Compost

Dr. Elaine R. Ingham

elaine.ingham@rodaleinstitute.org

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Quality Compost is all about LIFE

Conditions have to be right to maintain life

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Biology determines quality:

Chemistry is a result of biological activity

A Healthy Food Web Will:

- Suppress Disease (competition, inhibition, consumption; no more pesticides!)
- Retain Nutrients (stop run-off, leaching)
- Nutrients Available at rates plants require (eliminate fertilizer) leading to flavor and nutrition for animals and humans
- Decompose Toxins
- Build Soil Structure –(reduce water use, increase water holding capacity, increase rooting depth)

Soil Chemistry: Nutrient Pools

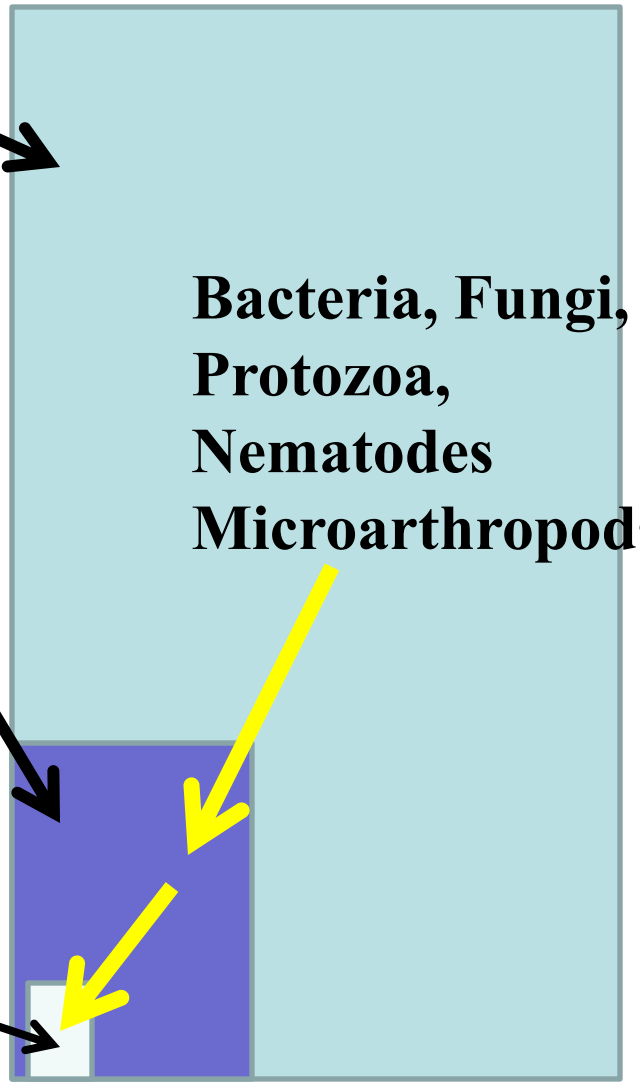
- **Total Nutrients** – not normally reported
  - Grind, complete digestion and combustion
- **Exchangeable Nutrients** (Melick 3, Ammonium Acetate 1N)
  - Strong extracting agents, but not ALL nutrients
- **Soluble Nutrients**
  - Extracts soil solution or water soluble nutrients
  - Available nutrients – made available how?
- **Plant Tissue Tests**
  - Total chemical components….. Balanced?

Nutrient Pools in Soil

Total – everything

Exchangeable - easily pulled off surfaces; easy to make soluble

Soluble – dissolved in soil solution; potentially available to plants



Without organisms to retain the soluble nutrients that a plant does not take up, or to change plant-not-available forms in plant-available forms, no new soluble nutrients will occur. Plants will suffer.

What biomass of each organism is needed so the plant gets the nutrients it needs?

Minerals in soil (Sparks 2003)

Element	Soils (mg/kg)		In the Earth's crust (mean)	In Sediments (mean)
	Median	Range		
O	490,000	-	474,000	486,000
Si	330,000	250,000-410,000	277,000	245,000
Al	71,000	10,000-300,000	82,000	72,000
Fe	40,000	2,000-550,000	41,000	41,000
C (total)	20,000	7,000-500,000	480	29,400
Ca	15,000	700-500,000	41,000	66,000
Mg	5,000	400-9,000	23,000	14,000
K	14,000	80-37,000	21,000	20,000
Na	5,000	150-25,000	23,000	5,700
Mn	1,000	20-10,000	950	770
Zn	90	1-900	75	95
Mo	1.2	0.1-40	1.5	2
Ni	50	2-750	80	52
Cu	30	2-250	50	33
N	2,000	200-5,000	25	470
P	800	35-5,300	1,000	670
S (total)	700	30-1,600	260	2,200

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The Soil Food Web

First trophic level:
Photosynthesizers

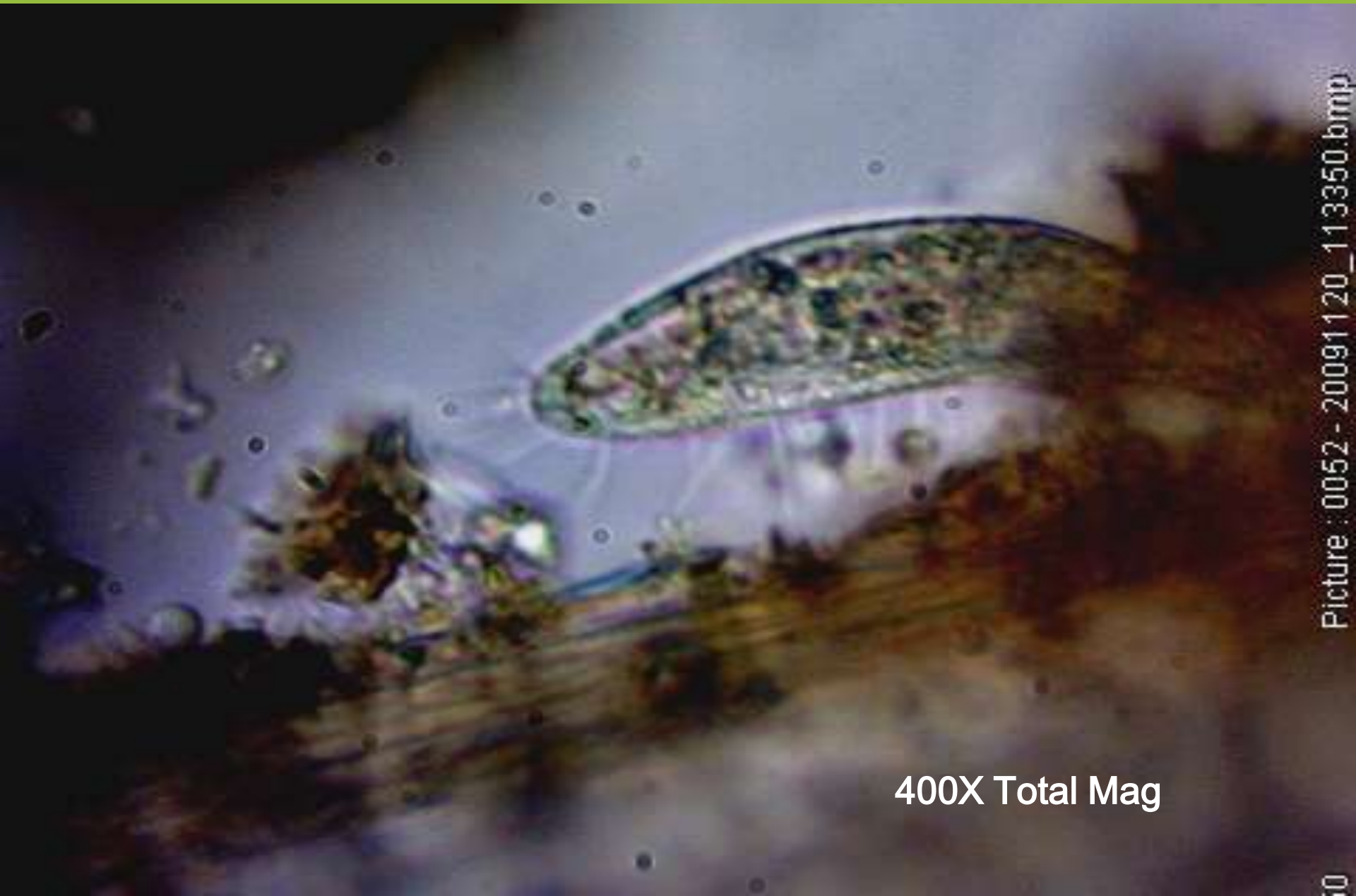
Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

Bacteria, Aggregates, Roots, Ciliate (Protozoan)



Numbers: Species or Individuals

We need to understand both species and individuals, but……

A high number of species means all the functions of that group could be done; a low number means missing functions.

ALSO need lots of individuals of each species active, doing their jobs to get the work performed.

BOTH have to happen.

Bacteria, fungi, humus, aggregates: 400X total magnification

Numbers versus Biomass

One elephant versus one mouse?
One fungus versus one bacterium?
Which is more important?

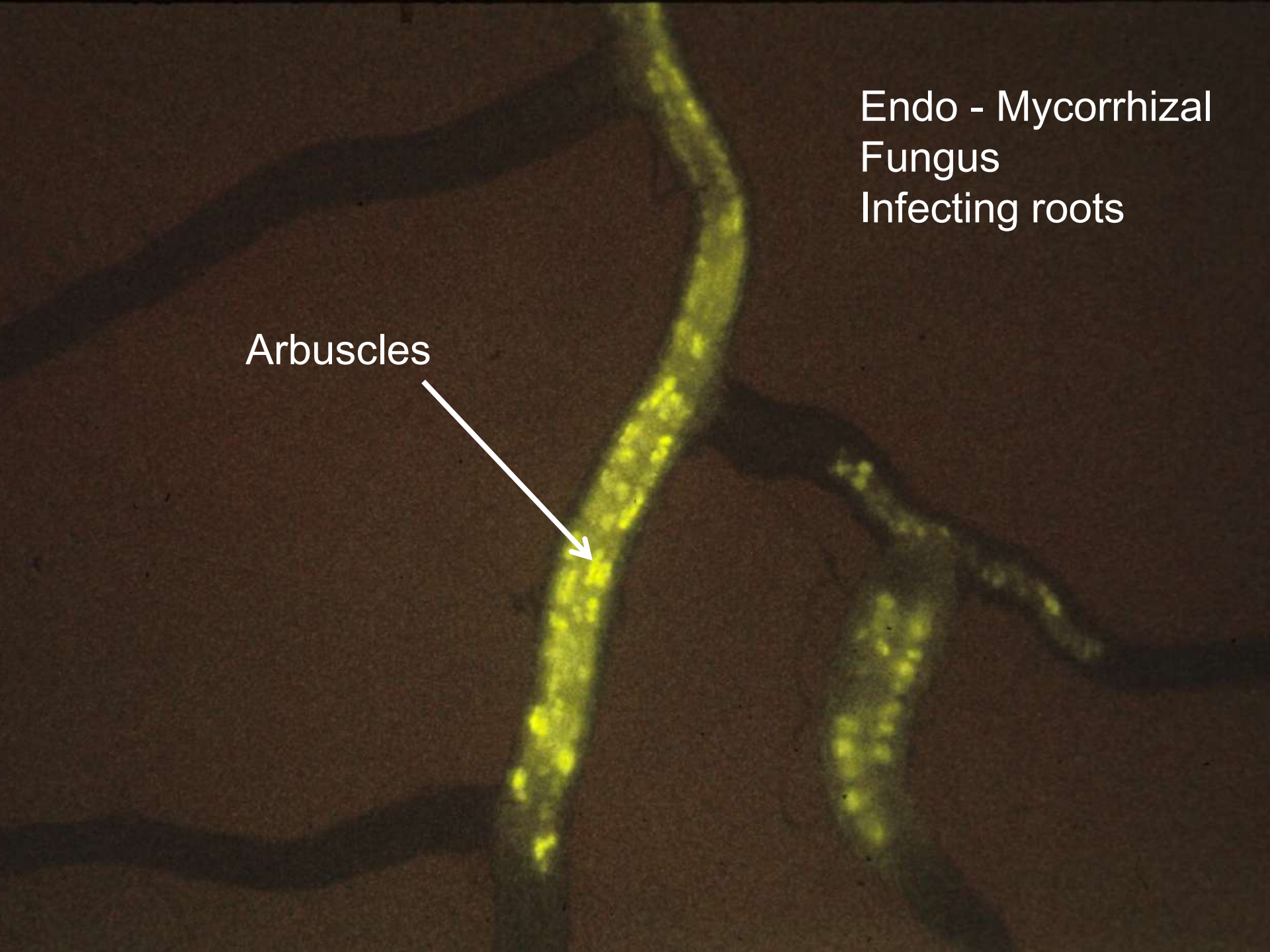
Fungi versus bacteria?

The largest organism on this planet is a fungus. Bacteria are just about the smallest organisms on the planet.

How do you compare function?
Biomass, not numbers

Josh Webber: Portmore Golf Course

North Devon, UK


Endo - Mycorrhizal
Fungus
Infecting roots
Arbuscles

Structure in soil; Holding nutrients

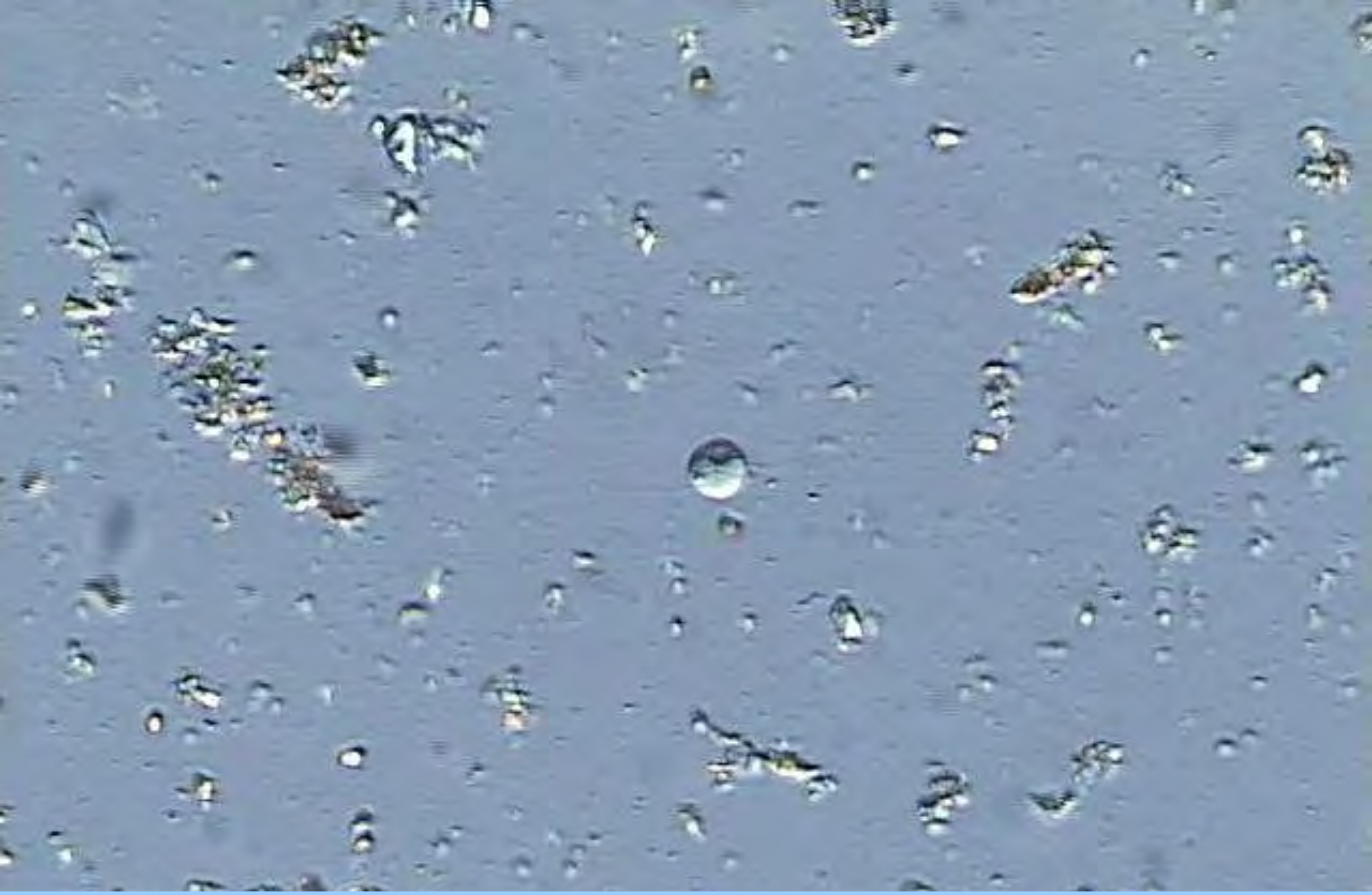
Bacteria make glue that hold small particles together, build “bricks”

Fungi mortar the bacterial bricks together to build walls, floors, ceilings and doors.

Fungi condense the simple compounds in soil into ever more complex forms, and thus are most responsible for making humus

Predator Morphology

Protozoa, Nematodes



Flagellates, soil bacteria – 400 X mag

Beneficial Nematodes

Hi! I'm Alaimus!
My mouth and lip hairs let you know who I am.

I live in the town of Vegetable Roots and eat aerobic bacteria the plant grows around its roots.

If bad-tasting anaerobic bacteria start growing or things get too shaken up, I leave.

My job is to turn excess nutrients in bacteria into plant-available forms of those nutrients. The job pays well. I have 200 children, and 40,000 grandchildren.

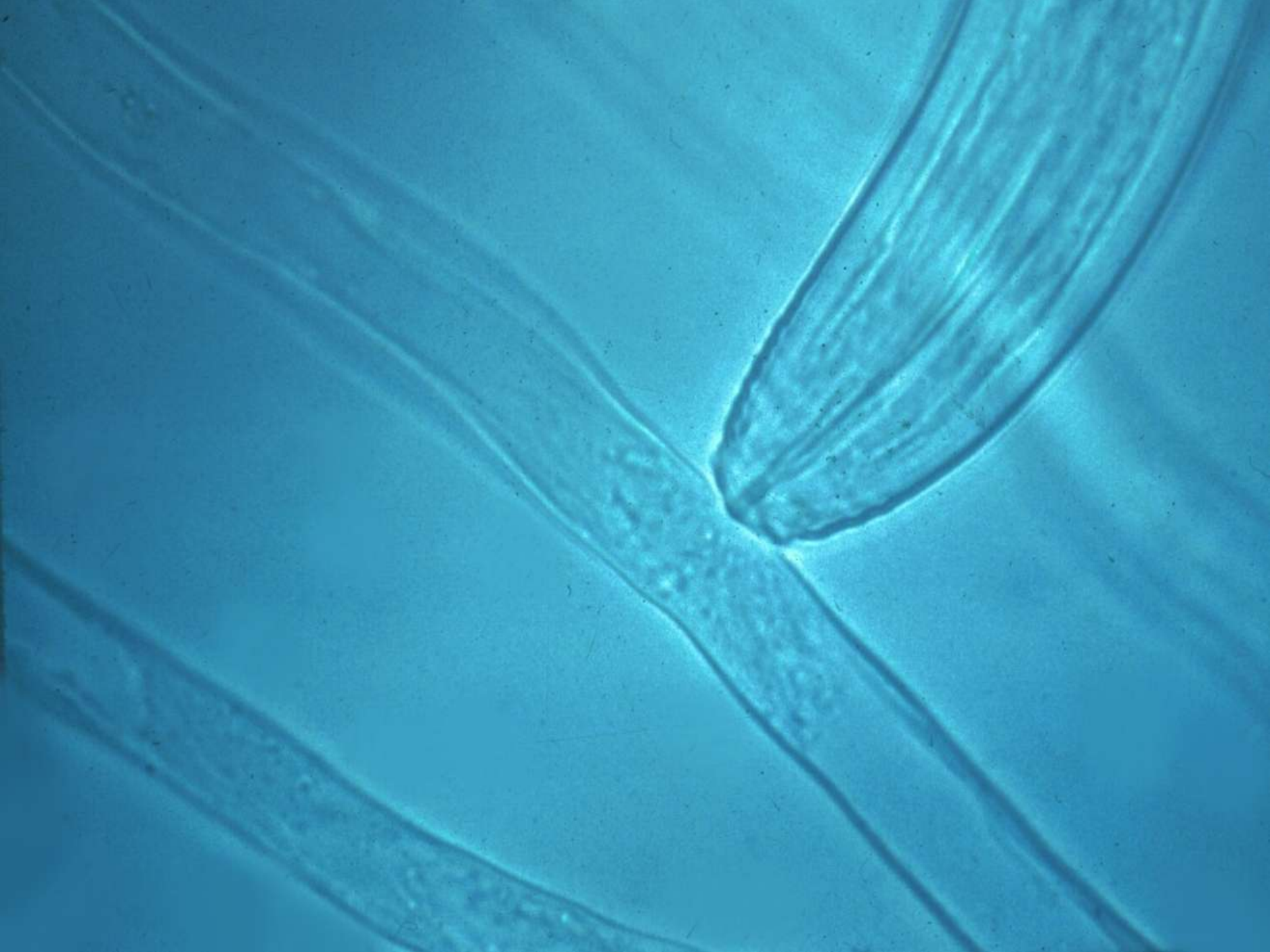
2009/09/02 11:18:14 Picture : 0048 - 20090902_111814.bmp

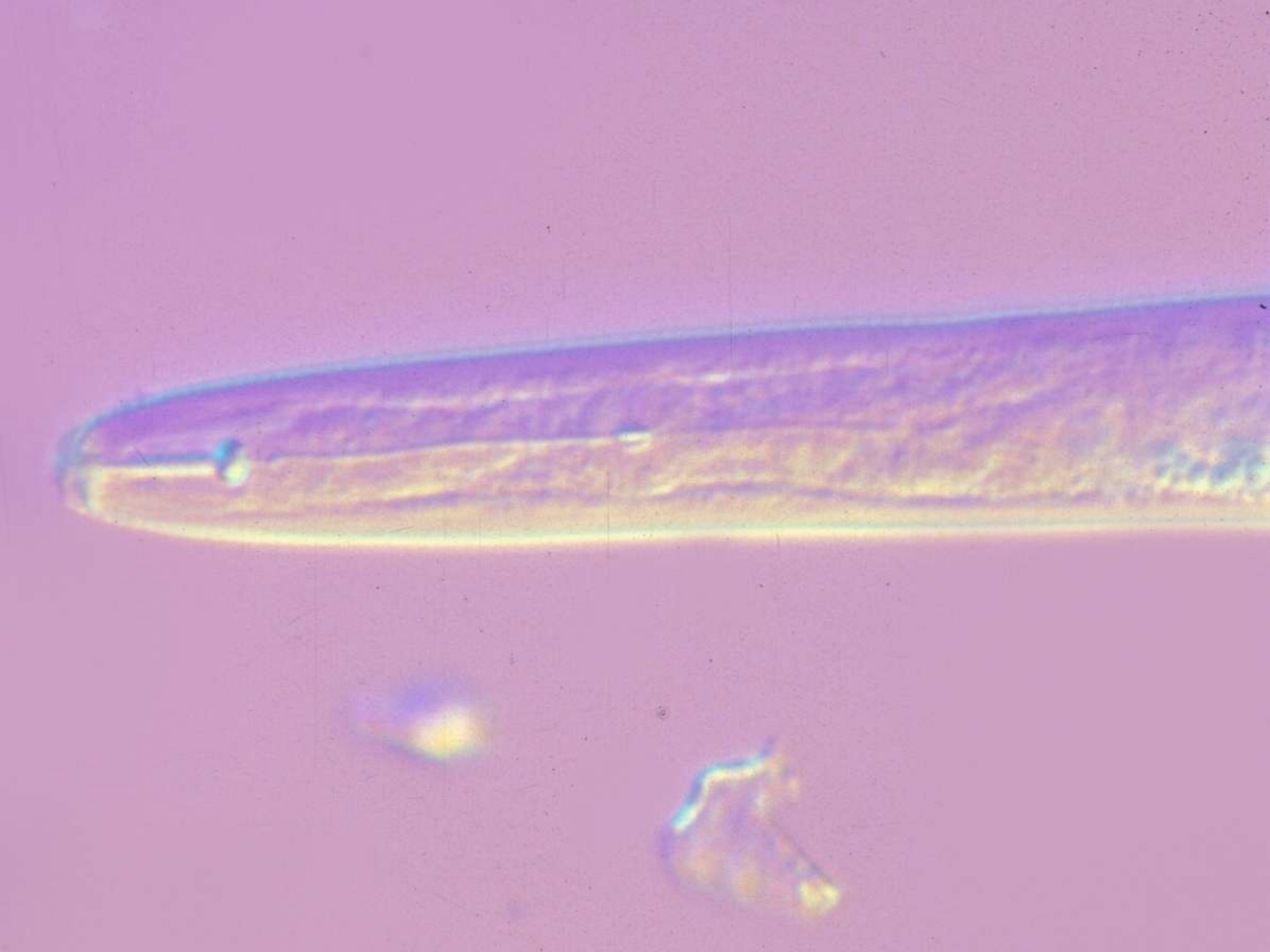
Nutrient Retention; Plant-available; Soluble, Exchangeable, Total

Bacteria and fungi form a massive wall around roots, because plants feed them

Protozoa and nematodes are attracted to the large number of their prey

Because nutrients are so much higher in bacteria and fungi than in their predators, excess nutrients are released, but in plant available forms





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Videos of Life in the Soil

Critter Movies!

What is compost?

- **Aerobic (so the good guys grow)**
- **decomposition**
  - REQUIRES BACTERIA and FUNGI in high diversity
  - Why high diversity? So decomposition will continue through all environmental conditions, from freezing to burning, wet to dry, when salts are a bit unbalanced…..
- **of a mix of organic material;**
  - High diversity requires lots of different foods to grow the organisms
- nutrient cycling requires predators

Does compost have a different food web than soil?

- Where do the organisms in compost come from?
  - Thermal compost
  - Worm or Vermi-compost
  - Static compost

- Why is composting needed? What kills them?
  - Kill human pathogens, plant pathogens,
  - Kill weed seed
  - Kill root-feeding nematodes
  - Concentrate nutrients

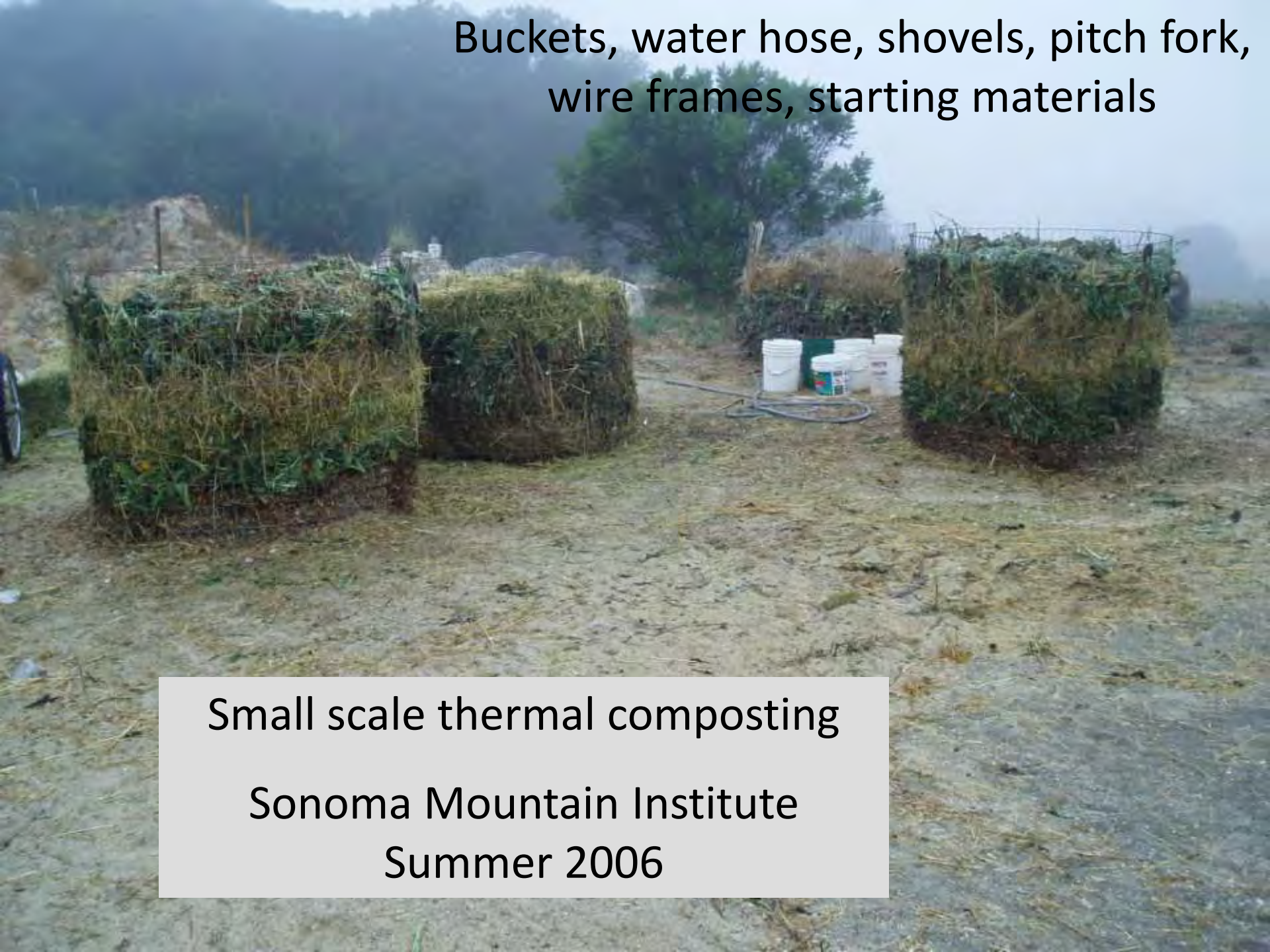
Thermal Compost

- The heat evolved in a thermal pile comes from the rapid growth of bacteria and fungi decomposing the organic matter in the pile

- Microbes use up oxygen rapidly when they grow rapidly.

- Thus, the pile must be turned if the temperature rises too high too fast, and bacteria, fungi, protozoa and nematodes need to be mixed evenly through the pile.

Biological Farming Technology
130,000 tonne annual composting facility



Small scale thermal composting

Sonoma Mountain Institute
Summer 2006


Packing down the
materials for contact


Relative percentages of the different starting materials

Another Example of a Composting Container

Worm Compost

- Worms consume bacteria and fungi. Bacterial and fungal growth must not be so fast that high heat is produced, or the worms would die.

- Must be careful not to add too much food at one time or lack of oxygen will kill the worms.

- Worms do the job of turning, mixing worm compost. Two jobs for the price of one is good.


How to set up and maintain a worm composting system
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by
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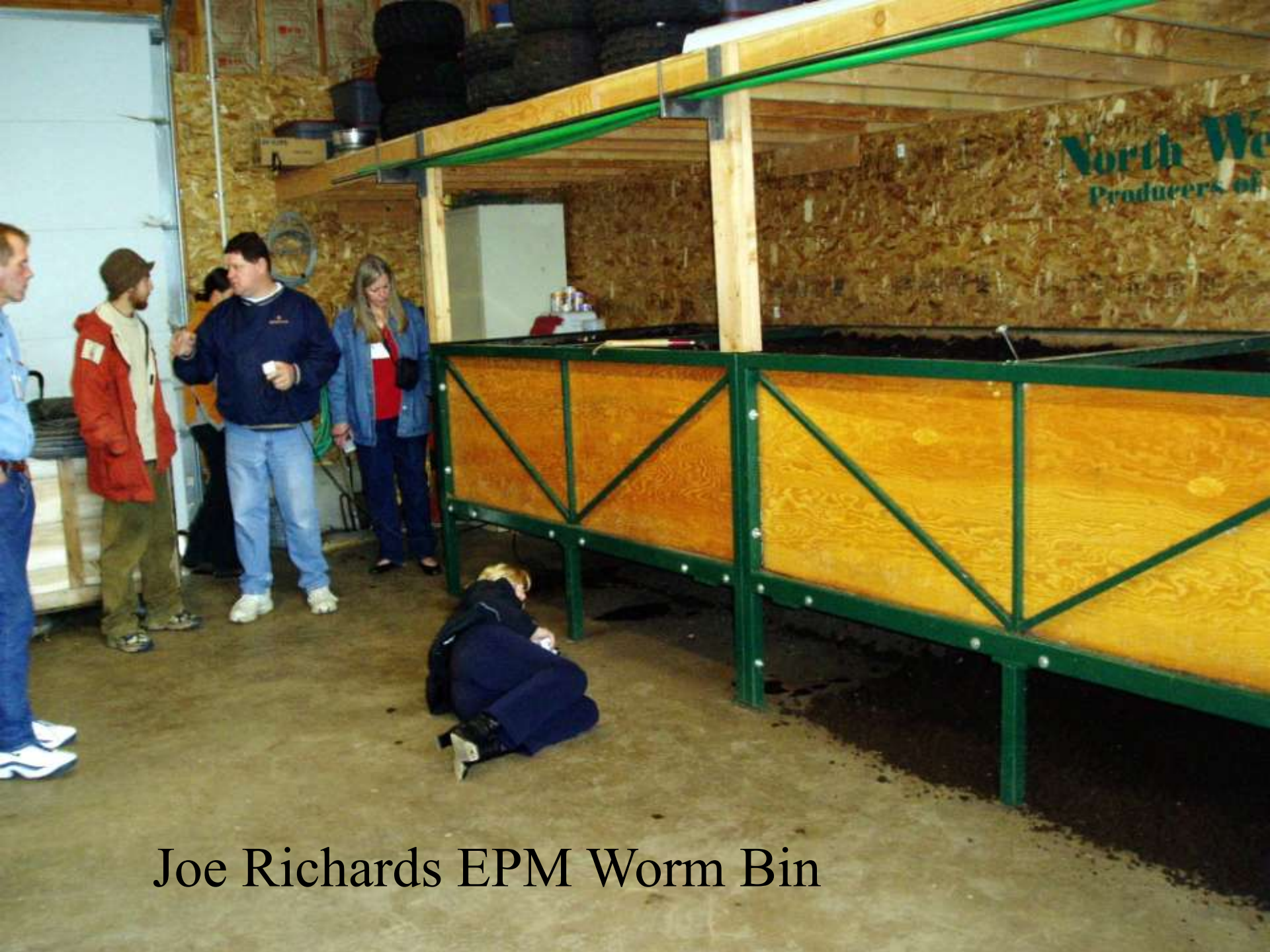
Recycle kitchen food waste
Save energy
Produce fertilizer for house plants and garden
Grow fishing worms
Reduce waste disposal cost
Mary Appelhof's
Worms Eat My Garbage
WORM·A·WAY
Patent Pending
Manufactured under license by
We Recycle Corporation, Milton, Ontario



Joe Richards EPM Worm Bin

Compost Thought Processes:

- Get the balances of starting materials correct
- Get the initial sets of organisms in the pile
- Then control decomposition processes
  - Temperature,
  - Water
  - Turning
- MONITOR what is going on in the pile
- Adjust if necessary

Things to think about:

- Starting materials: hi N, Green, Woody
- Organisms: Additional inoculum, wood chip piles and fungal inocula, add compost tea
- Turning: too hot, too dry, anaerobic smells
- Water: Chlorine? Chloramine?
- Covers
- Spreading: manure spreader, broadcast, snow blower, blower trucks

If anaerobic, it is NOT compost

- Beneficial fungi and bacteria are asleep or dead; this allows pathogens to win!
- Nutrient cyclers are dormant or dead
- Soluble N, P, S have been lost as gases
- Strong acids have been produced
- Alcohol, preservatives have been made


Anaerobic!
Actinobacteria
Black color
Stink

Anaerobic pockets and actinobacteria


2006 11 23

The Composting Process

- Get the balances of starting materials and organisms correct
  - High N (party), green (bacteria), woody (fungal)
  - Worms: only enough food for 3 days
- KEEP IT AEROBIC: Pathogens win in anaerobic
- Control decomposition processes

  Temperature caused by microbial growth (131, 150, 165F)

  Water – 50% or 70%

  Turning – shovels or worms? Timing to keep it aerobic
- Adjust if necessary
  - Too high temperature too fast, turn more, or add more woody
  - Add more high N is the party isn't hearty enough

Kinds of Starting Materials

High N (party) C:N around 10:1

– Legumes – make sure nodules on root systems

– Manure ------ BUT careful!!!!!!! NO salts!!!!!!!

Cow vs chicken vs pig (human)

– Seed (germ)------ aerate if brewing waste

Green (bacteria) C:N around 30:1

– Green plant material - CUT when green

Woody (fungal) C:N above 100:1

– Brown plant material, brown leaves, bark

– Wood, sawdust (careful how fine), chips, cobs, stalks

How much of each

High N (party) C:N around 10:1

– 25% for HOT piles, will have to turn a lot to cool things down, add air back into pile

– 10% for slower piles, less work but takes longer

Green (bacteria) C:N around 30:1

– 10% to 40% depending on how much bacteria your soil needs to have brought back

Woody (fungal) C:N above 100:1

– 35% to 65% depending on how lacking your soil is for fungi

What do you want to grow, match balances

The Thermal Composting Process

- Diversity is important

Hot compost	High N	Green	Woody	
21 days	25%	35%	40%	Use ACT at start
6 to 8 weeks	25%	30%	45%	Turn 5 times
3 months	10%	45%	45%	Turn twice


LOCAL
FOODS

Thermal Compost

- Heat to 131 F for a full 3 days to kill weed seed, pathogens, pests
  - But NOT HIGHER than 155 – 160 F so beneficials NOT killed
  - Turning required
- Regulations
  - Minimum 131 F for 10 – 15 days, turn 5 times; why the difference from above?

The Composting Process

- **Control decomposition processes**

  Temperature for long enough time kills:

  - **human pathogens,**
  - **plant pathogens,**
  - **root-feeding nematodes,**
  - **insect pests,**
  - **weed seed**

  131 F for 3 days

  150 F for 2 days

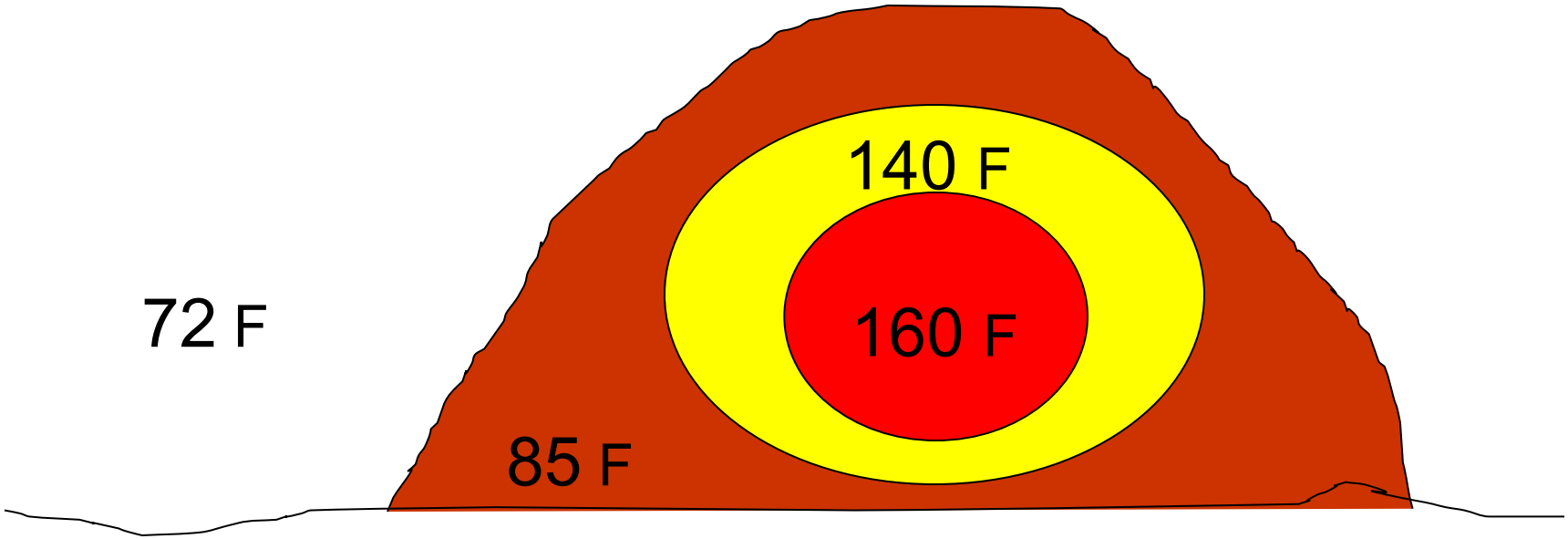
  165 F for 1 day

The Composting Process

Outside layer is not hot enough

Next layer is hot enough to kill in 3 days,

Inside needs to be turned NOW!!!!!



How to turn this pile so killed pathogen part moves to outside, while not-killed gets into the middle?

Thermal Composting

- **AEROBIC - Not below 5 to 6 mg/L oxygen, not above 7 to 9% CO2**
- **Physical structure – percent "chunkiness"**

  5% > 1 inch diameter
- **Turning – mechanically related to temperature or using earthworms**
- **50% Moisture**
  - **Too low, no decomposition**
  - **Too high, lack of oxygen**


Turn compost
when it reaches
high enough
temperature

Turning

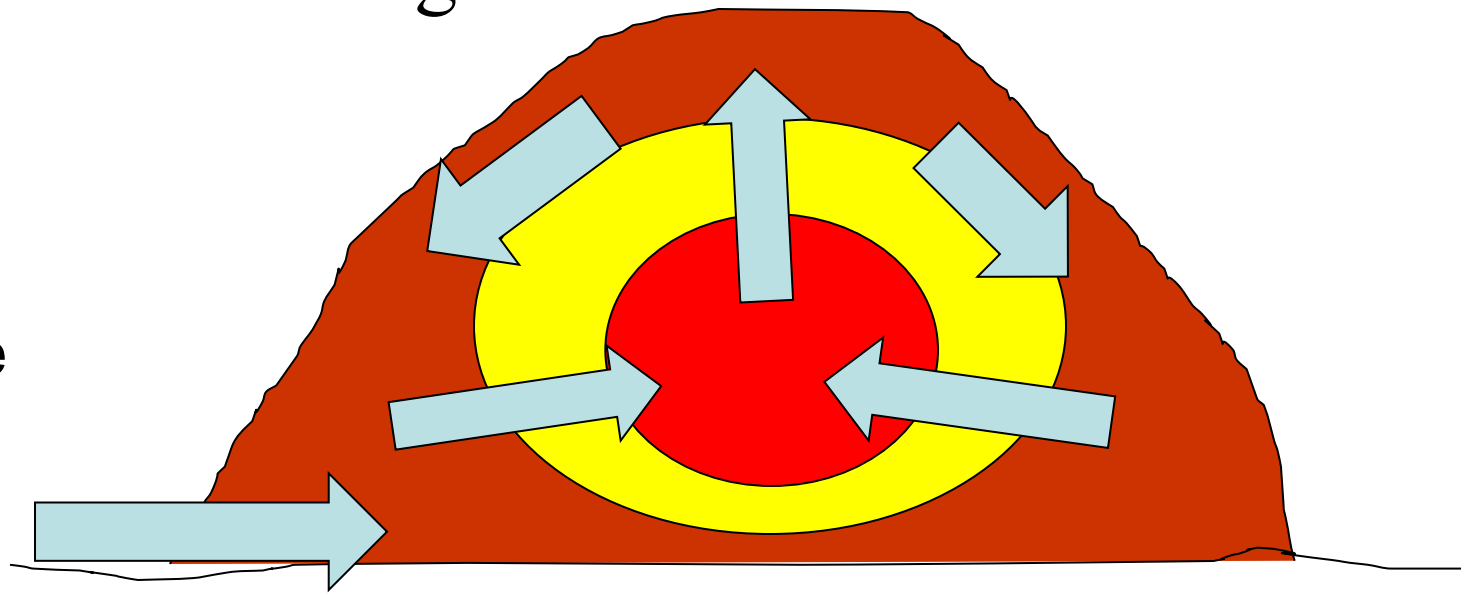
Windrow turner

The Composting Process

Outside layer needs to move to center

Center moves to outside top

Repeat at least 3 to maybe 5 times, depending on how good you are at turning



Make sure ALL the compost gets turned!

The Composting Process

- **Control decomposition processes**

  Water – THE HAND METHOD FOR MOISTURE

  50% for thermal piles

  70% for worm compost

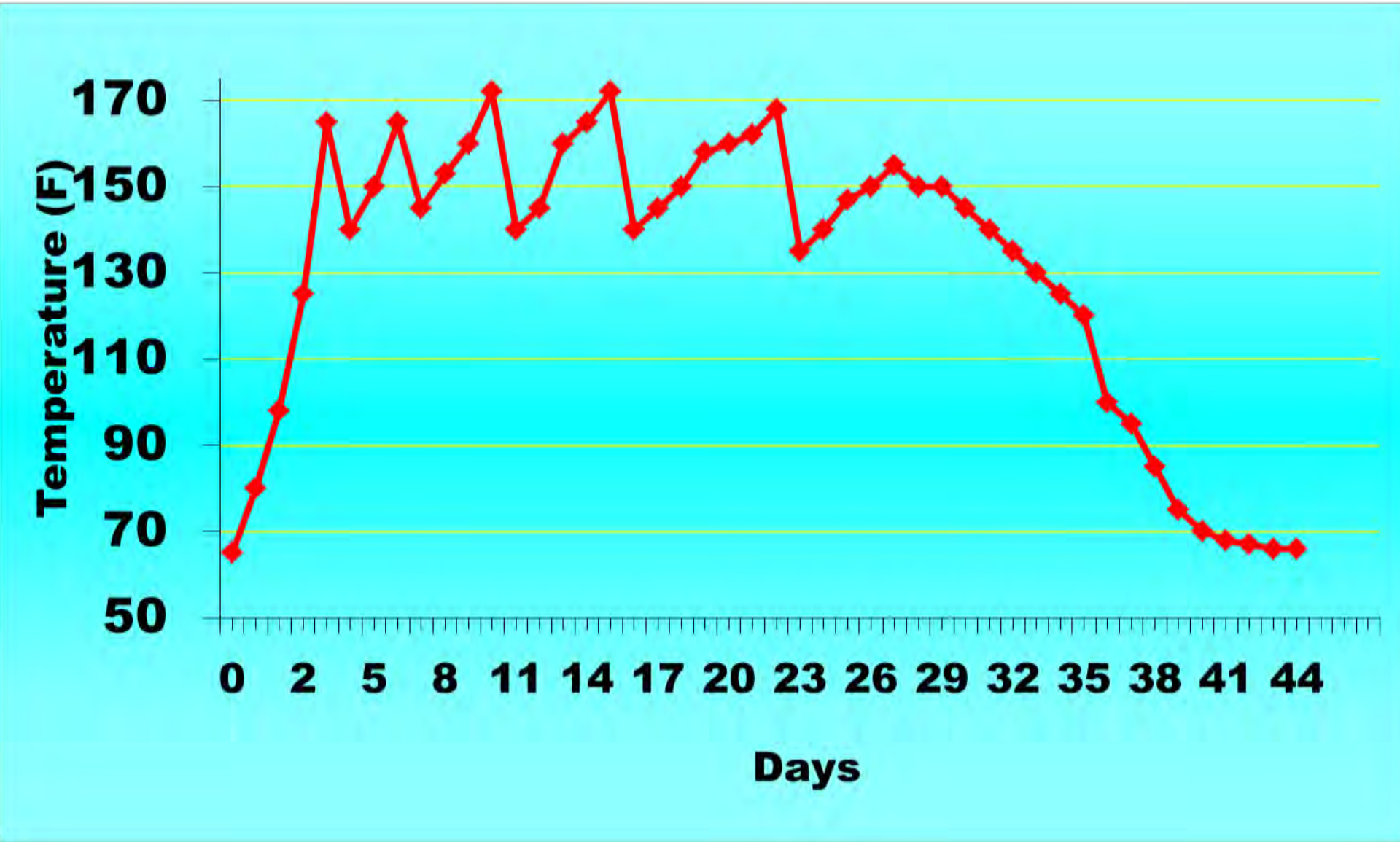
  Turning – shovels or worms? Timing to keep it aerobic

  COVER TO PREVENT WATER LOGGING, EVAPORATION

- Adjust if necessary
  - Too high temperature too fast, turn more, or add more woody
  - Add more high N is the party isn't hearty enough

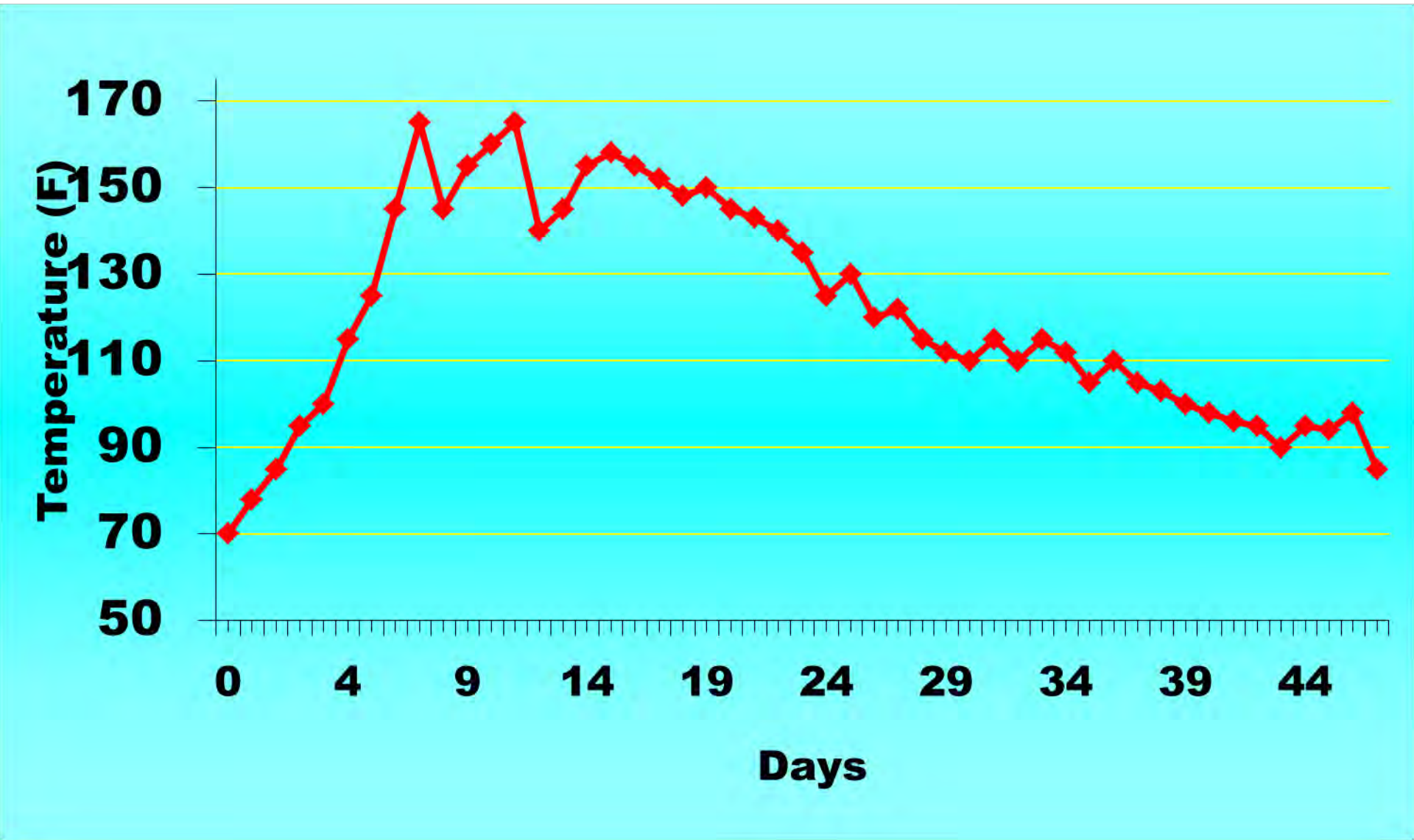
Thermal Compost: Commercial, 25% high N, 40% green, 55% woody

Turned 5 times while temperatures above 131 F, 50% moisture



Thermal Compost: Back-yard, 10% high N, 30% green, 60% woody

Turned 2 times while temperatures above 131 F. 50% moisture



Human Pathogens

- NOT PRESENT in properly made compost
- People who say pathogens will always be in compost are actually just saying they have no clue what real compost is.
- Pathogens require reduced oxygen conditions to win in competition with aerobic organisms

Human Pathogens

- Over 800 composts where the biology was correct, the temperature had stayed in range, and no detectable E. coli present

- Over 1000 black stinky stuff that someone was selling as compost where E.coli was way over 800 CFU

Why no Human Pathogens in properly made compost?

- Heat (kills bacteria, fungi, helminths, virus)
- Microbial competition (food, space)
- Inhibitors
- Predator consumption
- Passage through digestive system or contact with earthworm surfaces

Wait, doesn't heat kill the good guys too?

- Human pathogens don't survive high temperatures, but the beneficials are less sensitive AND they have resistant stages. As long as temperature doesn't get too hot too fast, the good guys survive.
- Temps: 131 F for 3 days; 150 F for 2 days; 165 for 24 hours, but not higher, because of use of oxygen

Scientific papers have been written stating that compost is sterile when it hits a temperature of 170 F.

- Is that true?

- Think it through……
- What causes heat in a compost pile?
- Can’t be sterile if organisms are growing, producing heat.

The Composting Process

- Maturity – microbial activity finished
  - Temperature does not elevate when turned
- Stability – nutrients are available
  - Immobilization phase ended
- Finished compost is mature and stable

How do you know it is “done”:

Mature Compost

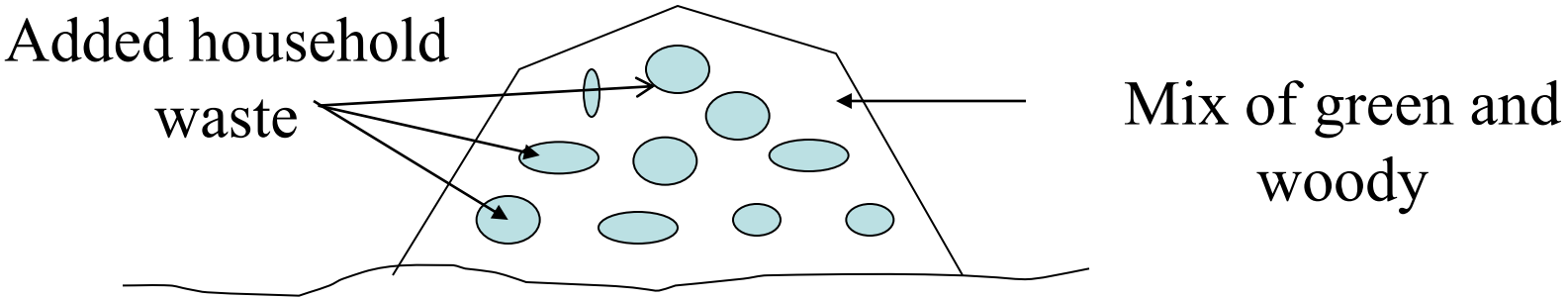
- No heating when you turn the pile
- Has a healthy food web:
- Balanced of organism depends on what you want to grow.
- Nutrient retention balanced by nutrients being made available to plants
- Diversity maximum - 6 months versus 2 years (Stable)

How to store compost

- Cover it!!!!!
- Too wet (anaerobic), too dry (the best preservative is dessication): Both are bad.
- 30% moisture is good
- Maintain balanced organism populations
- Windrows, boxes, BIG piles
- Compost left too long is top soil

House-hold Composting

- Make pile with 50% Green and 50% Woody
- Add household wastes into pile, at least **2 feet** into pile, spaced through pile, until no more “spaces” left



- Add 10% high nitrogen
- Start compost temperature cycle, measure temperature, moisture

Vermi-composting

- Cold composting method
- Layer organic matter onto top of worm bed
- 60 to 70% moisture is optimal
- Worms consume bacteria, fungi, protozoa, nematodes growing on foods added to the bin surface, make castings, shift upwards into new food
- Low rates of composting if cold, increase as temperature increases, but once above 85 to 90 F, worms get too hot and slow down again
- Harvest worm compost from bottom of table

Worm Composting

- Worms turn the compost, kill pathogens, pests by passage through digestive system, or contact on worm surface; BUT WHAT DENSITY FOR WHAT INPUT RATE?
- If too much food and worms do not use it fast enough (too hot, too cold, not enough worms, too dry, too wet), then the worm compost can become anaerobic and all the bad things happen
- DO NOT PUT more than 3 day supply of food into bin at any time. Wait for the worms to use it up, then add more. Too much food? Freeze, add as worms can manage it…… or you get flies!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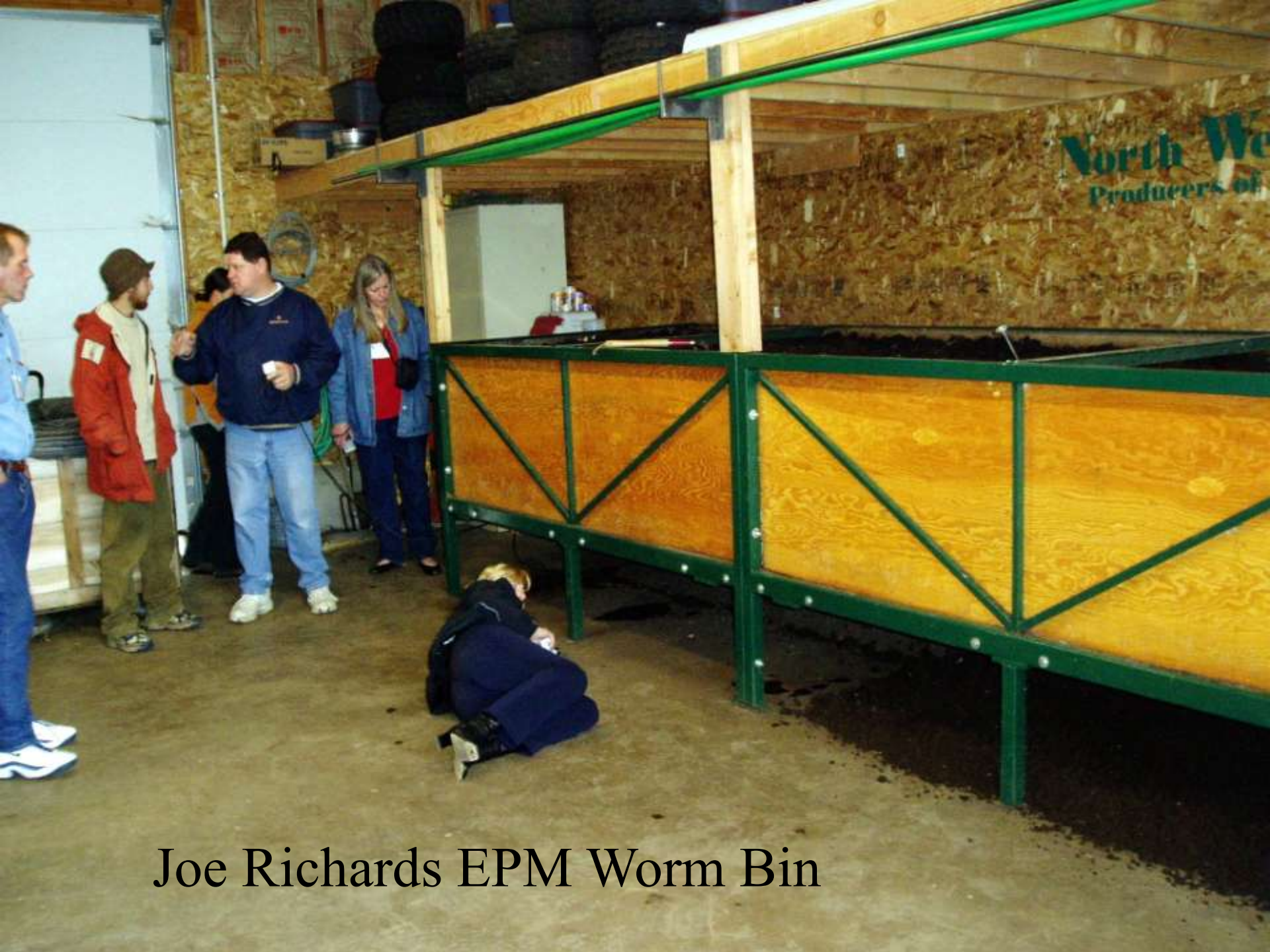


Joe Richards EPM Worm Bin


Harvesting
worm
compost

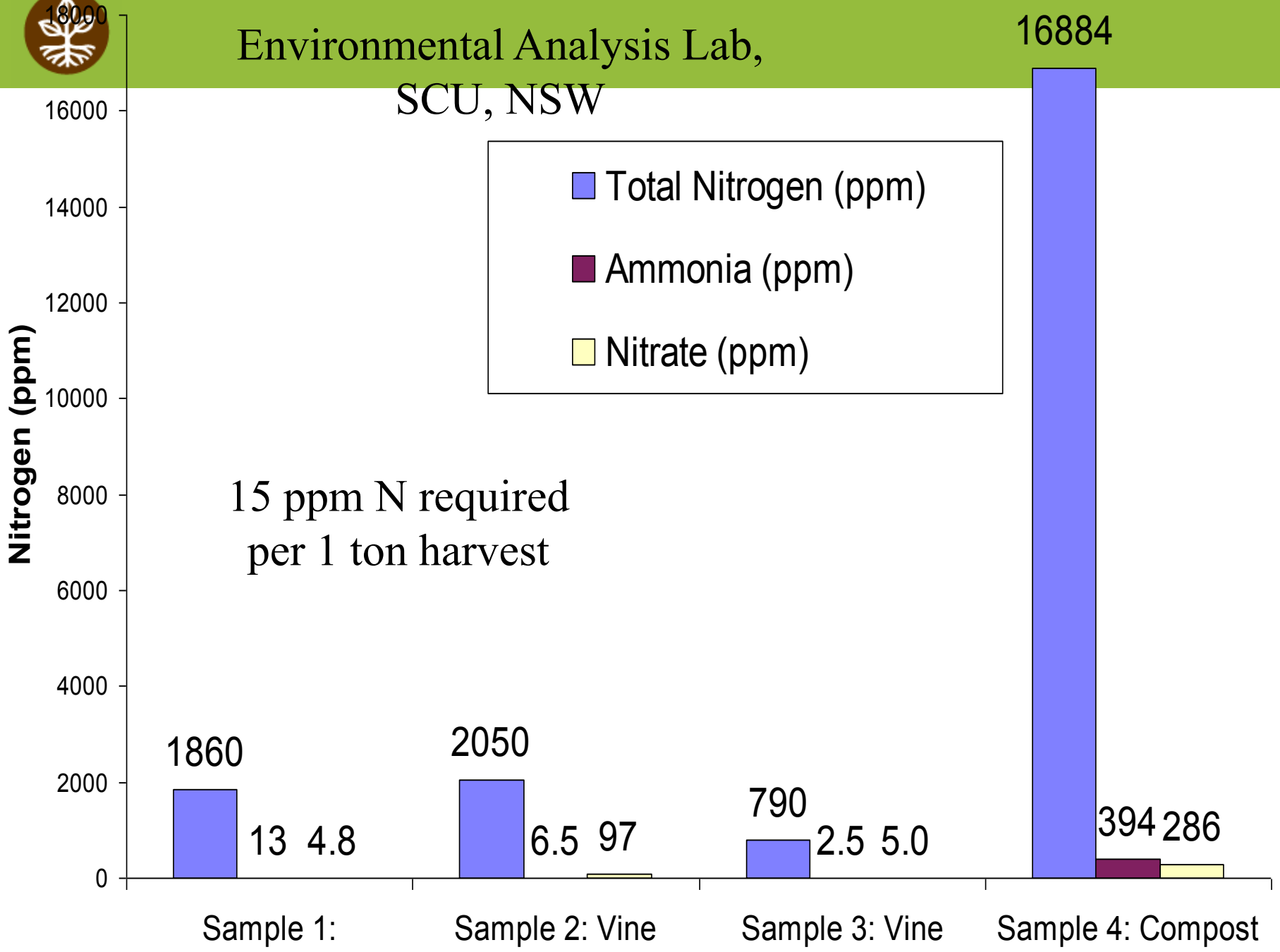
Harvesting worm compost

Sunburst Worm Farm,
South Australia

Is compost a fertilizer?

- What is fertilizer?
- N, P, K? What forms?
- Soluble, Exchangeable, Total pools
- What moves nutrients from one pool to another?
- What do plants take-up?
- How much is actually in compost?

Environmental Analysis Lab, SCU, NSW



Organisms after compost addition

Organism Assays	Agricultural Field	Compost (1ton/ac)	Two weeks later
Total bacteria (#/gram dry soil)	1 X 10^6	6 X 10^9	17 X 10^8
# of bacterial species/g soil	5,000	75,000 (25,000)	75,000 (25,000)
Total fungi (ug per g dry soil)	5	150	500
# of fungal species /g soil	500	25,000 (8,000)	25,000 (8,000)
Protozoa: F, A C	0, 0 1,450	12,000, 31,000 29	6,000, 17,000 67

Compost Contest

- Criteria
  - Color, Texture or aggregation, “stuff”
  - Water extract
    - Color, Muddiness, particulates
  - Microscope Readings
    - Bacteria……. Few? Lots? How many species?
    - Fungi…… Any at all? Number of strands? Diameters? Color
    - Protozoa…… None? Some? Lots? Flagellates or Amoebae? Ciliates?
    - Nematodes…How many? Beneficial or Bad?
    - Dilution?

Finished compost from a lay point of view

- Dark brown color: not black, not tan
- Humic acids extractable; not muddy
- Fungal biomass visible
- Actinobacteria not visible, unless plant is riparian, wetland, or mustard family
- Good forest-floor smell; no stinks
- Fluffy, not balled, not matted


6538


Monitor biology constantly