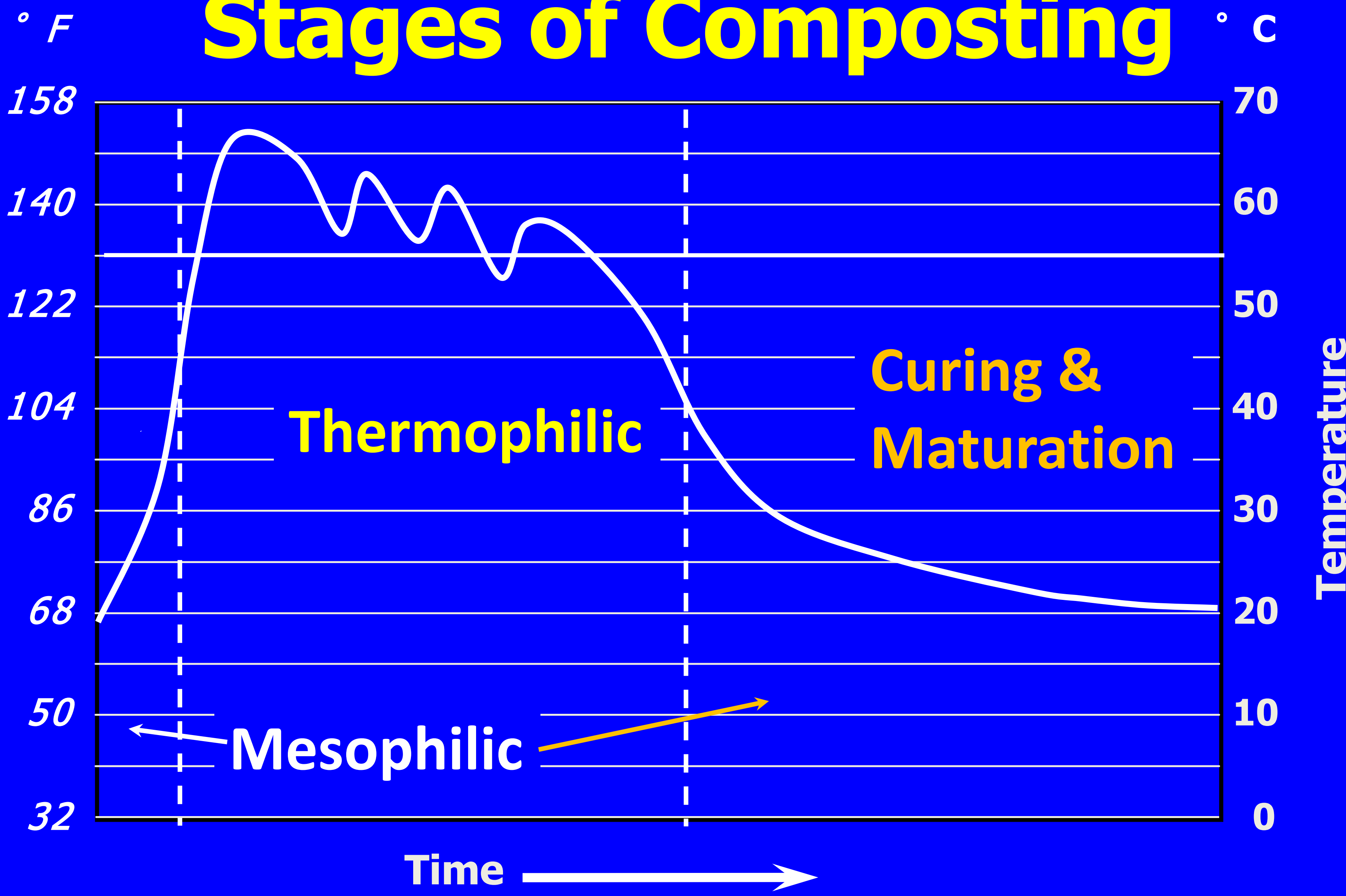
Progression of Carbon Decomposition During Composting

Sugars, starches – First to be decomposed (mesophilic bacteria); generate most metabolic activity (hi heat and CO_2)

Proteins, fats – Decomposed by thermophilic bacteria and actinomycetes; generate med heat and CO_2

Cellulose, hemicellulose – Most resistant C forms decomposed by actinomycetes and fungi

Stages of Composting



The Key Process Variables

for Control of the Composting Process

1. Initial <u>feedstock</u> properties
2. Pile <u>moisture</u>
3. Pile <u>aeration</u>
4. Pile <u>shape and size</u>
5. Pile <u>temperature</u>
6. Composting retention <u>time</u>

1. Feedstock Properties

- Carbon = energy source
- Nitrogen = protein source

Carbon to Nitrogen Ratio (C:N)

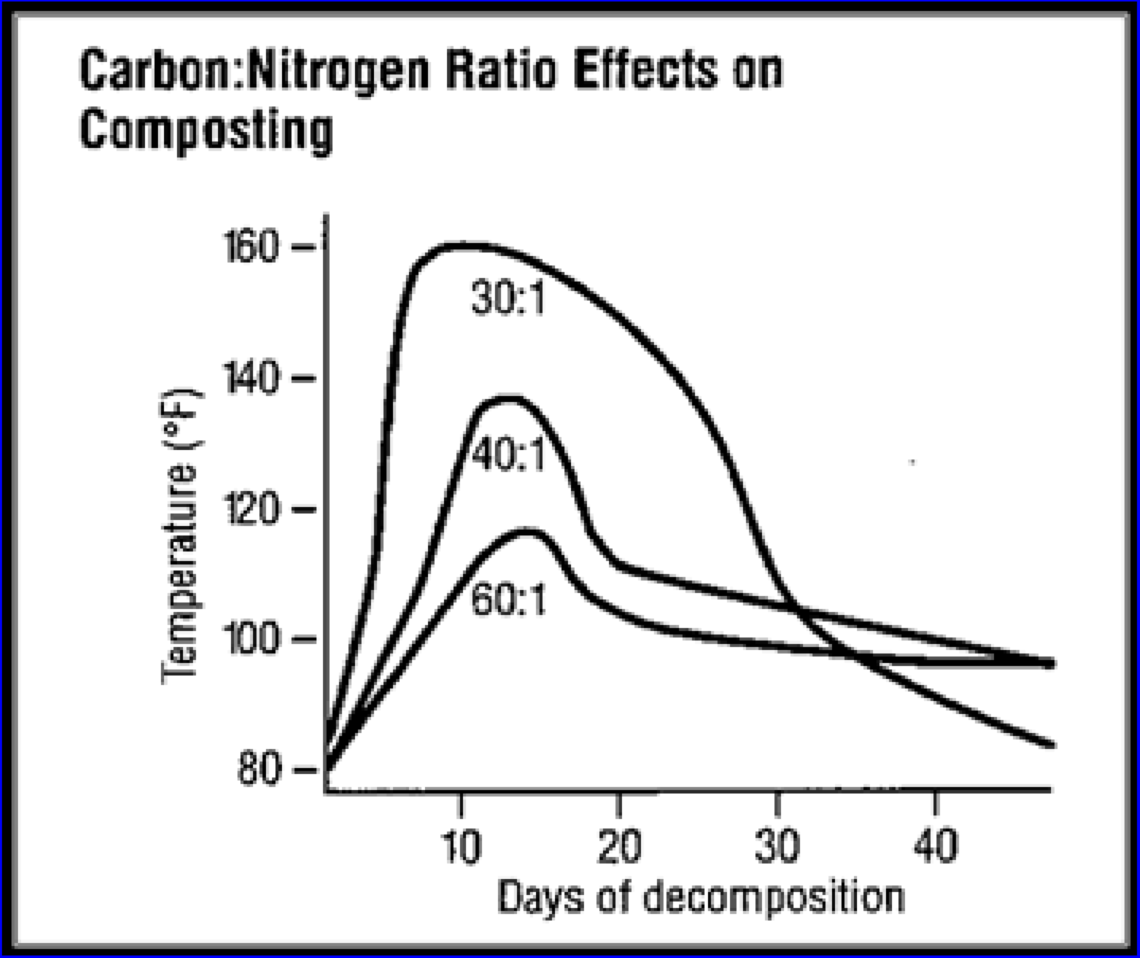
- **Ideal** starting range: **25:1 - 35:1**
- **High C:N**

  > 40:1 slows composting process (N limited)
- **Low C:N**

  < 20:1 results in net N release (as ammonia)

C:N

C:N Affects Composting Rate

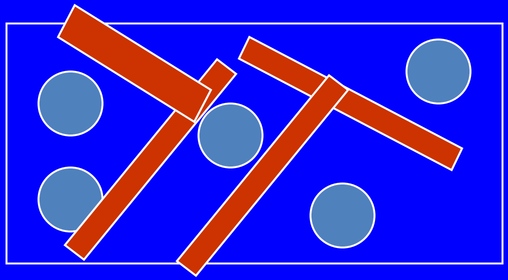


Particle Size and Shape

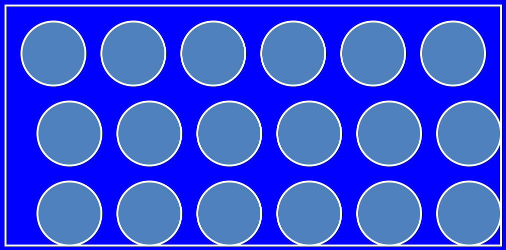
- Decomposition happens on surface
- Smaller particles = more surface area
- Very fine particles prevent air flow
- Rigid particles provide structure & help aerate

Adapted from T. Richard

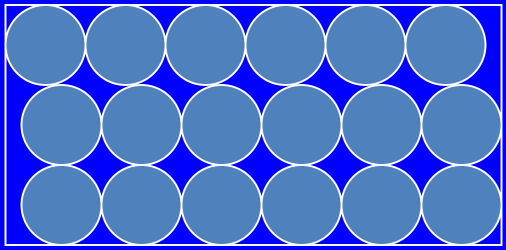
Particle Size and Porosity Effects on Aeration



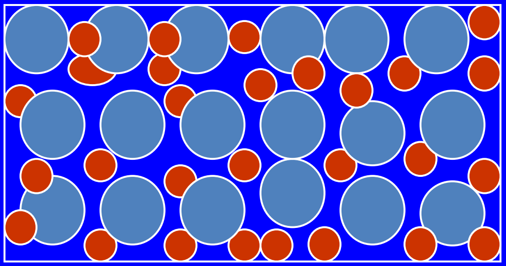
Loosely packed, well structured



Loosely packed, uniform particle size

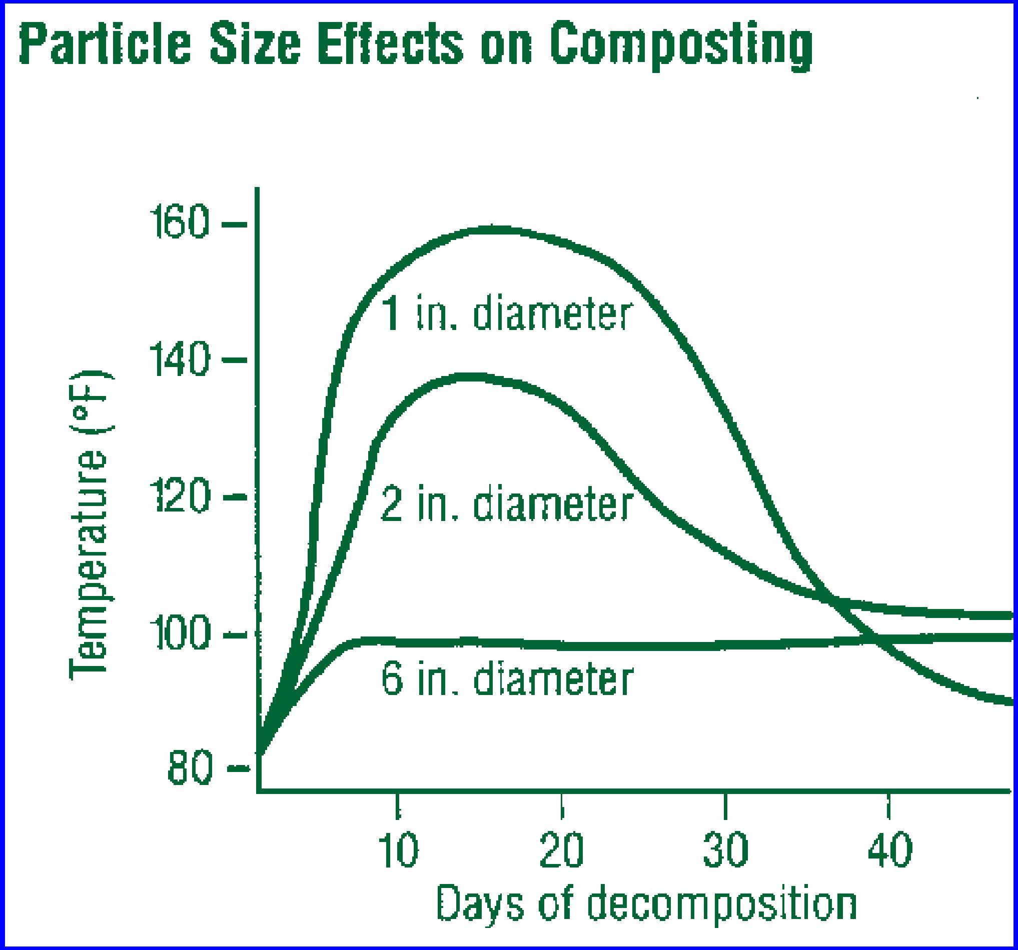


Tightly packed, uniform particle size



Tightly packed, mixed particle sizes

Particle Size Affects Composting Rate

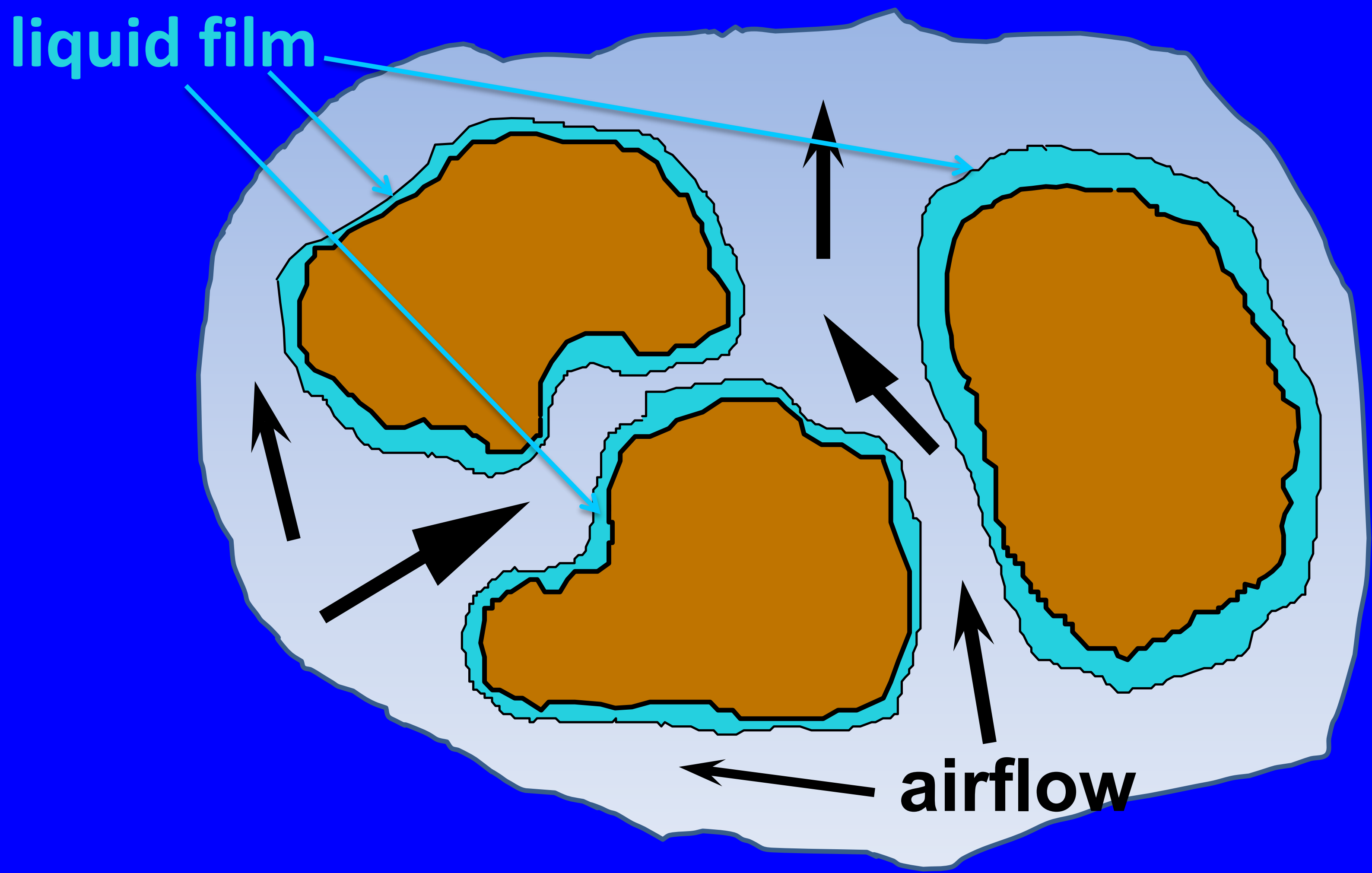


Bulk Density

- Measure of mass (weight) per unit volume
  - pounds/cubic foot, tons/cubic yard, kg/L
  - Examples
    - Water: 62 lb/ft^3, 1.44 ton/yd^3
    - Topsoil (dry): ~75 lb/ft^3, ~1.73 ton/yd^3
    - Compost : ~44 lb/ft^3, ~1200 lb/yd^3

Lower bulk density usually means greater porosity and free air space

Increased moisture blocks air passages, and air flow will decrease

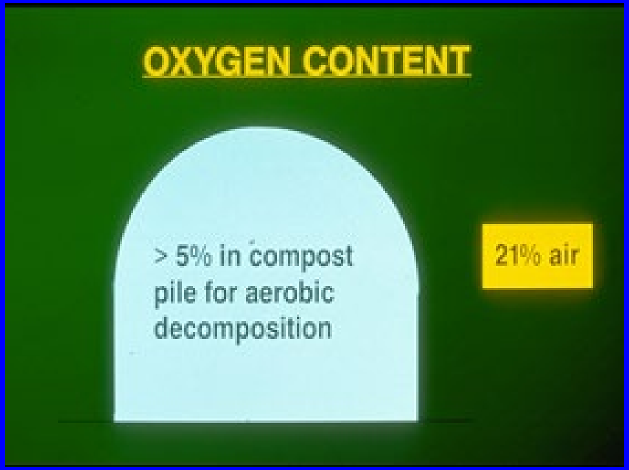


2. Pile Moisture

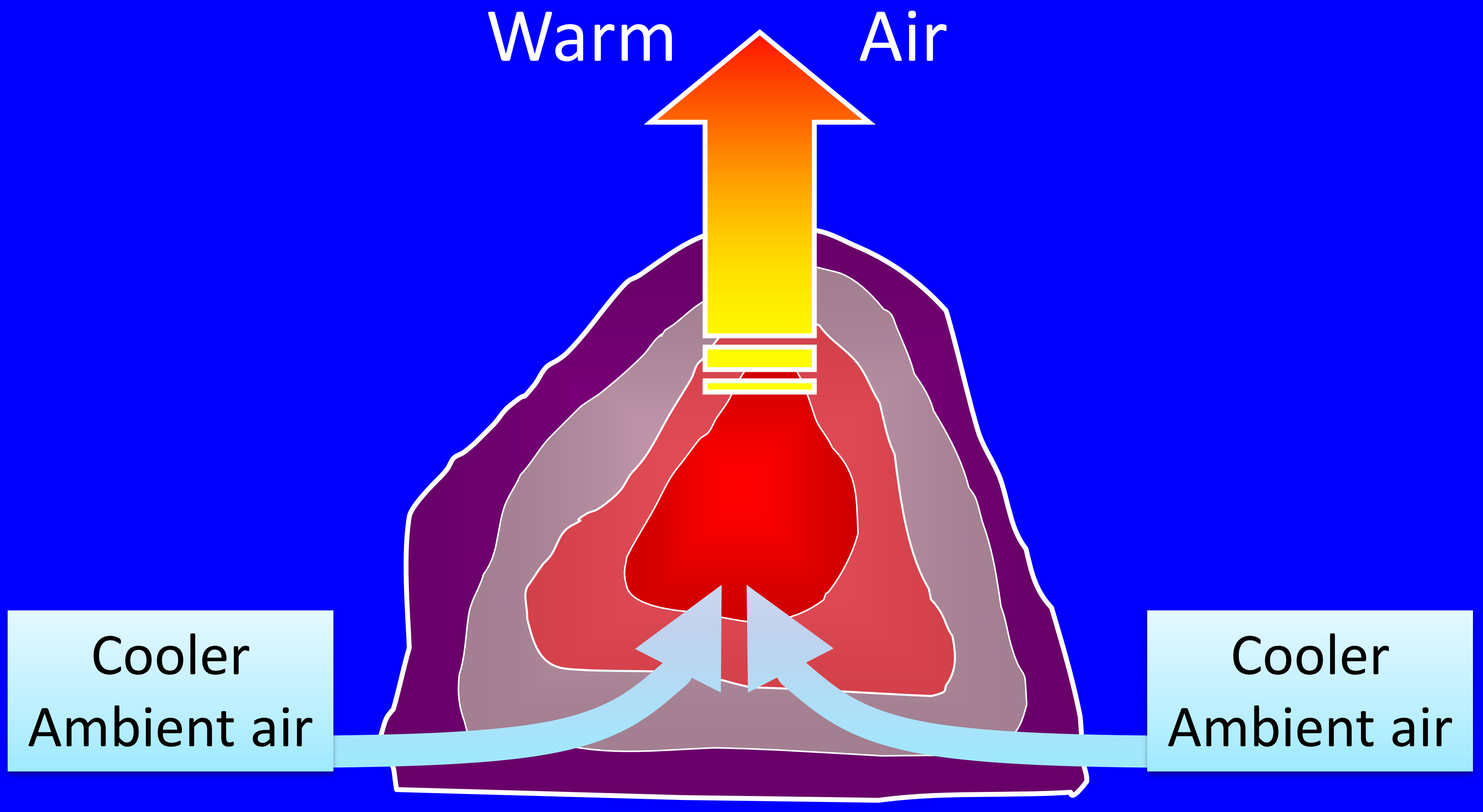
- Required by microbes for life processes, heating and cooling, place to live
- Optimum is 45-60% moisture
- > 65% means pore spaces filled
  - anaerobic conditions
- < 40% fungus dominates
  - difficult to re-wet
- < 35% dust problems

3. Pile Aeration

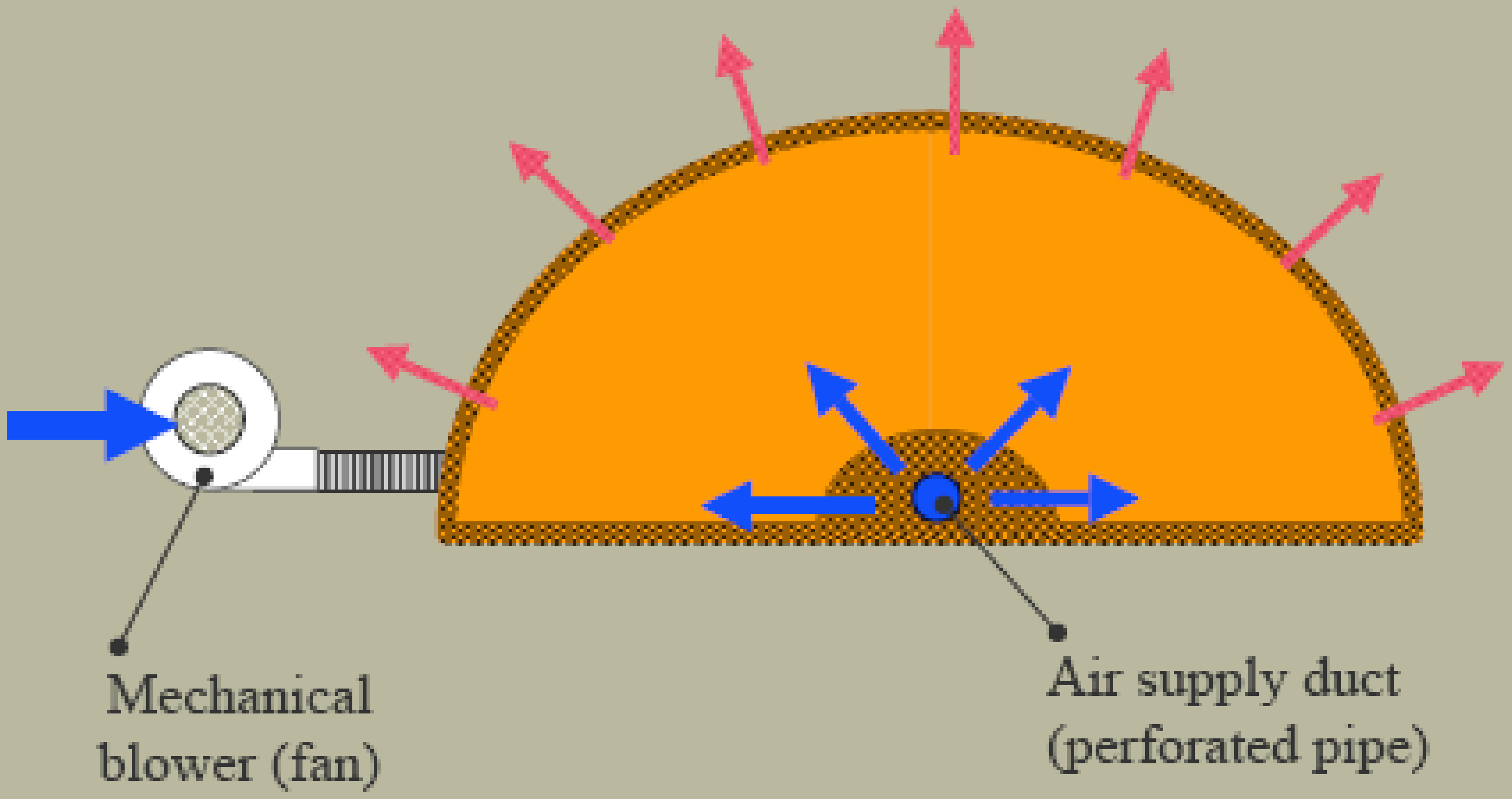
- Aeration supplies oxygen
- O_2 consumption increases with temperature
- Bacteria start anaerobic respiration <10% O_2
  - Slows decomposition
  - Produces odors



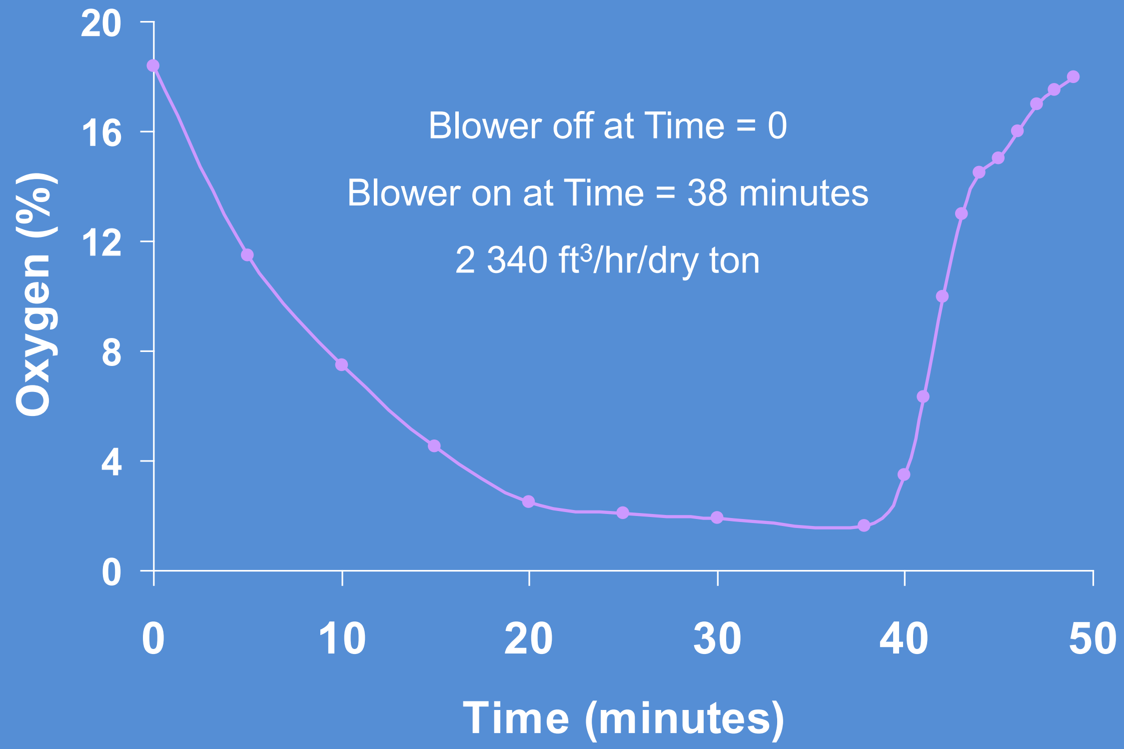
Convective Aeration



Forced Aeration



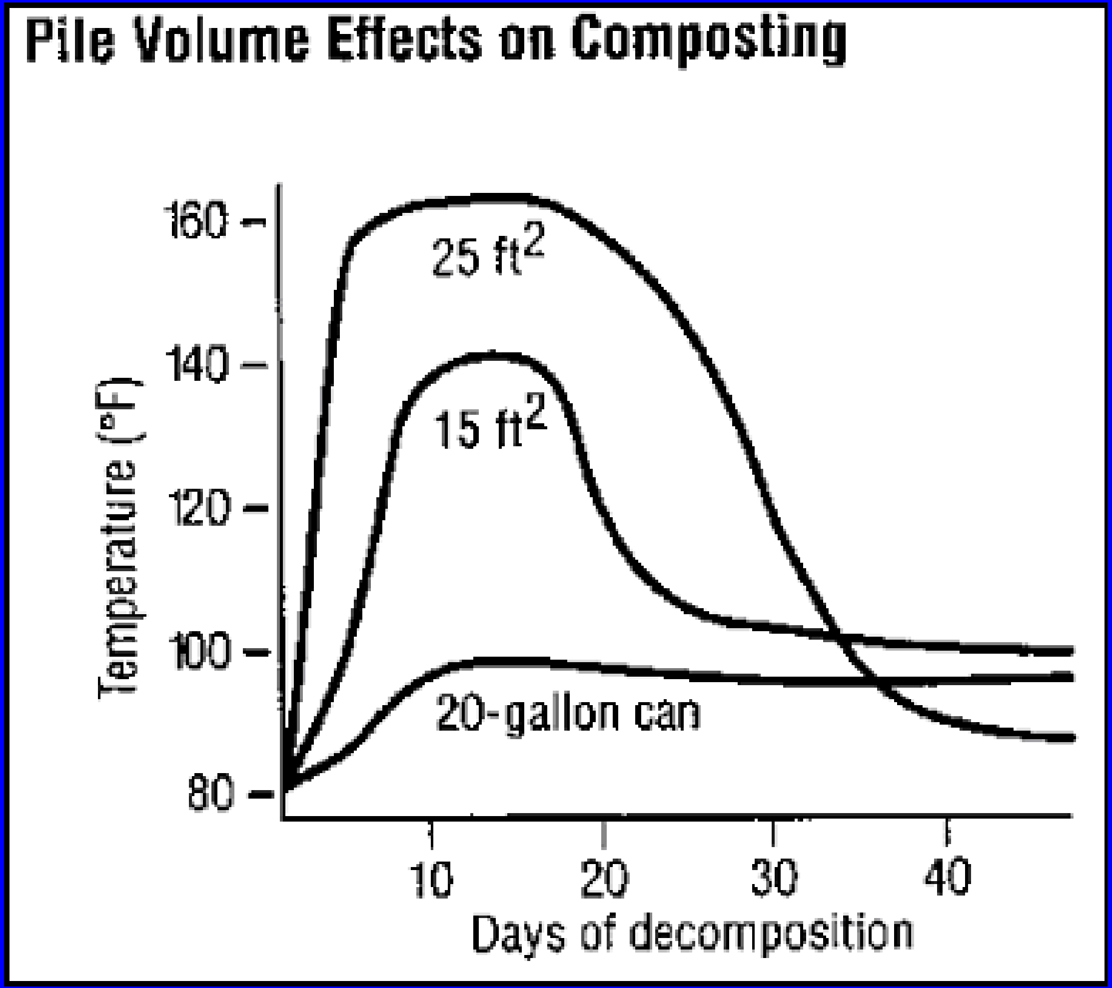
Oxygen depletion in an aerated static compost pile using raw sludge



4. Pile Shape and Size

- Smaller piles allow for greater air flow, especially to center of pile
- Larger piles retain temperatures
- Excessively large piles increase compaction
- You can compost with a big pile if have:
  - Good structure
  - Higher C:N
  - Low bulk density
- Equipment should match pile size

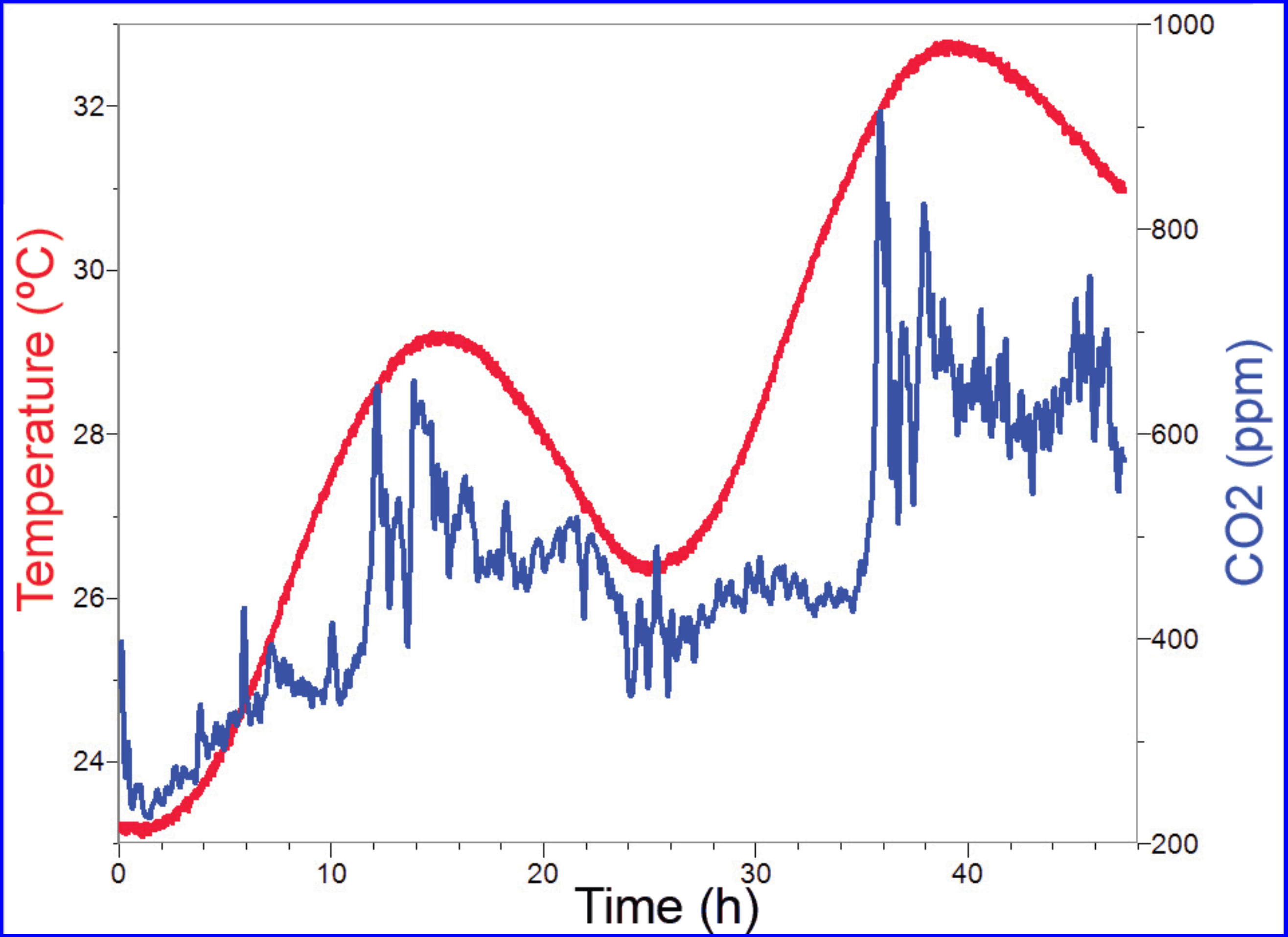
Pile Volume Affects Composting Rate



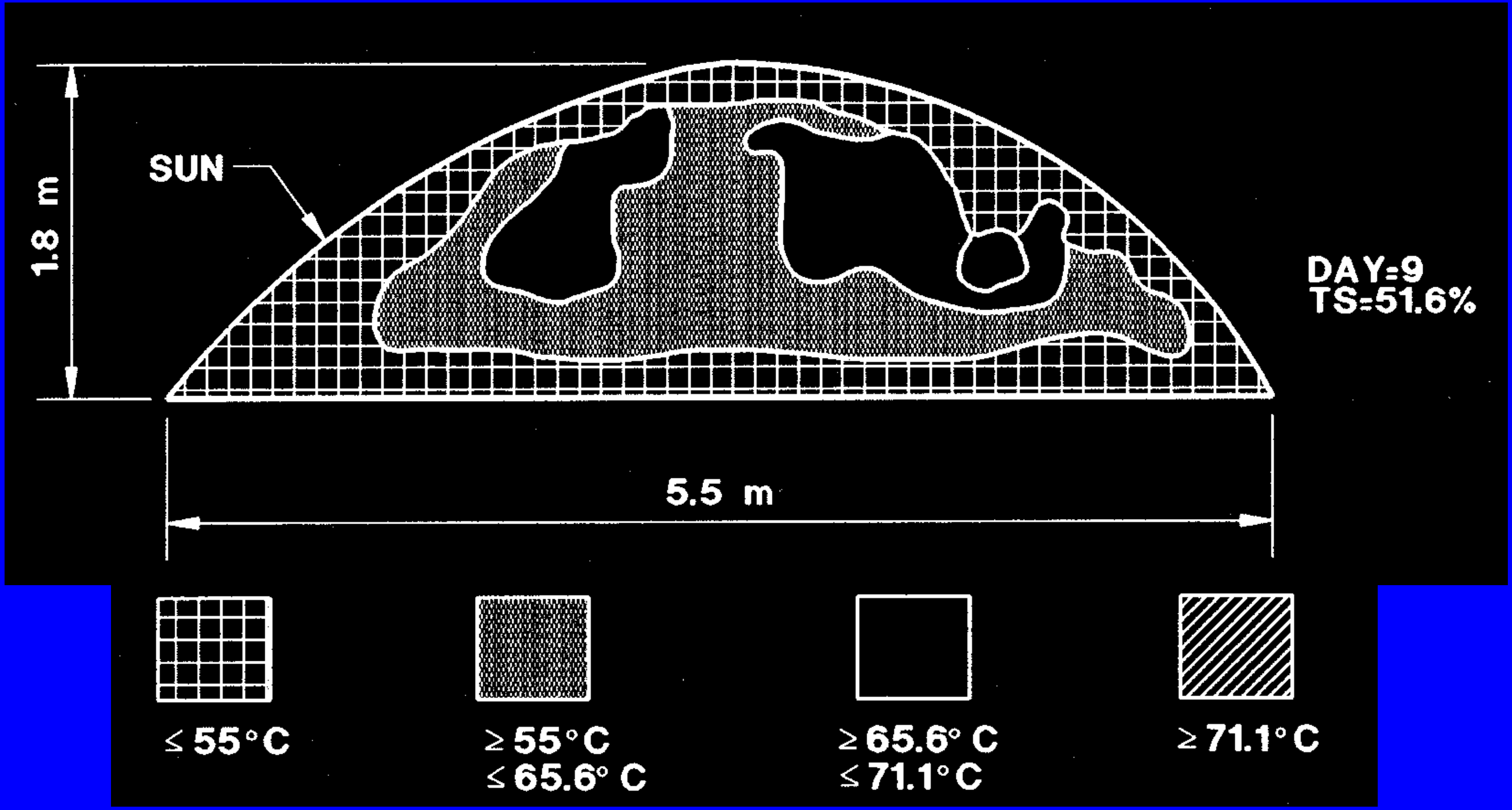
5. Temperature

- Higher temperatures: **faster** decomposition
- Excessively high temperature (> 160ºF , 71°C): reduces microbial diversity and **slows** composting
- Most weeds and pathogens killed at temps 131ºF (55ºC) or higher

Relationship between Temperature and Respiration



Isothermal Variation in a Windrow
(40% Fresh Sludge, 60% Sawdust)

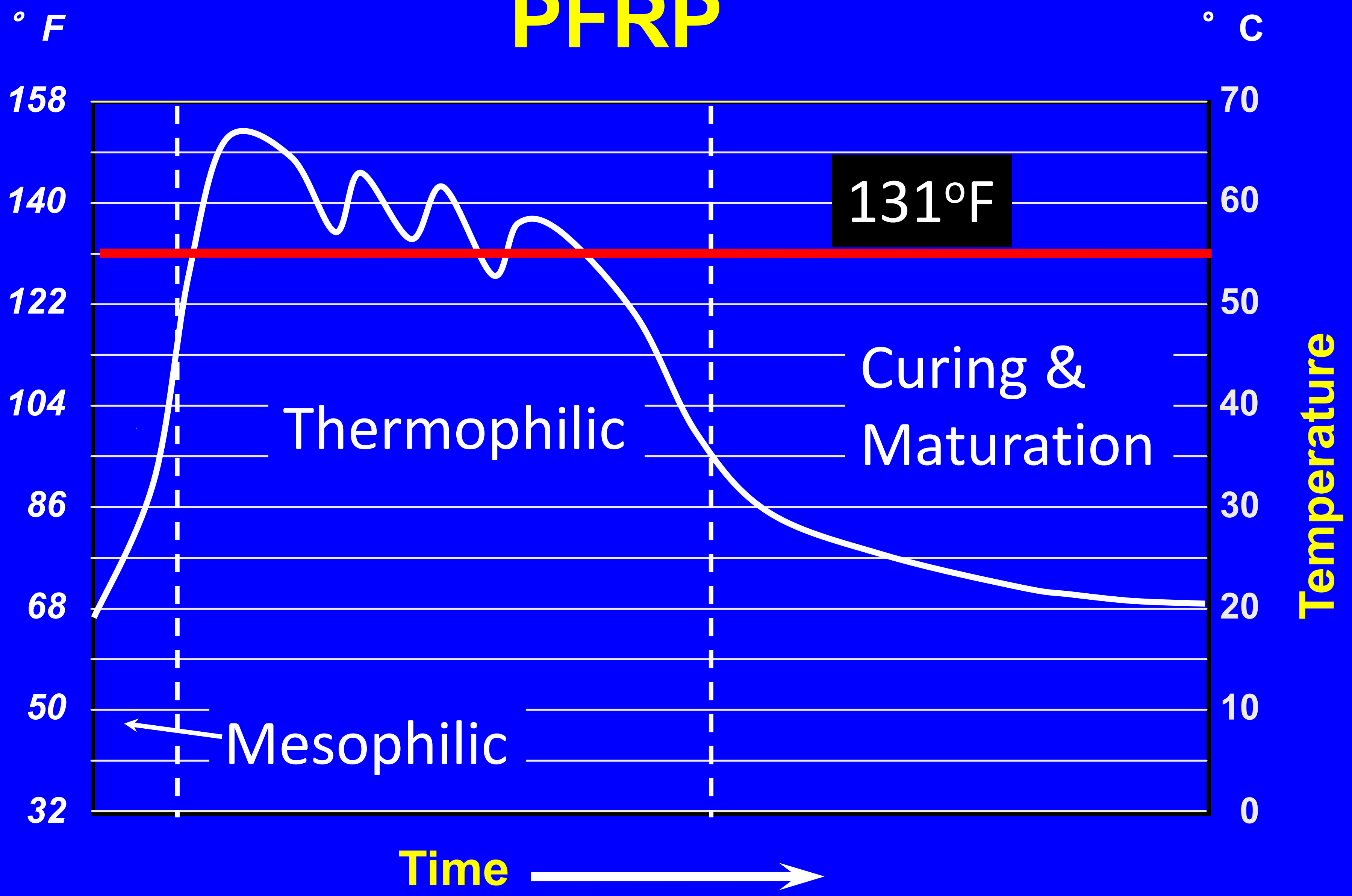


PFRP

Process to Further Reduce Pathogens

- Time and Temperature requirements to assure pathogen reduction
- Aerated Static Pile and In-vessel:
  - 131°F (55°C) or higher for 3 days
- Turned windrow:
  - 131F (55°C) or higher for 15 days or more with 5 turnings

PFRP



° F
° C
158
140
122
104
86
68
50
32
70
60
50
40
30
20
10
0
131°F
Thermophilic
Curing &
Maturation
Mesophilic
Temperature
Time

Recommended Conditions

Variable	Recommended Range
Initial C:N ratio	25:1 to 40:1
Moisture content	50% to 60%
O_2 concentration	>>5%
Temperature	55 to 65 °C (131-149 °F)

Recommended Conditions

Variable	Recommended Range
Initial bulk density	<1100 lbs/cu yd
Particle size	1/8 to ½ in
pH	5.5 to 8.0

6. Time

- Mesophilic
  - a few days to 2 weeks
- Thermophilic
  - 3 weeks to several months
- Curing and maturation
  - 1 to several months
  - eliminates inhibitors to seed germination and crop growth

Curing (Compost maturation)

- Mesophilic process
- Respiration reduced
  - O_2 uptake
  - Heat generation
  - Moisture loss
- Recolonization by soil microbes

Property Changes at Completion

- Temperature < 10°C warmer than ambient
- Can't recognize original materials; dark color
- Stable; smells earthy
- Volume: 25%-60% ↓
- Mass: 40-80% ↓