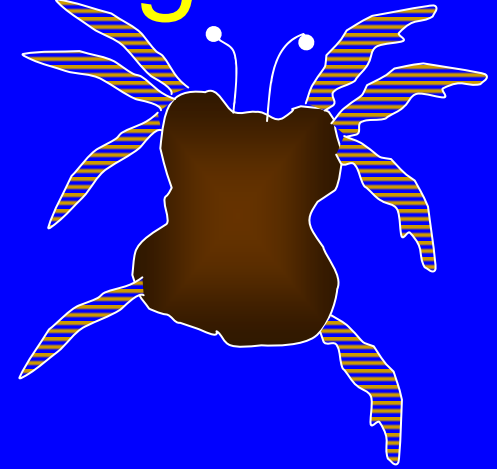
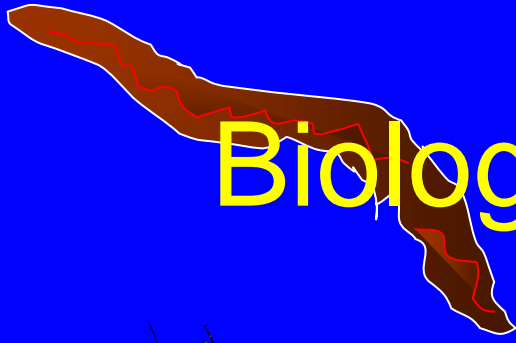
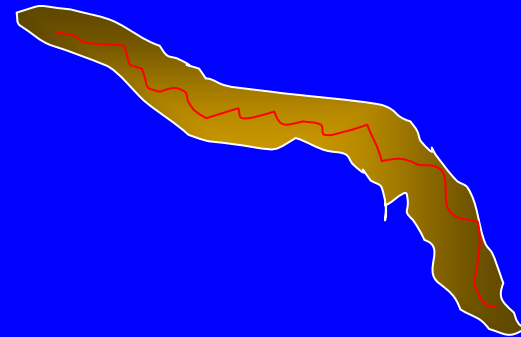


# Biology of Composting



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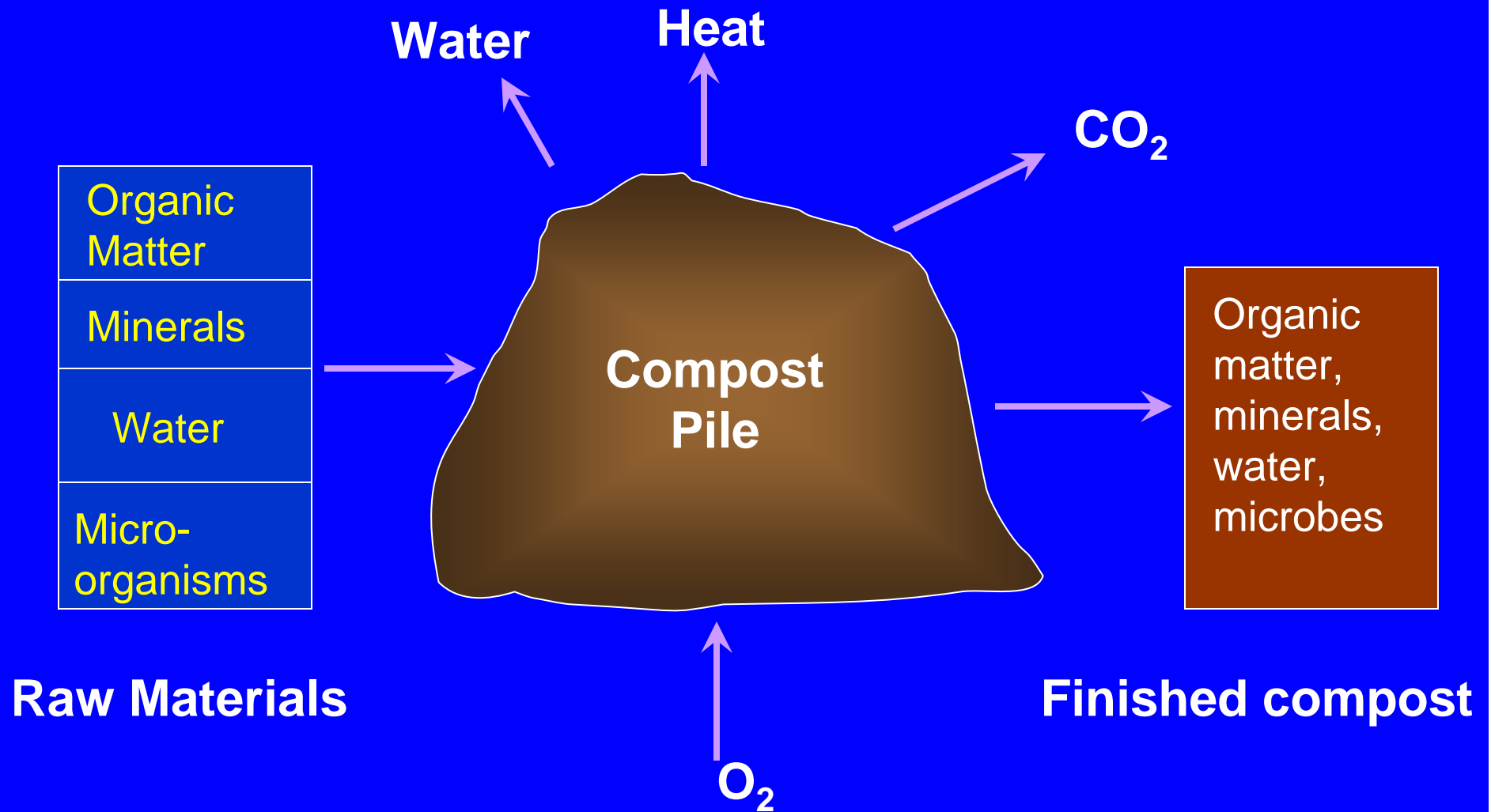
# Why Biology?

BECAUSE COMPOSTING IS A  
BIOLOGICALLY-MEDIATED  
PROCESS

# Definition of Composting

Transformation of raw organic materials into biologically-stable, humic substances suitable for a variety of soil-plant uses.

# 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

# How Is Compost Produced?

Combination of microbial processes at work

1. **Decomposition:** breakdown of plant and animal remains into stable organic materials
2. **Humification:** conversion of organic matter into humus (resistant to microbial attack)
3. **Immobilization:** microbial tie up of inorganic molecules into their own cells.
4. **Mineralization:** microbial release of inorganic ions (nutrients like nitrate, ammonium, phosphate)

# Microbes break down organic compounds to:

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

# Energy yielding processes include:

- **Aerobic respiration:** use of  $O_2$  as primary oxidizing agent
- **Anaerobic respiration:** use of inorganic substances other than  $O_2$  as oxidizing agent (e.g., nitrate)
- **Fermentation:** use of an organic compound as oxidizing agent (produces acetic acid)

O<sub>2</sub> Respiration most efficient process in terms of energy yield.

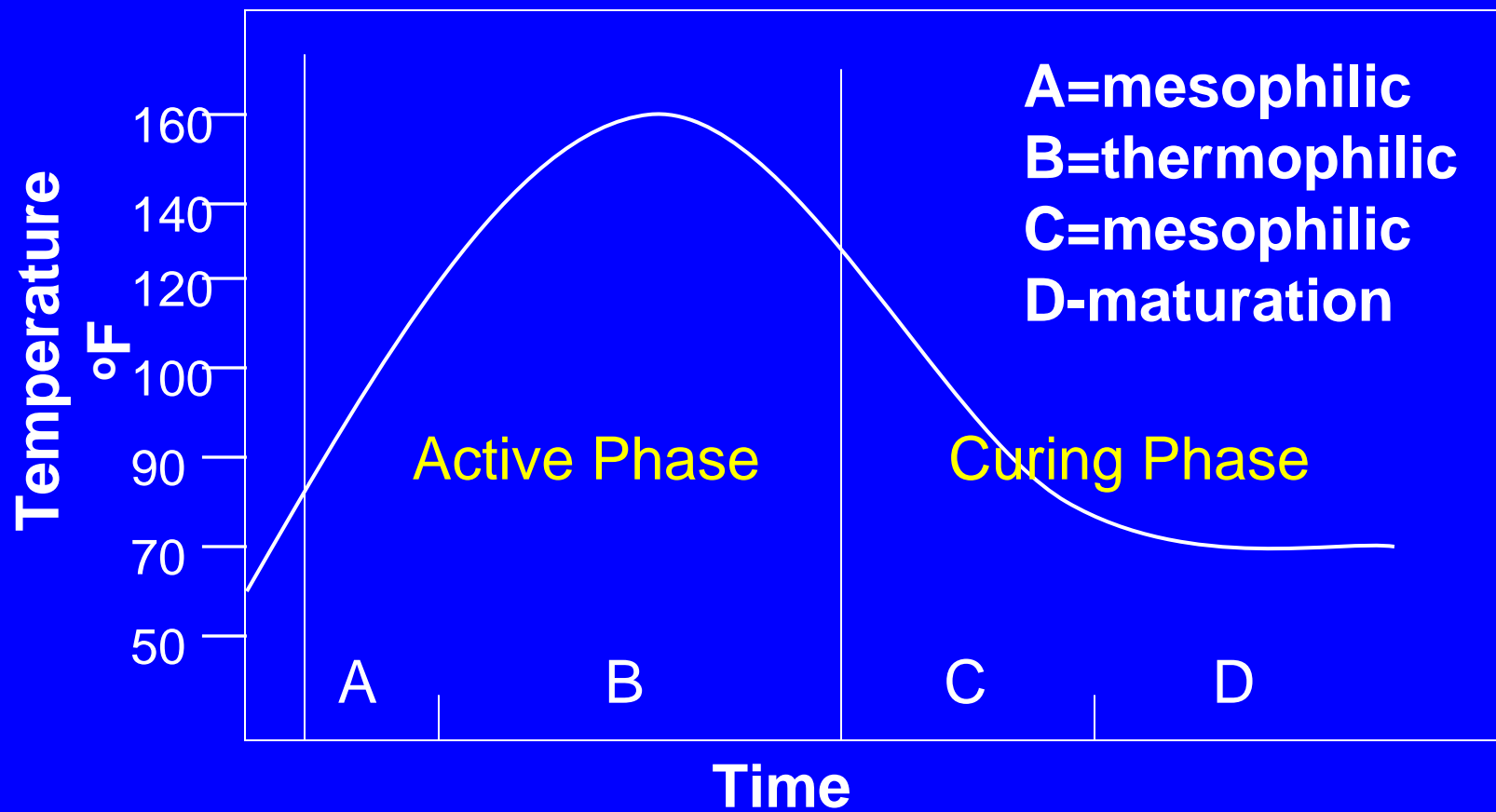
Aerobic (O<sub>2</sub>) breakdown of organic materials is quickest way to achieve biological stability.

“Heat” generated in composting is by-product of microbial metabolism.

# Phases of Aerobic Composting

- **Mesophilic phase**: moderate temps., lasts for a few days
- **Thermophilic phase**, high temps., lasts from a few days to several weeks
- **Curing and maturation phase**, moderate to ambient temps., lasts 1-2 months.

# Simplified Temperature Changes in an Aerobic Compost Pile



# **Organisms involved in the composting process**

# Succession of microbial communities during composting

- **Mesophilic bacteria** break down soluble, readily degradable compounds (sugars, starches)
- **Thermophilic bacteria** break down proteins, fats, cellulose, hemicellulose
- **Fungi and actinomycetes** (filamentous bacteria) important during curing phase in attacking most resistant compounds

# Mesofauna (the “teeth and tongue”)

- Snails, slugs, mites, sow bugs, worms, springtails, ants, centipedes, millipedes, nematodes, beetles
- They do most of initial mechanical break down of organic materials into smaller particles

# Micro-organisms (“the stomach and intestines”)

- Bacteria, fungi, actinomycetes, protozoa
- Largely responsible for most of composting process
- Present in feedstocks, soil or can be added as inoculants

# Microbial classes based on:

- O<sub>2</sub> consumption
- Temperature range over which they function
- “Food” quality (some better at degrading certain C compounds than others)

# Oxygen consumption

- **aerobes** (greatest percentage of microbes in compost pile)
  - **facultative** (use oxygen, but can switch to other substrates when  $O_2$  becomes limiting)
  - **obligate** (cannot survive without  $O_2$ )
- **anaerobes** (mostly killed or inhibited on exposure to  $O_2$ ; some are facultative)

# Temperature range

- **thermophiles** (function at temperatures above 113 °F (45-70 °C))
- **mesophiles** (function at temperatures between 50-113 °F (10-45 °C))

Mesophiles initiate composting process, and, as temperature increases, thermophiles take over.

Mesophiles recolonize compost during curing phase.

# Pathogens

- *Escherichia coli*, *Salmonella spp.*, *Staphylococcus aureus*, *Bacillus subtilis*, *Clostridium botulinum* are most common.
- Moist heat more effective in killing pathogens than dry heat.
- More pathogens killed at acid or alkaline pH conditions than at neutral (pH 7) pH.

# Pathogens, cont'd

- Certain pathogens require longer times and higher temps to be killed than others.
- USEPA requires either 3 days at 55°C or 5 days at 40 °C to kill pathogens.
- We know nothing about composting effects on prions (“mad cow” organisms)

**Substrate (feedstock) quality  
and environmental factors  
affecting composting process**

# Carbon compounds

- Carbohydrates (sugars)
- Fats, oils
- Cellulose (chains of simple sugars)
- hemicellulose (branched chains, bundle cellulose chains)
- Chitin (insects, shellfish and fungi)
- Lignin (complex polymer)

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
- Ideal starting range is 25-40:1

## Rules of thumb:

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

Animal wastes more N rich than plant wastes.

# 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

# Lignin and Biodegradability

- Higher % lignin in feedstock, lower the bioavailability to microbes
- Forage labs can measure lignin content
- Can estimate bioavailability of organic material if you know the % lignin and % volatile solids
- Equation:  
$$0.83 - (0.028 \times \text{lignin}\% / \text{volatile solids}\%)$$
  
(Source: Cornell Composting website-research under anaerobic conditions!!).

# Correction Table for %C and C:N Ratio based on % Lignin

Material	% C (total)	C:N (total)	% lignin	%C biodeg- radable	C:N biodeg- radable	% Cell wall
newsprint	39	115	21	18	54	97
Wheat straw	51	89	23	34	58	95
Poultry manure	43	9.6	2	42	9.3	38
Maple wood chip	50	51	13	44	45	32

Source: Cornell Composting Webpage

# Lignin decomposition under aerobic conditions

- Lignin decomposition much higher under aerobic than anaerobic conditions
- Promote conditions for white rot fungi
  - Add small quantities of N to woody materials (as little as 0.12%N)
  - Promote high moisture conditions (65-83%)
  - High temperatures (thermophilic range)

# Phosphorus

- sugar phosphates (constituents of nucleic acids)
- phytate (structural component of plants and seeds)
- phospholipids (components of cell membranes)
- Most plant P in organic forms; animal waste P largely in inorganic forms.

Microbes need P as well as N to make biomass

C:P ratio also important in regulating composting process

**C:P >100:1** considered threshold above which net P immobilization is expected to occur.

# Oxygen content

- Since most efficient composting is aerobic, need O<sub>2</sub>.
- Atmospheric O<sub>2</sub> concentration: 21%.
- O<sub>2</sub> levels in compost air shouldn't go below ~5% for aerobic composting; 10% optimal.
- As pile heats up, more O<sub>2</sub> will be consumed.

# Moisture content

- Optimal range 45-60% by weight.
- Low moisture impedes composting process because
  - microbes need water
  - piles more susceptible to spontaneous combustion because moisture content regulates temperature rise.
- Moisture content  $< 30\%$  creates dust problems.

## 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 ( $> 70\text{ }^{\circ}\text{C}$  or  $170\text{ }^{\circ}\text{F}$ ) can inhibit biodegradation.
- 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

- Bacterial decomposers prefer pH range 6.0-7.5
- Fungal decomposers prefer pH range 5.5-8.0
- Ideal range 5.8-7.2
- If pH exceeds 7.5 can promote ammonia gas loss

## pH cont'd

- Certain feedstocks can increase pH (paper processing wastes, cement kiln dust), while food wastes can lower pH.
- Production of organic acids and anaerobic conditions can lower pH < 4.5, limiting microbial activity

# Particle size

- Microbial activity is related to accessibility of substrate.
- Smaller particles have more surface area per unit volume than large particles; enhances accessibility to substrate.
- HOWEVER, v. fine particles create small pores → restricted air flow could lead to anaerobic conditions.
- Wood chips create porosity, but carbon isn't available to microbes.

# Pile Size/Shape

- Pile size will affect O<sub>2</sub> content and temperature.
  - Small piles maintain higher internal O<sub>2</sub> concentrations than large piles.
  - Large piles retain higher temperatures than small piles.
- Ideal pile height, 6-8 ft.

# 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 <sub>2</sub> Conc.	> 5%	~10%
Particle size	3-13 mm	variable
pH	5.5-9.0	6.5-8.0
Temperature	43-66 °C	54-60 °C

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