The Biology of Composting

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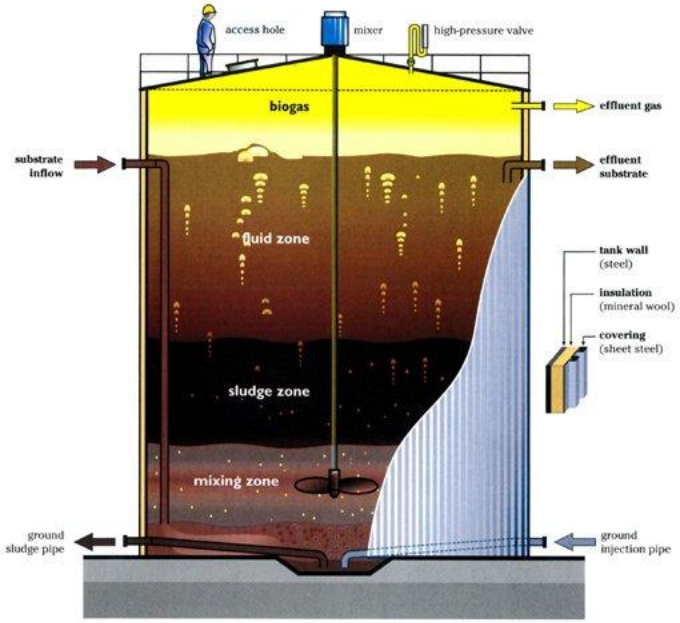
Systems Covered…

- First We'll Discuss Composting
- Then…Digestion—Later on…



What is Composting?

- A biological process that *transforms* raw organic materials into a nutrient rich, biologically-stable soil additive suitable for plant and crop use.

Stages of Organic Matter Transformation

- Decomposition
- Humification
- Immobilization
- Mineralization

Factors Directly Impacting Microbial Activity

- Temperature
- C:N ratio
- Oxygen content (porosity)
- Moisture content
- pH
- Particle size

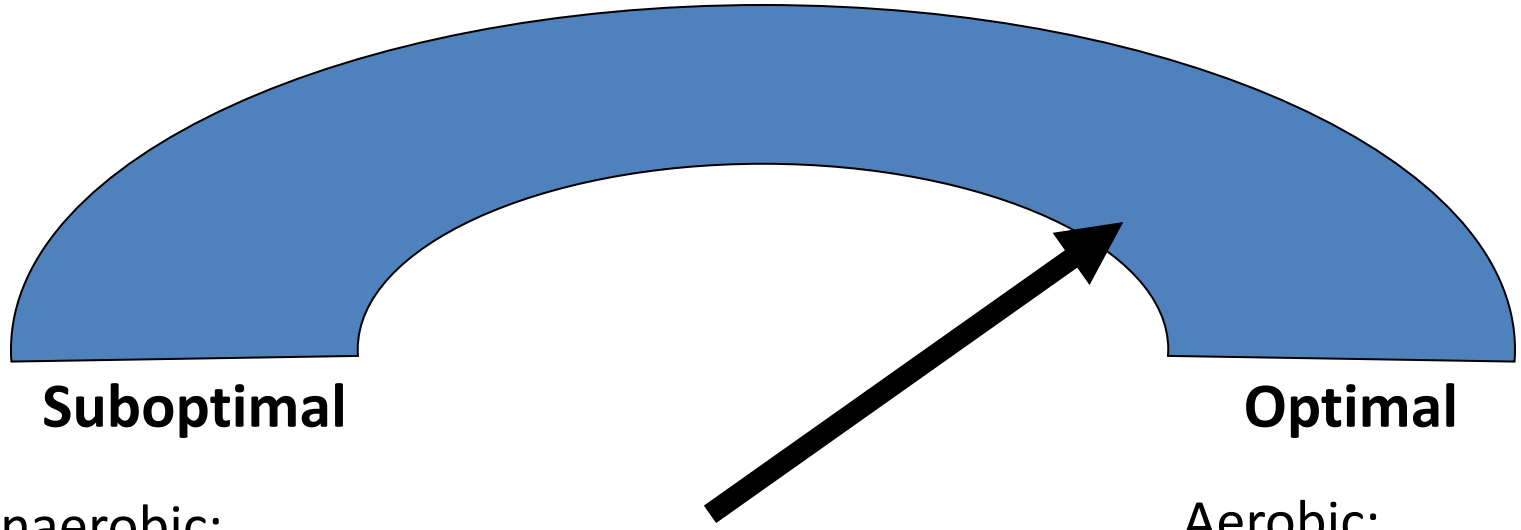
Microbial Classification

Based on two factors:

Oxygen consumption

- Aerobes (use O_2, largest population)
  - –Facultative-use O_2, but can swap
  - –Obligate-use O_2 only!
- Anaerobes (mostly killed or inhibited by O_2, but can be facultative)

Anaerobic vs Aerobic Composting

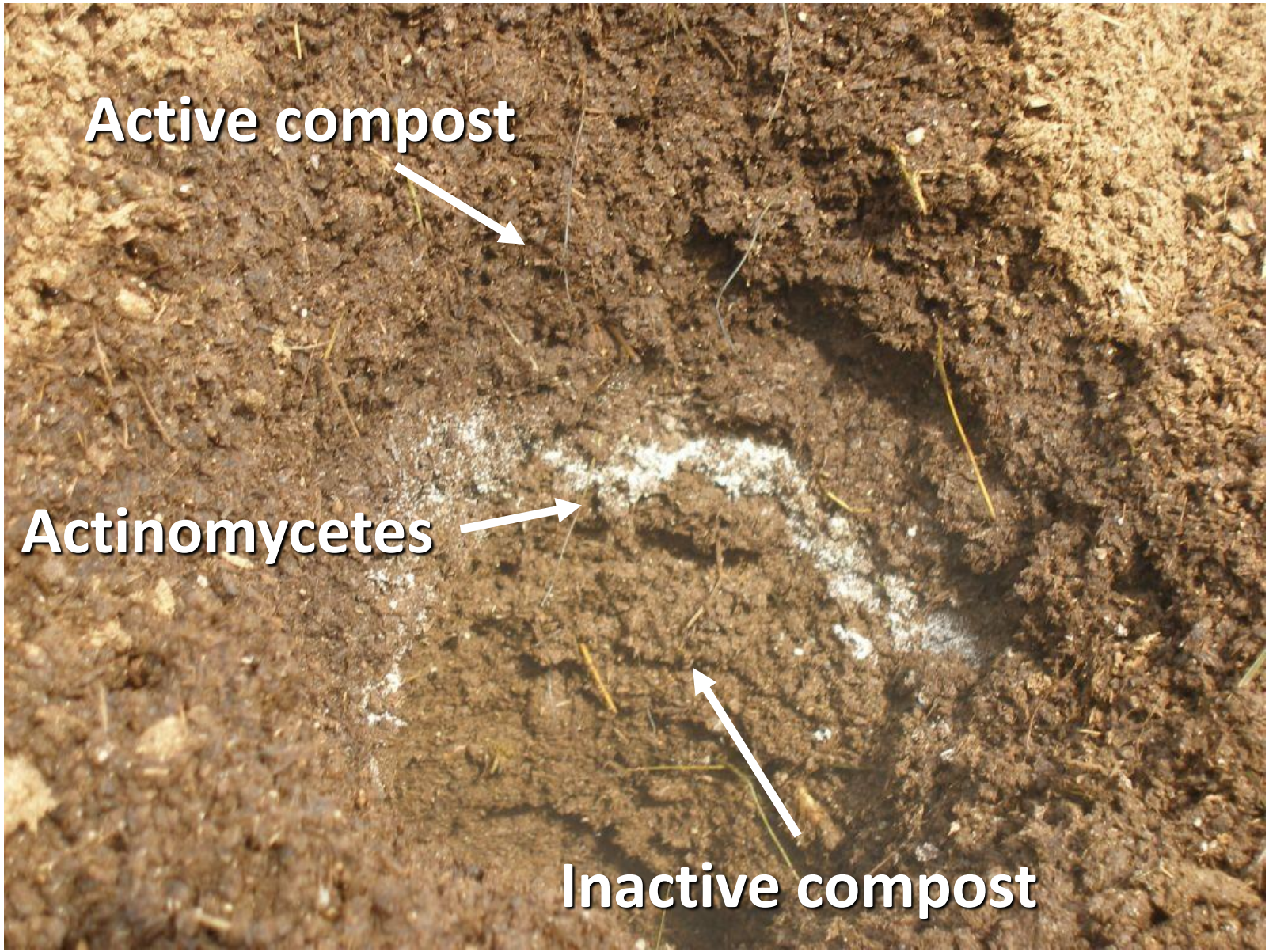


Anaerobic:

- Low oxygen
- Inefficient
- High odors

Aerobic:

- High oxygen
- Efficient
- Low odors

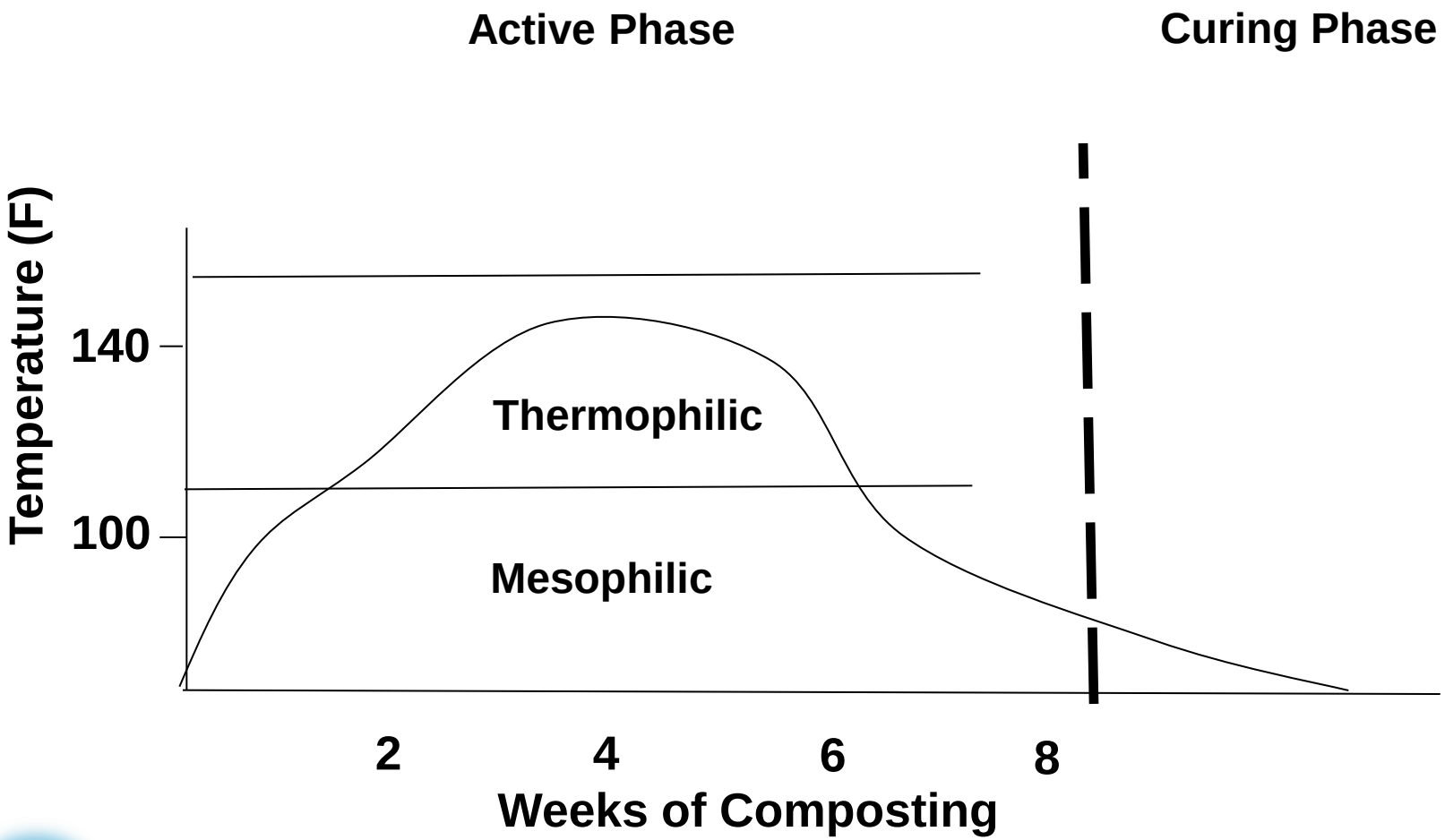

Active compost
Actinomycetes
Inactive compost

Microbial Classification (cont.)

Temperature range

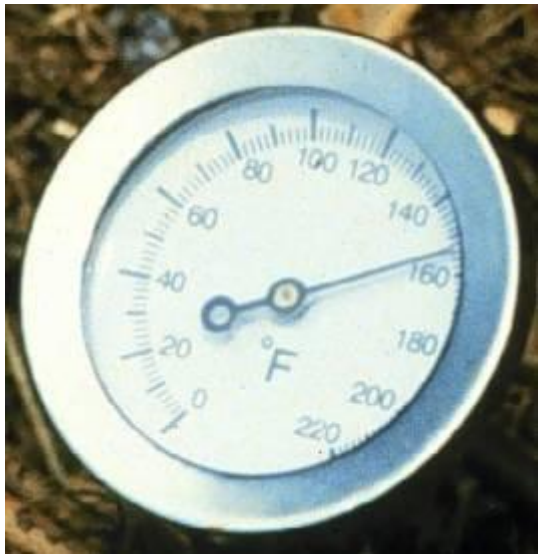
- Mesophiles (function at 50-110 ^{o} F)
  - Initiate compost process
  - Replaced by thermophiles as temperature increases
  - Re-colonize compost during curing phase
- Thermophiles (function at 110-160 ^{o} F)
  - Do most of active composting

Phases of Aerobic Composting



Aerobic Composting and Temperature

- Active composting occurs in the temperature range of 50°F to 160°F
- Pile temperature may increase above 140°F but this is too hot for most bacteria and decomposition will slow until temperature decreases again



Remember, compost pile heat is the direct result of microbial metabolism!

So…What is a C:N Ratio? (Brown : Green Ratio)

- Supply of total carbon compared to total nitrogen in compost feedstock
- If C:N is too high the compost process will slow
- If C:N is too low, more likely to lose nitrogen as ammonia gas or in leachate
- Ideal initial C:N mixture range is 20 – 30:1

Oxygen Content

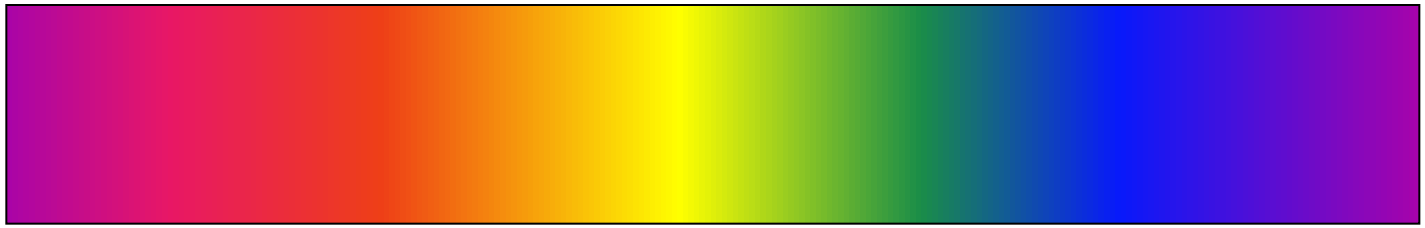
- Need oxygen for most efficient process
- 21% oxygen in air
- 5%-10% is optimal for compost process
  - <5% process slows remarkably
- As pile heats more oxygen will be consumed by microbes

Compost Moisture

0%

50-65%

100 %



Too dry

Optimal conditions for microbes

Too wet

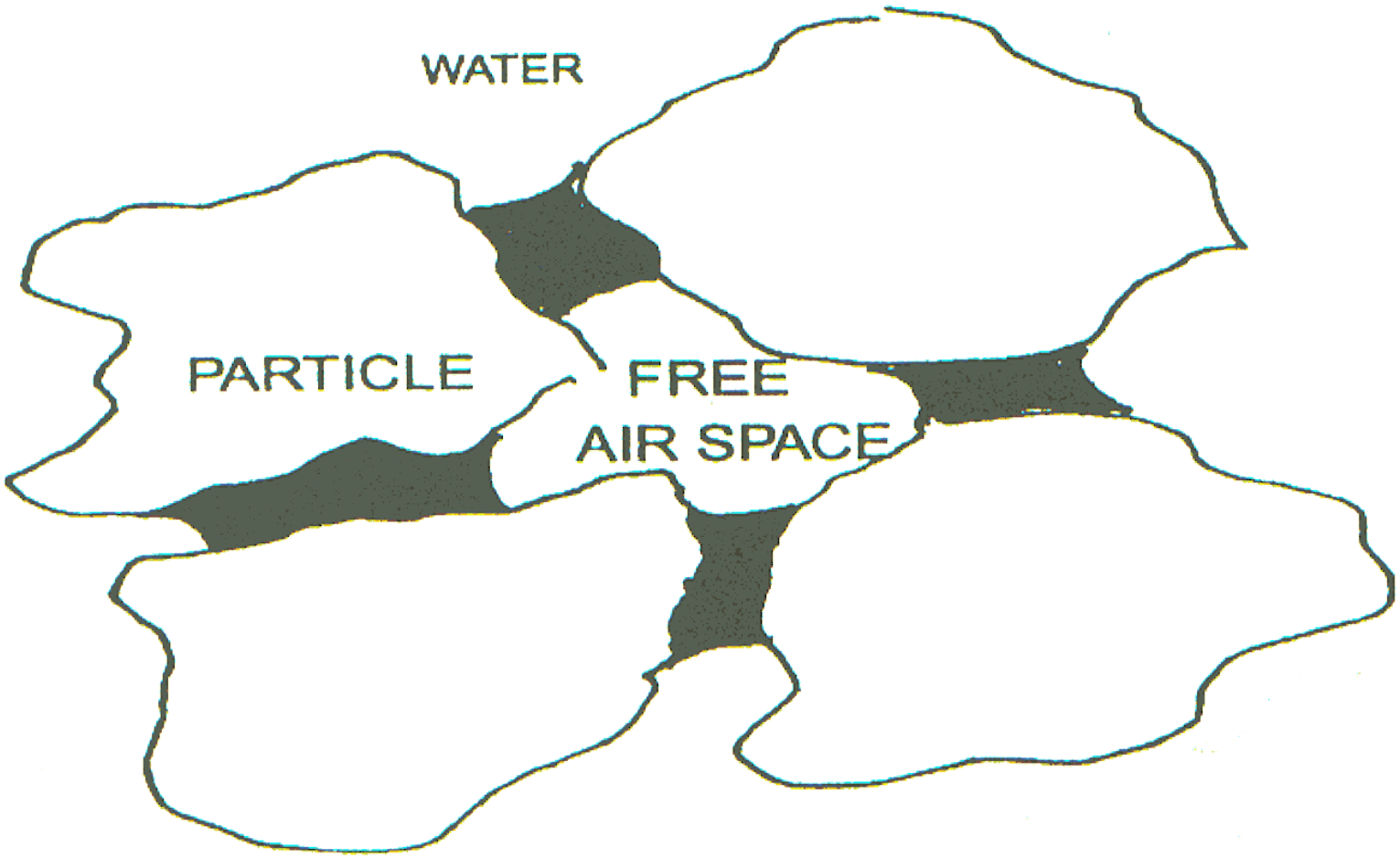
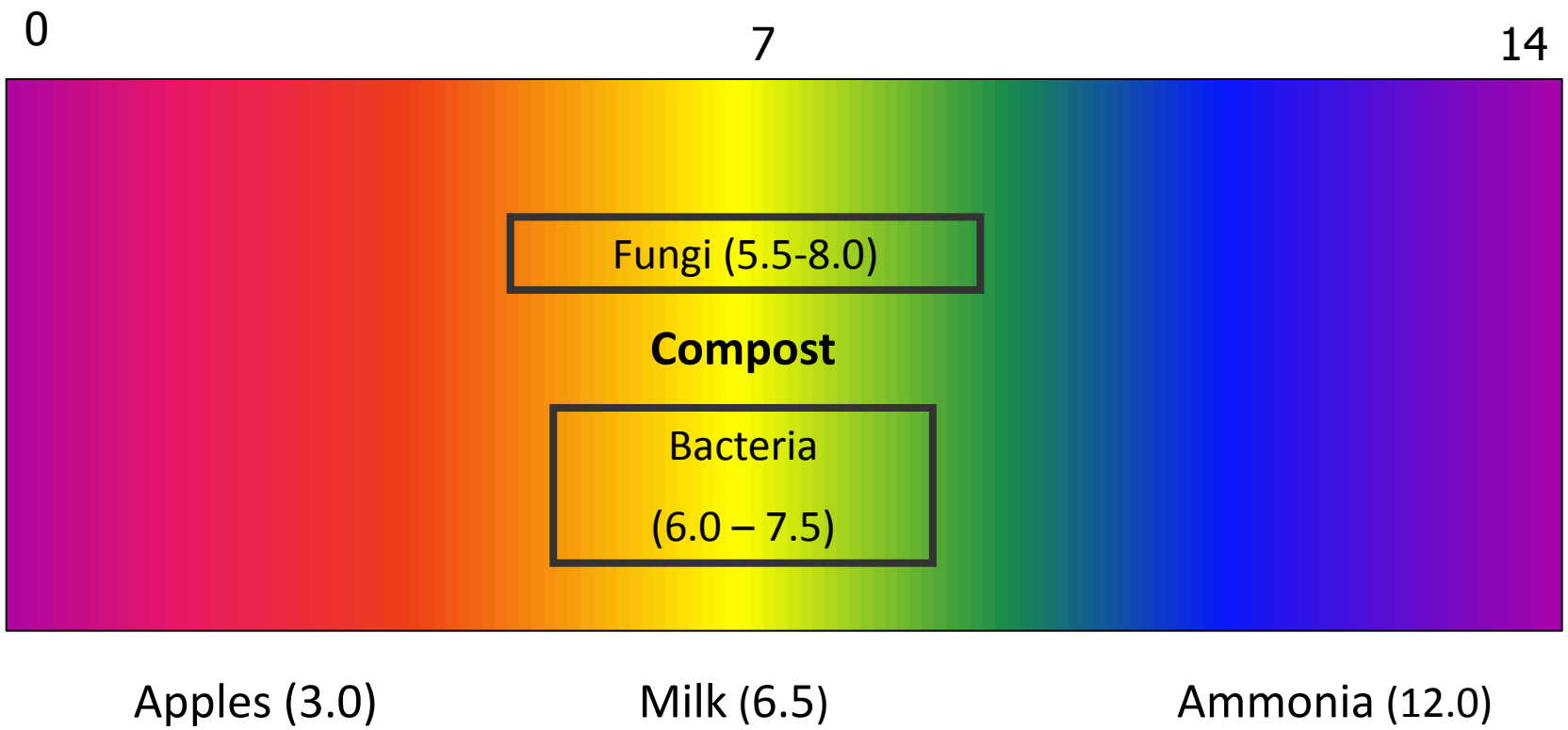


FIGURE 2.10. The relationship of free air space to water and particles in a composting media.

pH
(log scale)


0
7
14
Fungi (5.5-8.0)
Compost
Bacteria
(6.0 – 7.5)
Apples (3.0)
Milk (6.5)
Ammonia (12.0)

Particle Size

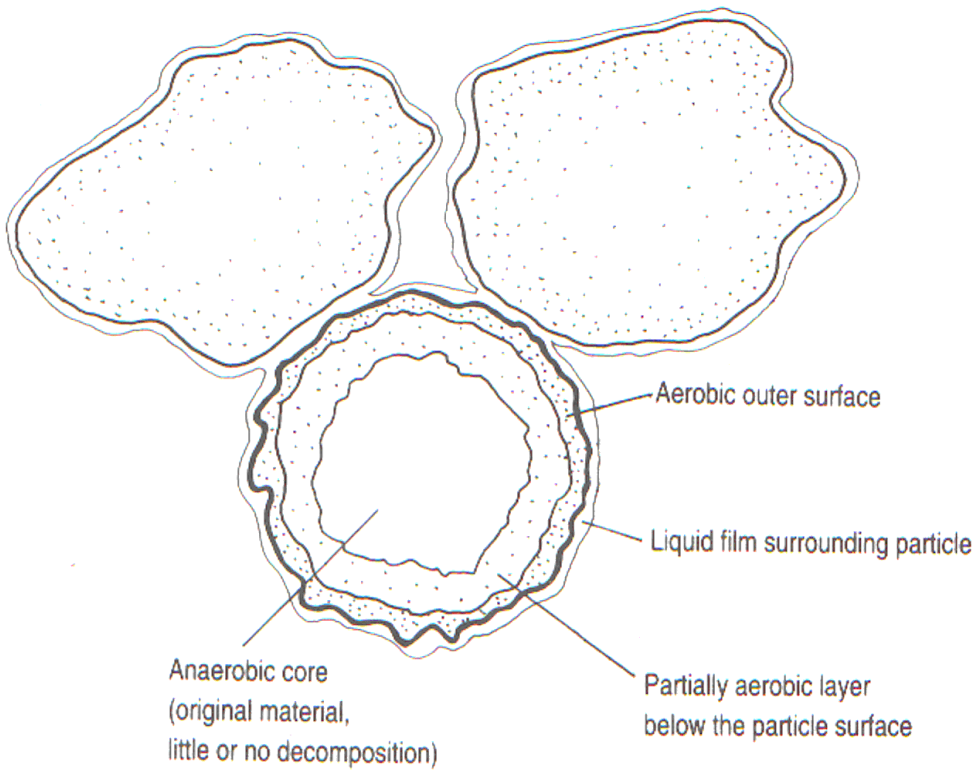
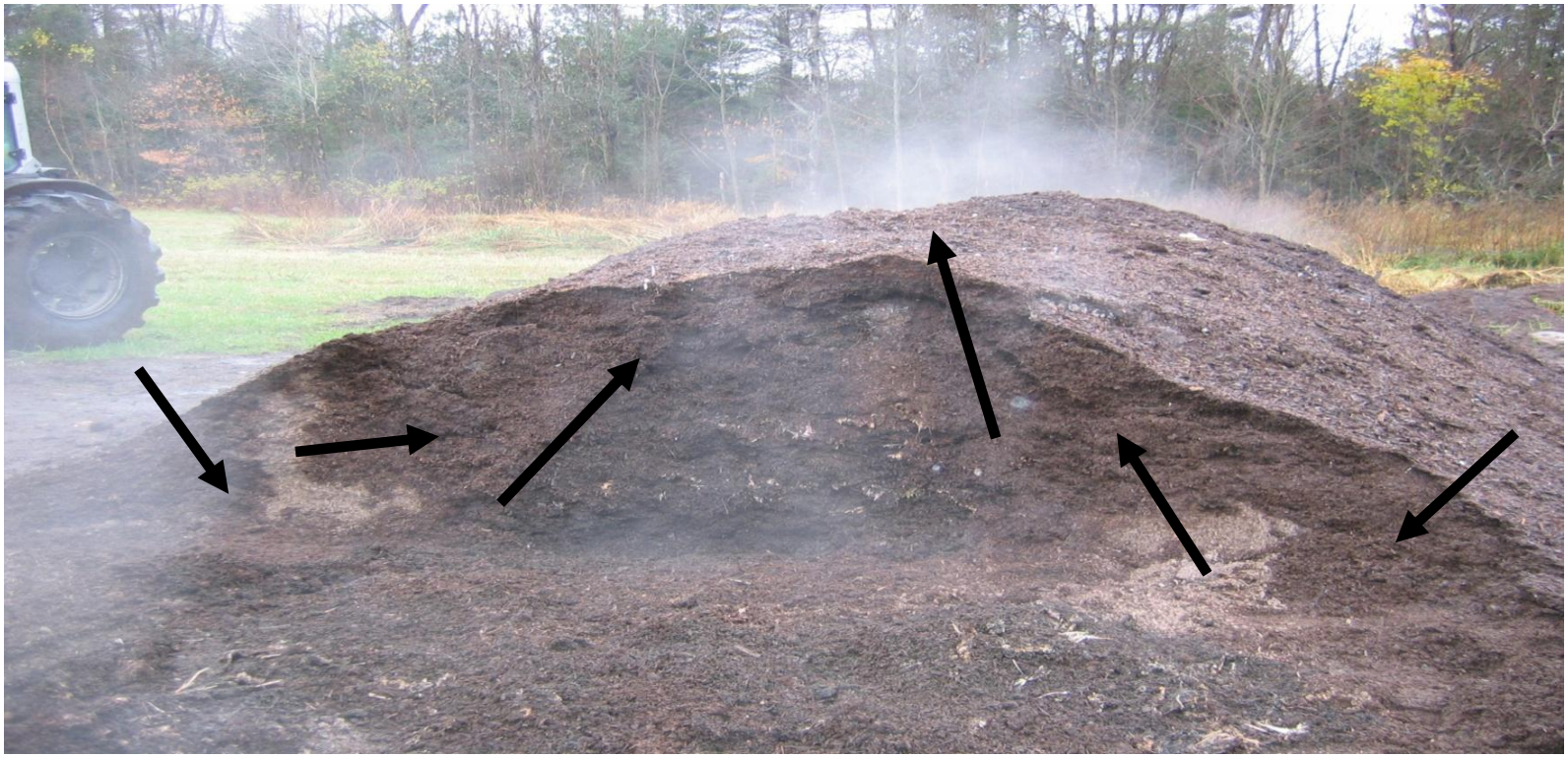


Figure 2.4
Decomposition of solid particles.

Microbial activity is related to availability of food source

Does Texture Really Matter?

Moisture Distribution vs. Air Flow Through Compost Pile



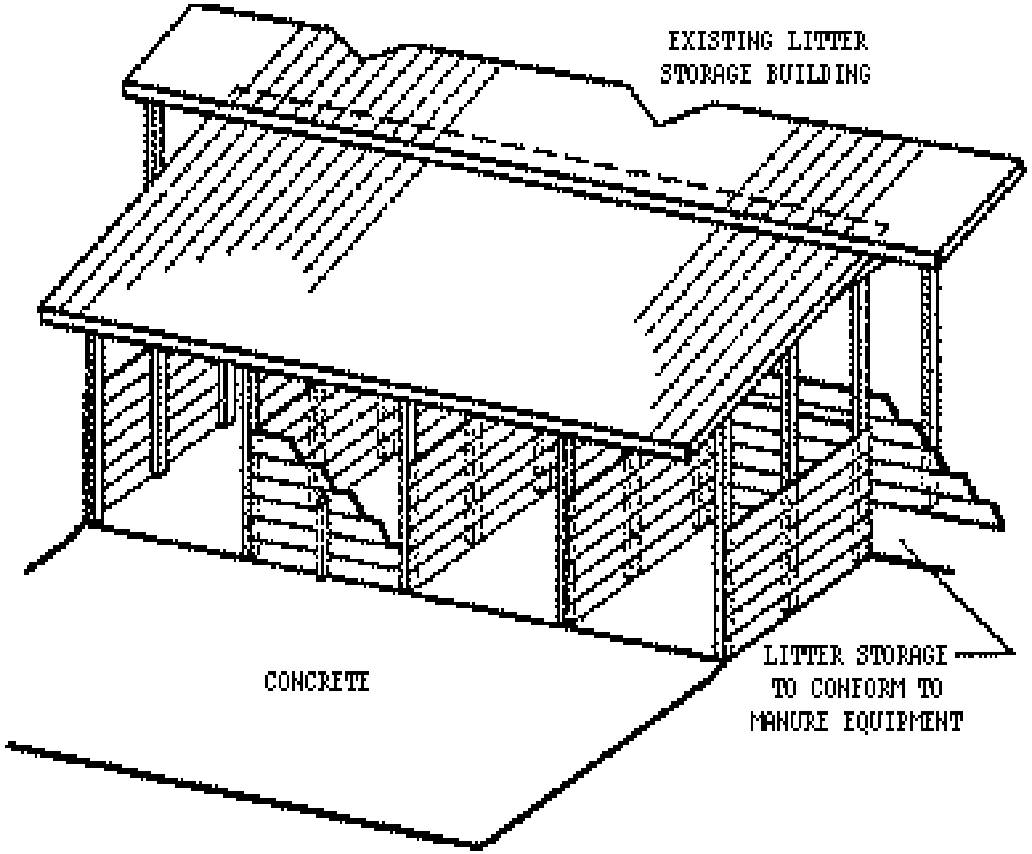
Mixing

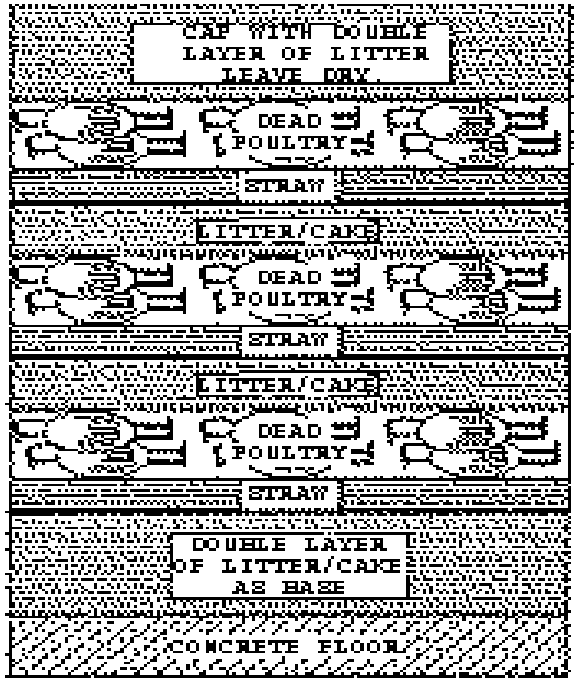
Or…

Compost Systems

Maryland Bin System

- Inexpensive to build and operate
- Fast turn around
- Designed for small scale applications
- Layering and turning can be labor intensive
- Produces crude compost suitable for crop use


EXISTING LITTER
STORAGE BUILDING
CONCRETE
LITTER STORAGE
TO CONFORM TO
MANURE EQUIPMENT

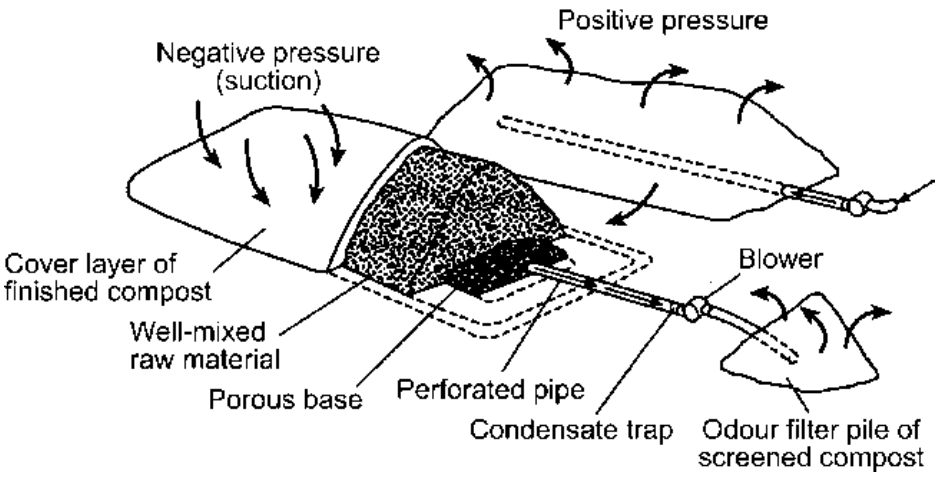

CAP WITH DOUBLE
LAYER OF LITTER
LEAVE DRY
DEAD
POULTRY
STRAW
LITTER/CAKE
DEAD
POULTRY
STRAW
LITTER/CAKE
DEAD
POULTRY
STRAW
DOUBLE LAYER
OF LITTER/CAKE
AS BASE
CONCRETE FLOOR

Static Pile

- Compost ingredients simply stacked into a pile and left to decompose
- Least labor intensive, piles turned 4X/yr
- Least expensive method with minimal equipment (front-end loader)
- Piles require long time to finish composting
- Piles must be thoroughly mixed to ensure aerobic composting
- Potential for odor generation
- Usually used for leaves and manure

Aerated Static Pile

- Initial mixture critical, must be homogeneous with good porosity
- Odor Control
  - Outer filter layer
  - Positive vs. negative aeration
  - Enclose w/biofilter

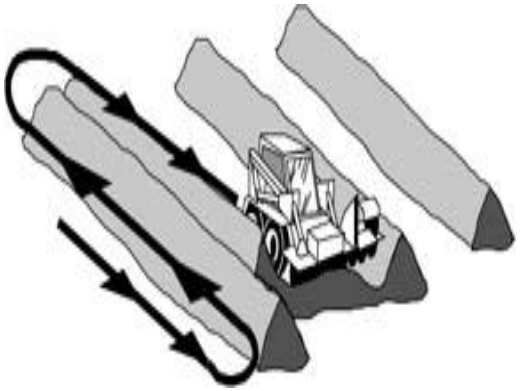


- Higher capital cost than passive system due to blowers, monitoring, and man power
- Most common biosolid application in Maine

Turned Windrow

- Compost is formed into long, narrow piles (windrows) and then subsequently turned at regular intervals
- Typical cross-section is 3-6 feet high by 10-12 feet wide
- Turning provides aeration, rebuilds porosity, and breaks down ingredients
- Requires temperature monitoring and specialized equipment

Front-End Loader vs. Turner



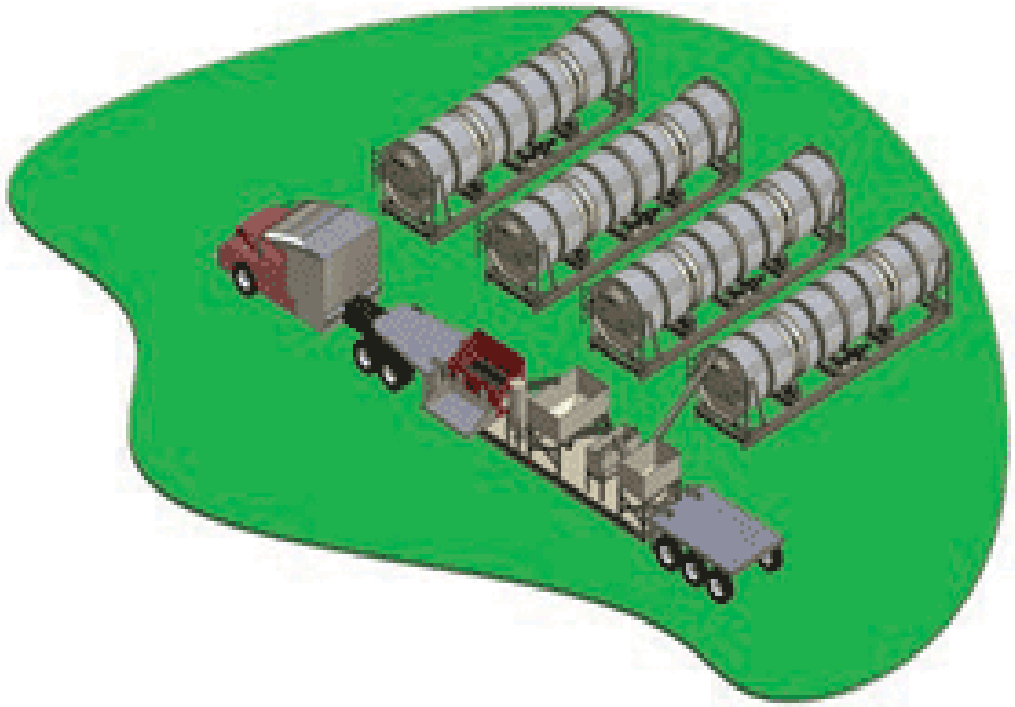
- Front-end loader works well for small scale operations (<500 cubic yd/yr)
  - >500 cubic yd/yr loader tends to be time whereas turner can accomplish task in half the time
- Turner physically agitates ingredients, loader tends to form balls of compost
- Turner represents additional cost, as it requires a tractor to run. Most facilities have front-end loader

In-Vessel

- Most expensive option for composting - both capital and operational
- Allows all facets of operation to be enclosed
- Odors are captured and treated in biofilter

- Allows you to optimize the process through continuous monitoring feedback and process control
- Fastest compost time
- Required routine maintenance

X-Act Composting Systems

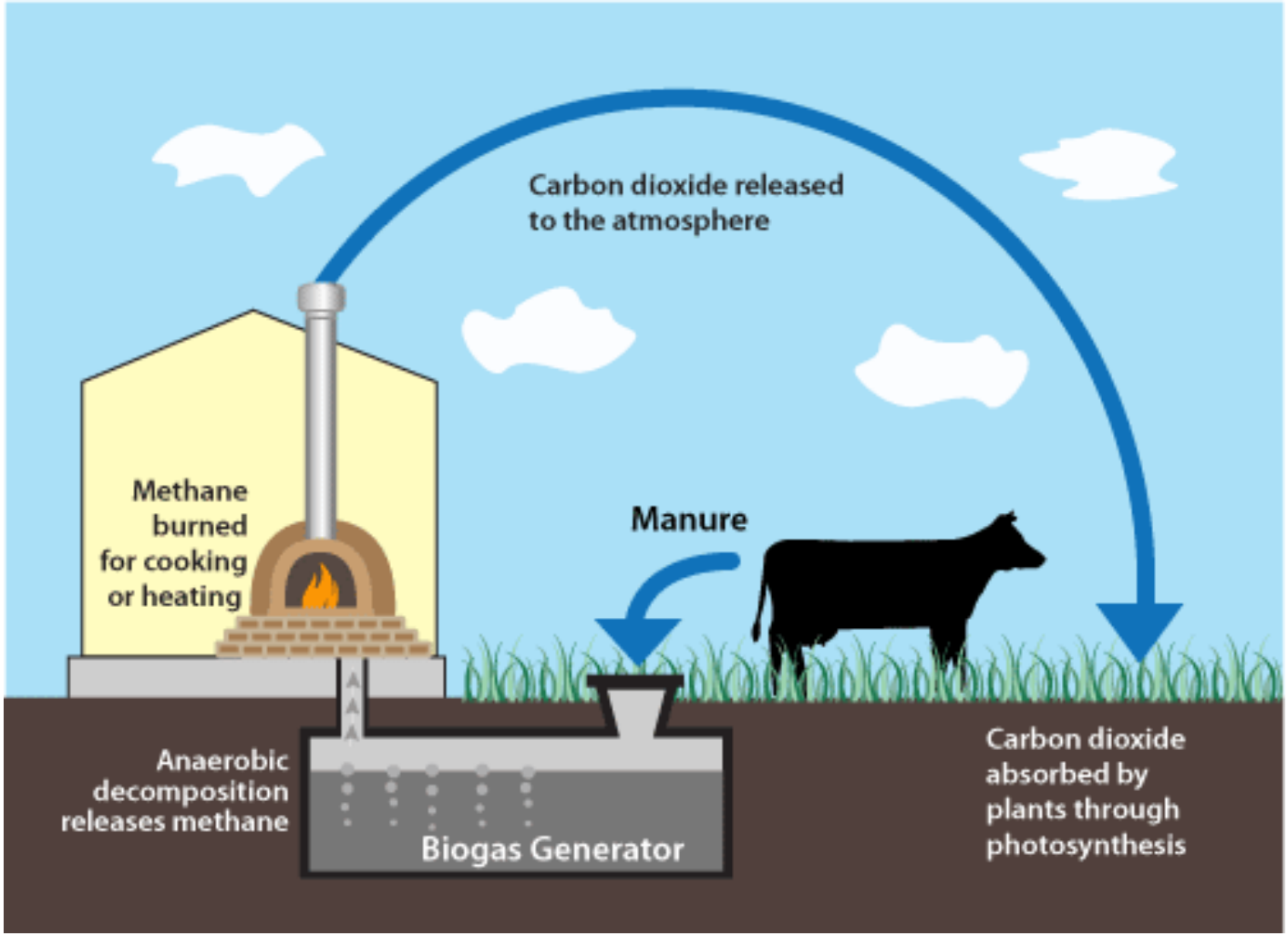


All Together Now…

Optimal range

- C:N ratio—20 to 30:1
- % moisture—50-65%
- Oxygen—5-10%
- pH—5.5-8.2 (acceptable)
- Particle size—1/4 to 3 inches (largest dimension)
- Temperature—thermophilic (110 -160 ^{o} F)

A brief word on Digestion…



Advantage of anaerobic processes

1. Less energy requirement as no aeration is needed

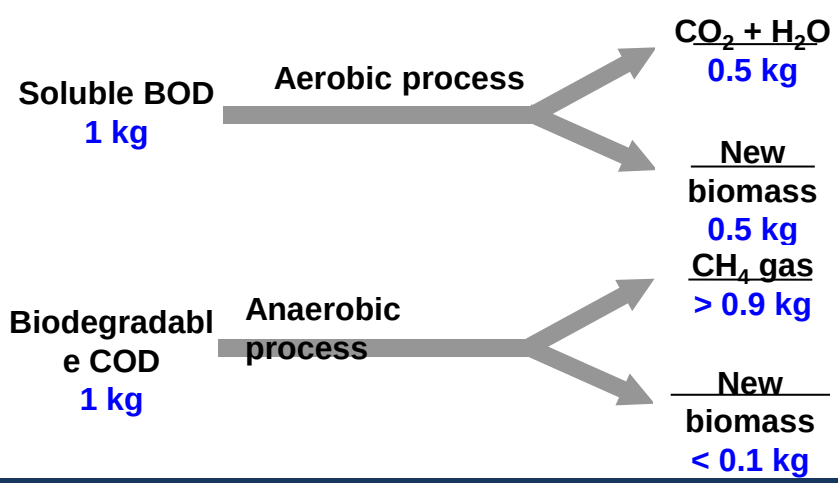
   0.5-0.75 kWh energy is needed for every 1 kg of COD removal by aerobic processes

2. Energy generation in the form of methane gas

   1.16 kWh energy is produced for every 1 kg of COD fermented in anaerobic process

3. Less biomass (sludge) generation

   Anaerobic process produces only 20% of sludge compared with aerobic process



...Advantages of anaerobic processes

1. Less nutrients (N & P) required

   Lower biomass synthesis rate also implies less nutrients requirement : 20% of aerobic

2. Application of higher organic loading rate

   Organic loading rates of 5-10 times higher than that of aerobic processes are possible

3. Space saving

   Higher loading rates require smaller reactor volumes thereby saving on disposal cost

Limitations of anaerobic processes

1. Long start-up time

   Because of lower biomass synthesis rate, it requires a longer start-up time to attain a biomass concentration

2. Long recovery time

   If an anaerobic system is subjected to disturbances either due to biomass wash-out, toxic substances or shock loading, it may take longer time for the system to return to normal operating conditions

3. Specific nutrients/trace metal requirements

   Anaerobic microorganisms, especially methanogens, have specific nutrients e.g. Fe, Ni, and Co requirement for optimum growth

4. More susceptible to changes in environmental conditions

   Anaerobic microorganisms especially methanogens are prone to changes in conditions such as temperature, pH, redox potential, etc.

...Limitations of anaerobic processes

5. Treatment of sulfate-rich wastewater

The presence of sulfate not only reduces the methane yield due to substrate Competition, but also inhibits the methanogens due to sulfide production

6. Effluent quality of treated wastewater

The minimum substrate concentration (S_{min}) from which microorganisms are able to generate energy for their growth and maintenance is much higher for anaerobic treatment systems. Anaerobic processes may not be able to degrade organic matter to the level to meet the discharge limits for ultimate disposal.

7. Treatment of high protein & nitrogen containing wastewater

The anaerobic degradation of proteins produces amines which are no longer able to be degraded anaerobically. Similarly nitrogen remains unchanged during anaerobic treatment.

Picking The Right System

- Answer the feedstock questions
- Determine your annual production and end-uses
  - Compost product
  - Energy and digestate fertilizer
- Develop a financial/business plan
  - Capital for equipment, labor, storage, etc.
- View as many real-life situations as you can