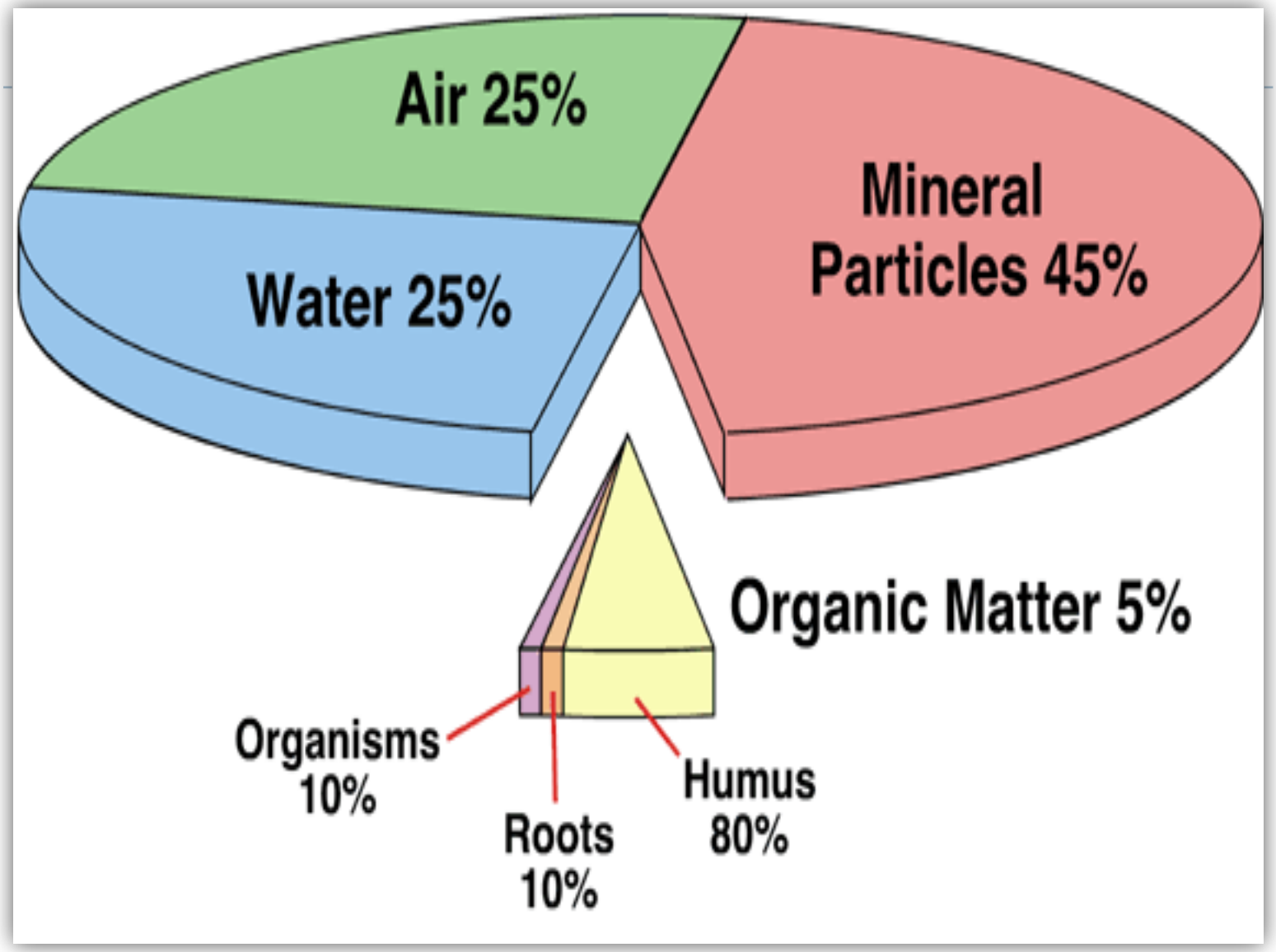
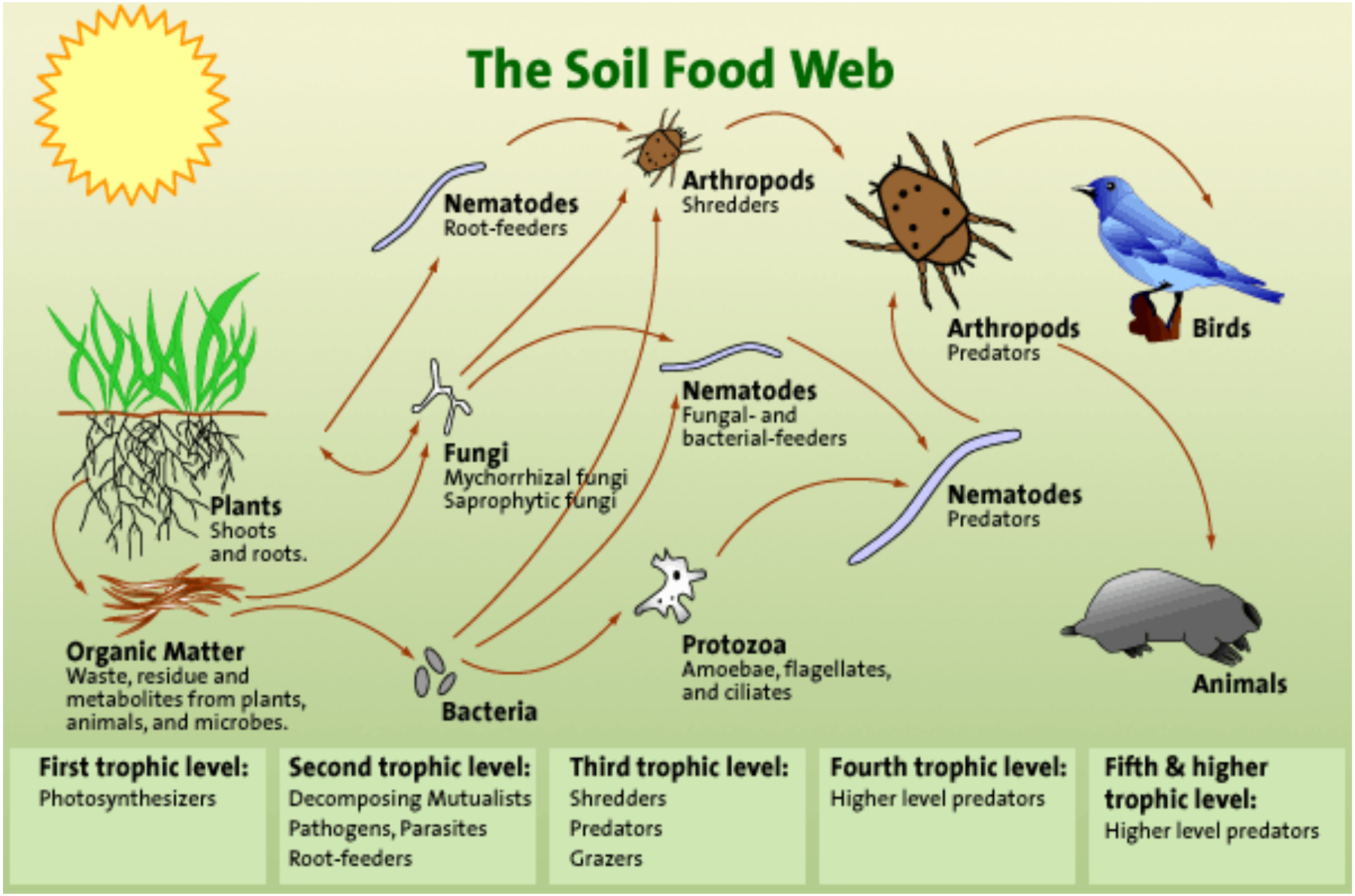
# Good Dirt: Soil Repair & Restoration

# What is Dirt?


Air 25%
Mineral Particles 45%
Water 25%
Organic Matter 5%
Organisms 10%
Roots 10%
Humus 80%

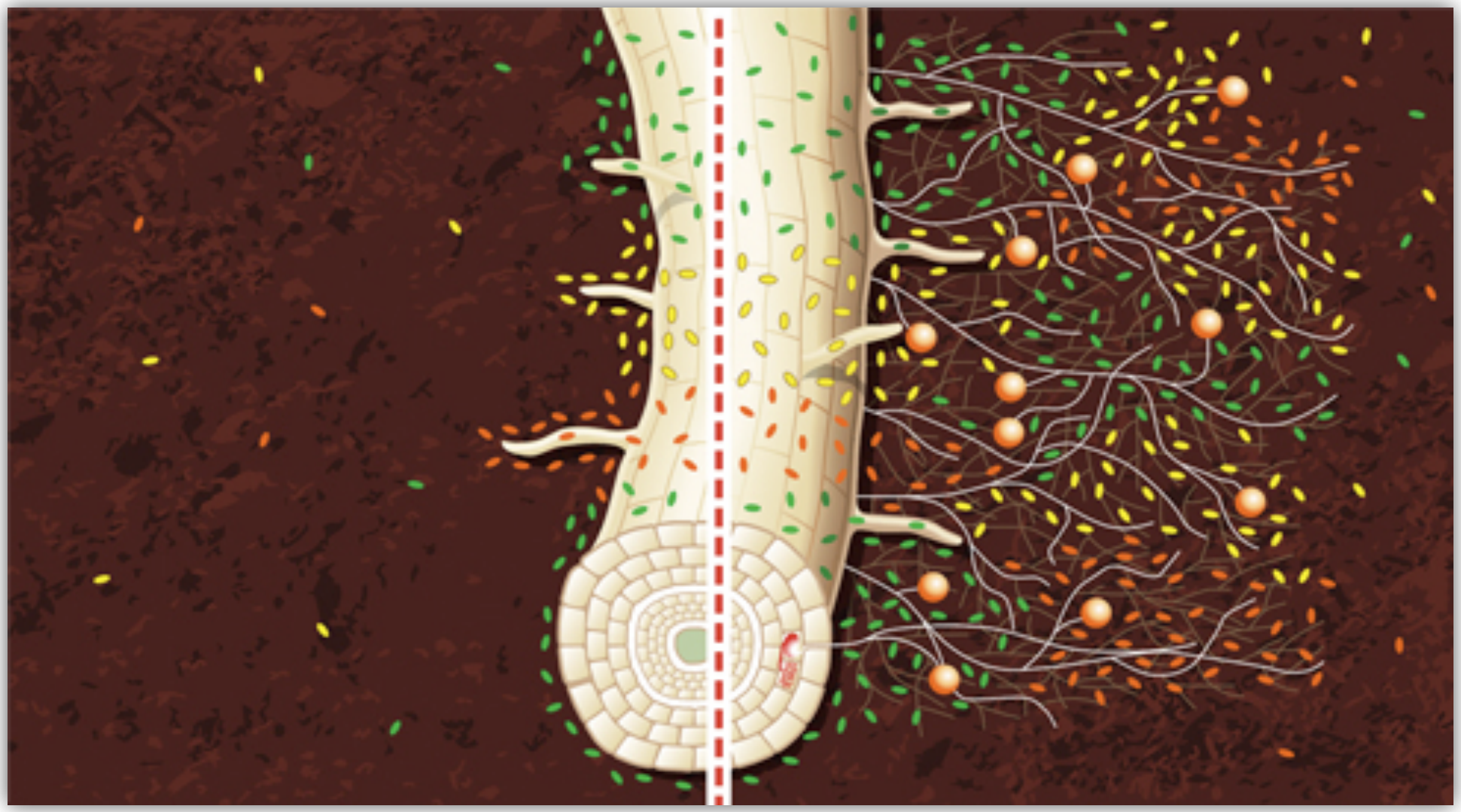



In one acre of healthy soil, you will find 2000 pounds of bacteria, 2400 pounds of fungi, 133 pounds of protozoa, 900 pounds each of earthworms and arthropods.

# Overview of the Soil Food Web

- The soil food web describes the relationship between plants, soil and organisms in the soil.
- Plants uptake nutrients through their roots, but they are stationary and their roots reach only so far.
- Plants use photosynthesis to create sugars and proteins which they excrete from their roots. These are called exudates. Exudates feed bacteria and fungi, drawing them to the area around the roots which is called the rhizosphere.
- Plants control the number and type of micro-organisms that occupy the rhizosphere for their own benefit. Micro-organisms extend the plants reach in gathering water and nutrients.
- Bacteria and fungi attract prey such as nematodes and protozoa, which in turn attract larger organisms such as arthropods. Feeding, eliminating and dying happens in around the rhizosphere. The wastes and corspes of these organisms provide nutrients in a form which is readily available to the plants
- Micro-organisms control soil pH, fix nitrogen and participate in sequestering carbon, phospohorous and other micro nutrients in the soil.

# The Rhizosphere



# Bacteria Basics

- Bacteria decompose and recycle three of the elements neccesary for life:: nitrogen carbon and sulfur.
- These are held inside their bodies until they are eaten or die and decay, leaving the nutrients in the soil in a form that plants can utilize.
- Root exudates are the favorite food of many bacteria, so they concentrate in the rhizosphere
- Bacteria are the bottom of the food chain—everyone eats them, If there are not enough bacteria, everyone starves.
- There are aerobic and anerobic bacteria. Aerobic bacteria, especially actinomycetes make the sweet smell we associate with good dirt
- Special bacteria fix nitrogen including Azotobacter & Rhizobia
- Nitrifying bacteria convert nitrogen into a form that can be used by plants
- Bacteria influence Soil pH and soil structure with their Biofilm

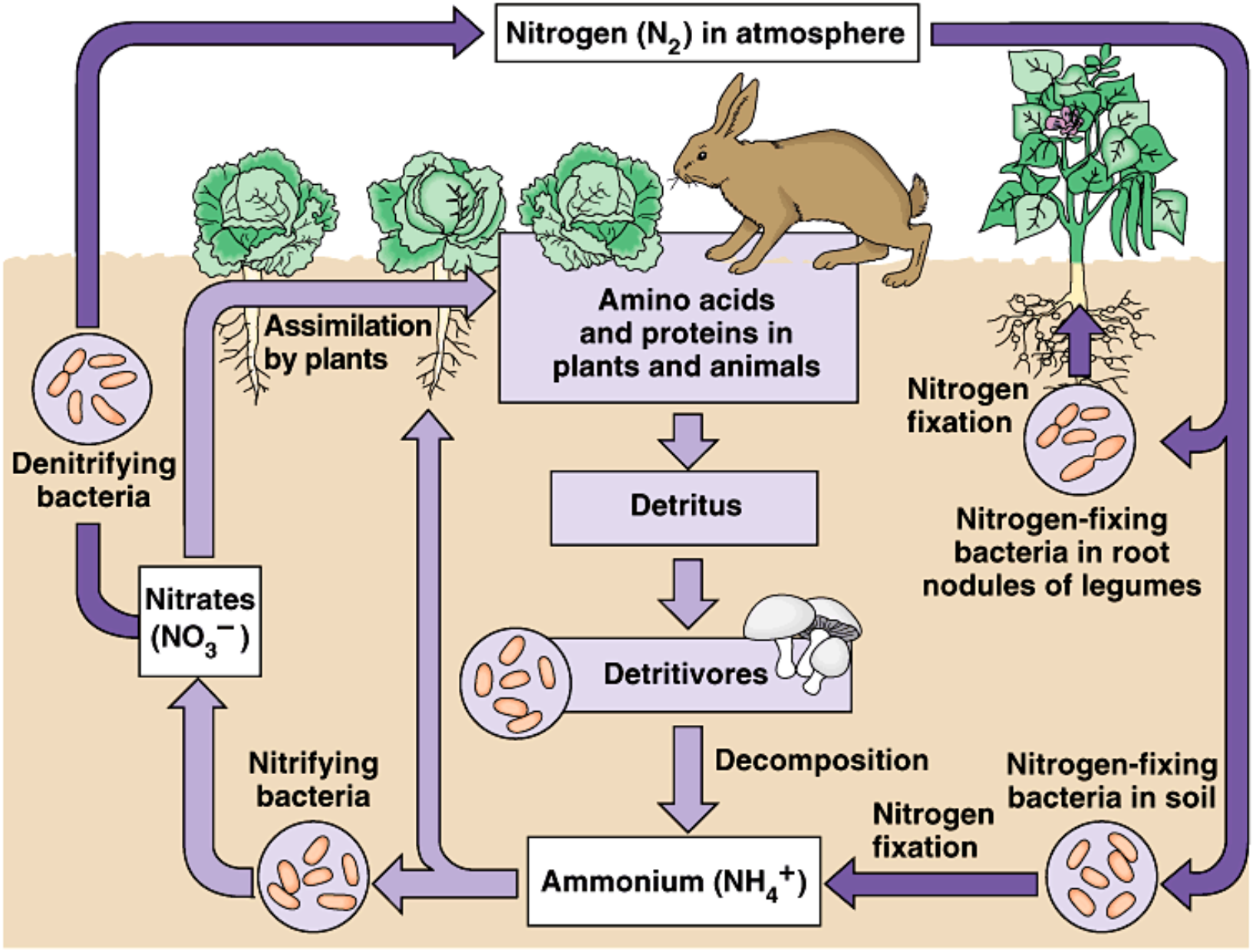
# Rhizobium

Rhizobium live inside the root tissue of legumes and produce visable nodules

# Nitrogen Cycle

- Nitrogen is necessary for the creation of amino and nucleic acids—the building blocks of life.
- Almost all nitrogen is bound in organic matter—it does not occur naturally in soils
- Atmospheric nitrogen is held by strong bonds and is useless for plants needs. It must be "fixed" with oxygen or hydrogen to produce ammonium, nitrate or nitrite
- Certain bacteria fix nitrogen including Azotobacter & Rhizobia
- Nitrifying bacteria convert ammonium (waste product generated by protozoa and nematodes) into nitrites and nitrates (a form of nitrogen plants can uptake and use)
- Denitrifying bacteria convert nitrate and nitrites back into gas.

# Nitrogen Cycle



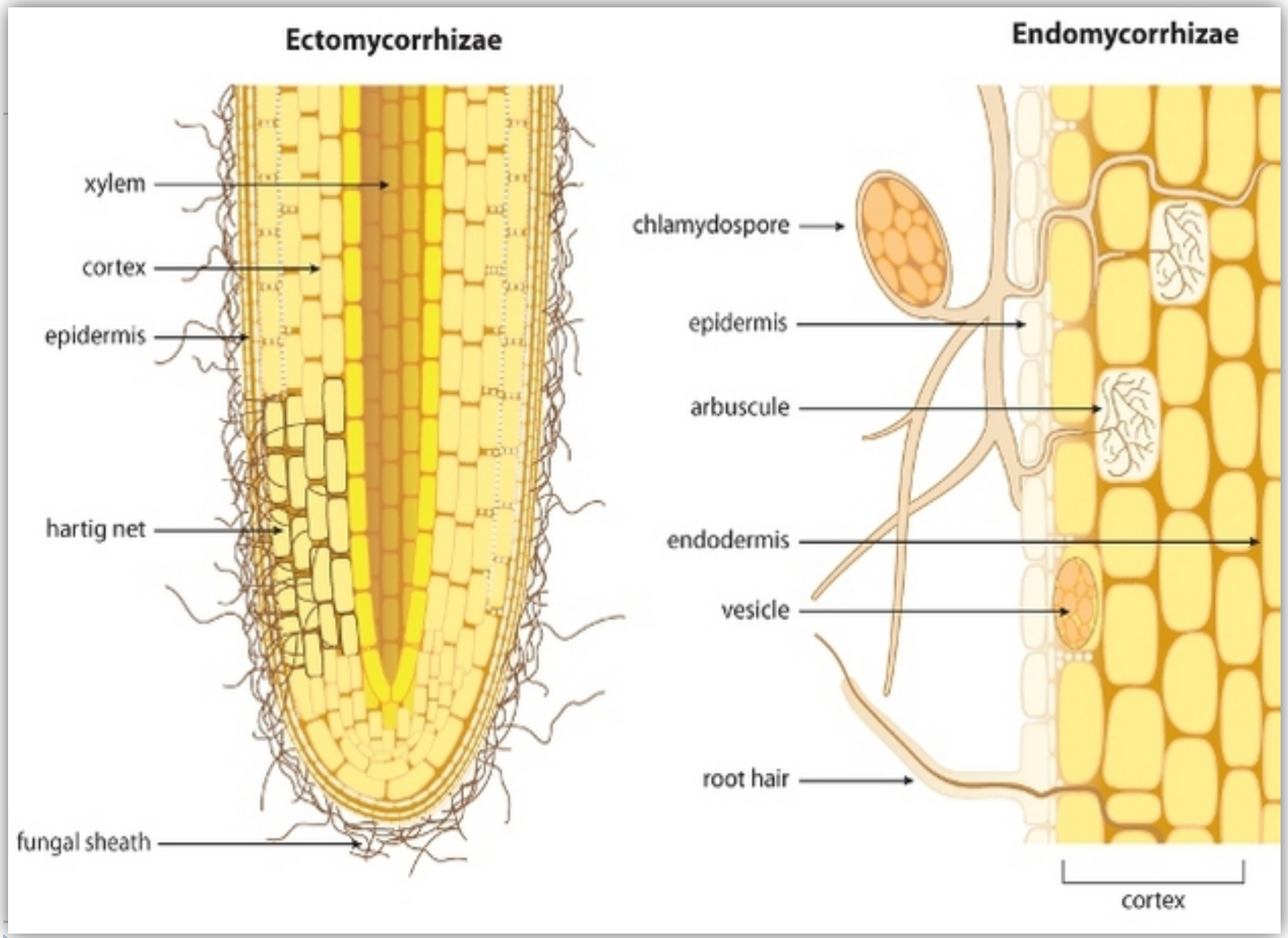
# FUNGI

# Fungi

- Primary decomposers and digesters
- Bring nutrients from decay on surface down into the soil
- Release nutrients, including nitrogen at their death
- Hyphae leave a network of soil pores
- Transport water and nutrients up to a mile
- Gather and make phoshorous available to plants
- Protect plants from predators
- Influence soil acidity and create conditions for mature forests

# Mycorrhizae

- Mutual relationships between plants and mushrooms
- Normally present in healthy soil
- Increase reach and surface area of the roots up to 1000 times
- "Infect" a root to obtain a continuous supply of carbohydrate
- Able to decompose chemicals that bind to organic matter and clay and make these bio-available to plants
- Absorb nitrogen, phosphorous, copper, potassium calcium, magnesium, zinc and iron and transport to exchange sites inside the roots.
- 17% of a plants photosynthetically derived carbon is used to feed a fungal network that provided 60-85% of the plants nitrogen.
- Mycorrhizae make phosphorous available to the plant. Without the fungi you can add as much phosphorous as you like, but the plant cannot use it.


Ectomycorrhizae
xylem
cortex
epidermis
hartig net
fungal sheath
Endomycorrhizae
chlamydospore
epidermis
arbuscule
endodermis
vesicle
root hair
cortex

# Endomycorrhizae

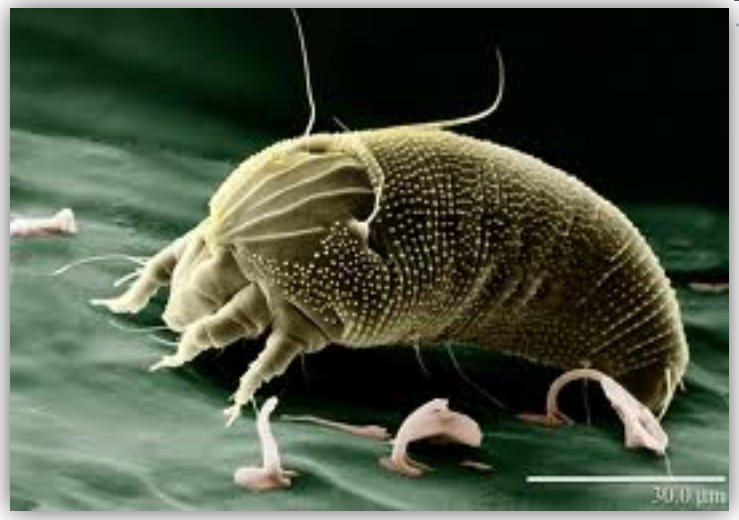
- Enter the roots and grow both inside & out
- 150 known species associate  with over 200,000 plants.
- They can only exists in association with their host plants, otherwise they die.

# Ectomycorrhizae

- Attach to roots forming a sheath or mantle
- More than 4000 species identified
- Have visable fruiting bodies including  Ascomycetes (underground fruiting bodies like truffles)  and Basidiomycetes (above ground fruiting bodies like boletes, morels, puffballs, inkcaps and agarics)
- Form associations with hardwood trees and conifers including beeches, oaks, pines, filberts and walnuts
- Approx 10% of plants associate with EM fungi


Most plants do not perform as well without mycorrhizal associations.
Some cannot perform at all if the fungi is not present.

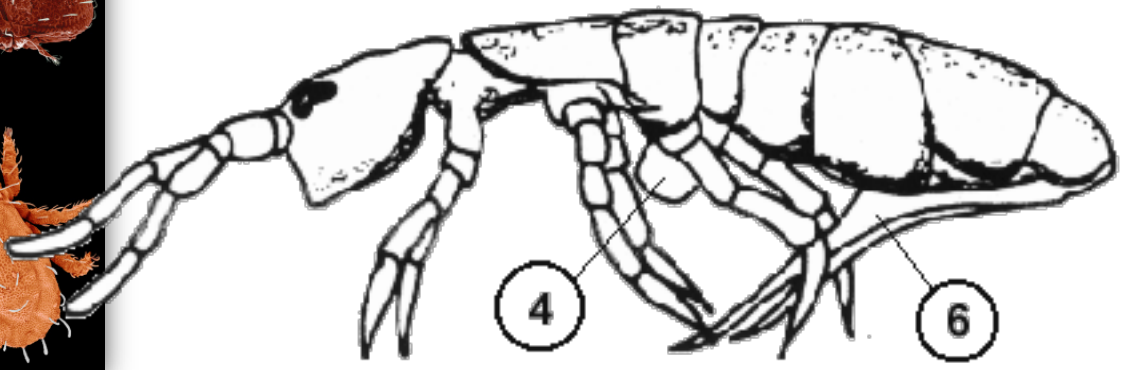
# Arthropods




# Arthropods in the Soil Food Web

- Shredders, predators, prey, aerators
- Several micro-arthropods play dominant roles in the soil food web, as important producers of humus

Mites and springtails are major recyclers and decomposers. 15,000 species of mites live in the soil and as many as 400,000 can live in a square yard of soil.



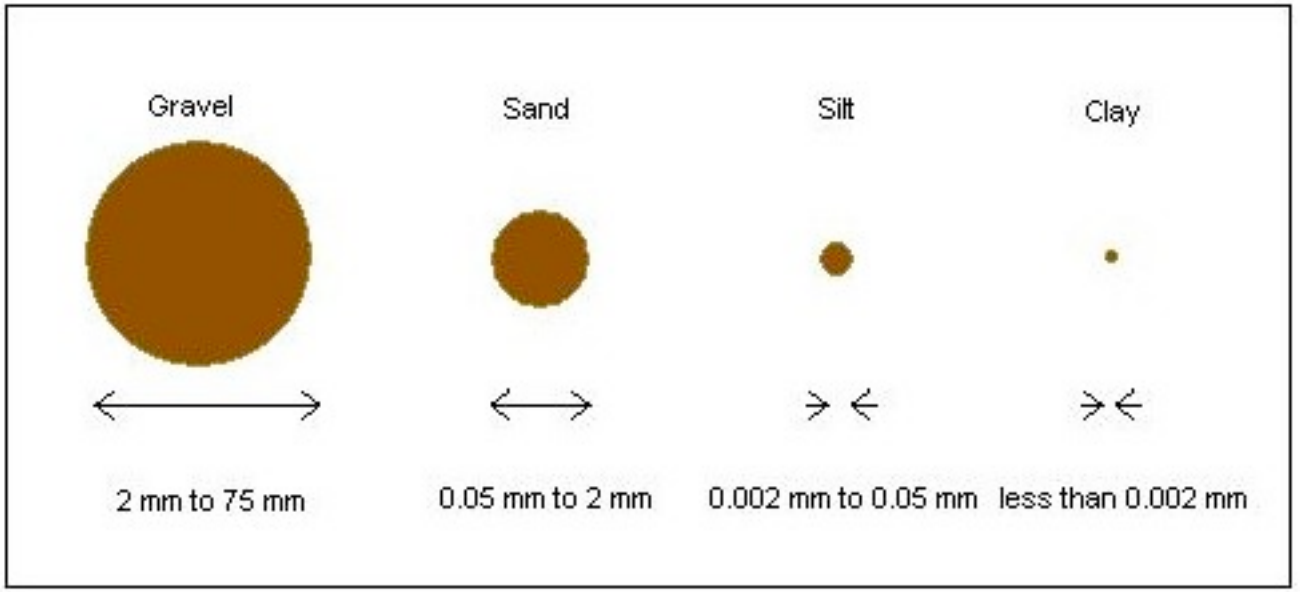
# Earthworms

An acre of good agricultural soil can have  2-3 million earthworms

# Earthworms

- Master shredders,  Eat at surface and bring nutrients deep into the soil.
- Master aerators . Can travel through compacted soil. Different types of burrows, surface dwellers, deep dwellers
- Vermicastings
  - Higher in organic matter than soil
  - Have 7x the available phosphate, 10x the available postassium, 5x the available nitrogen,  3x the available magnesium and 1.5x the calcium
  - Worms can deposit 10-15 tons of castings per acre annually

# Soil Texture

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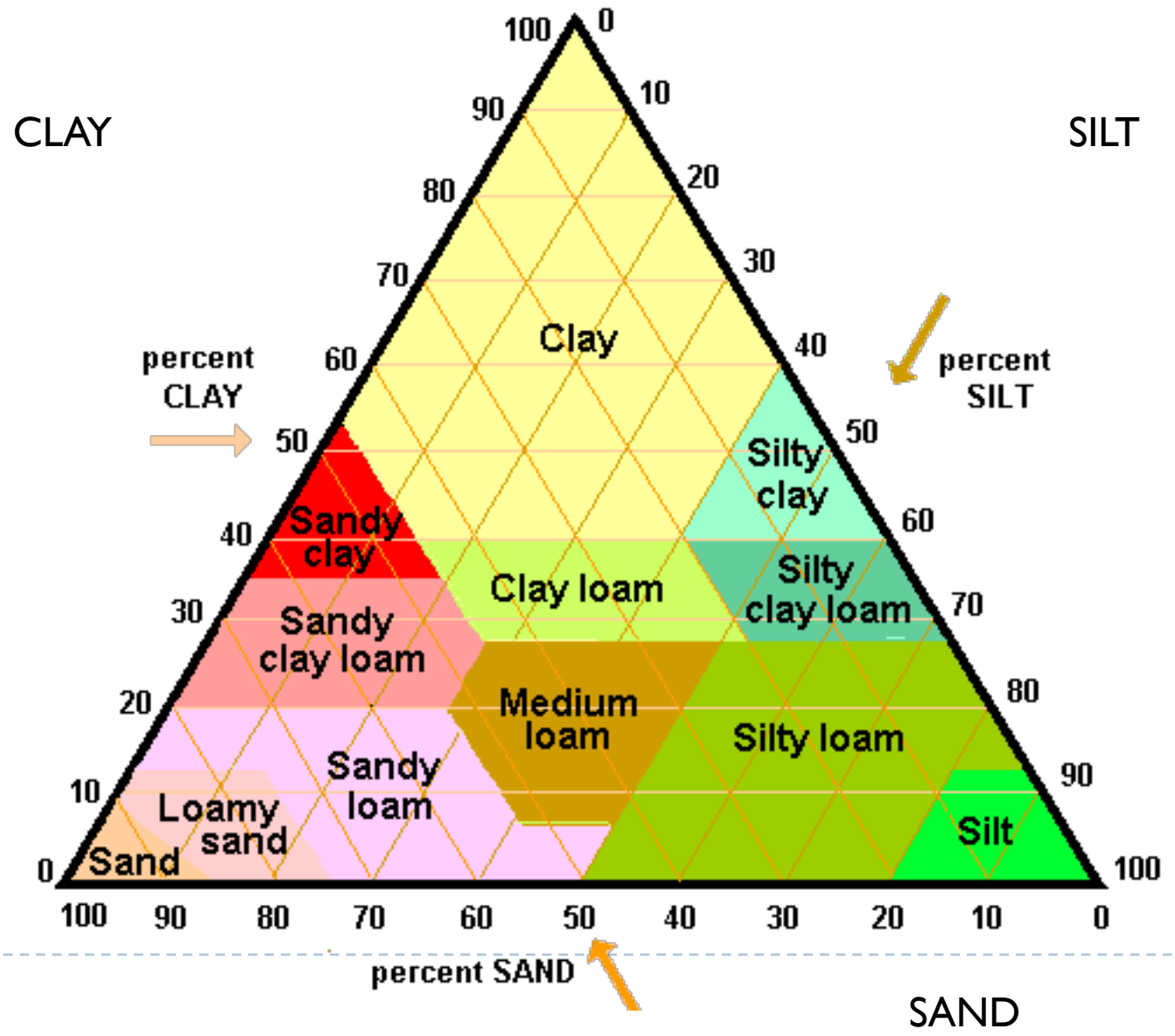
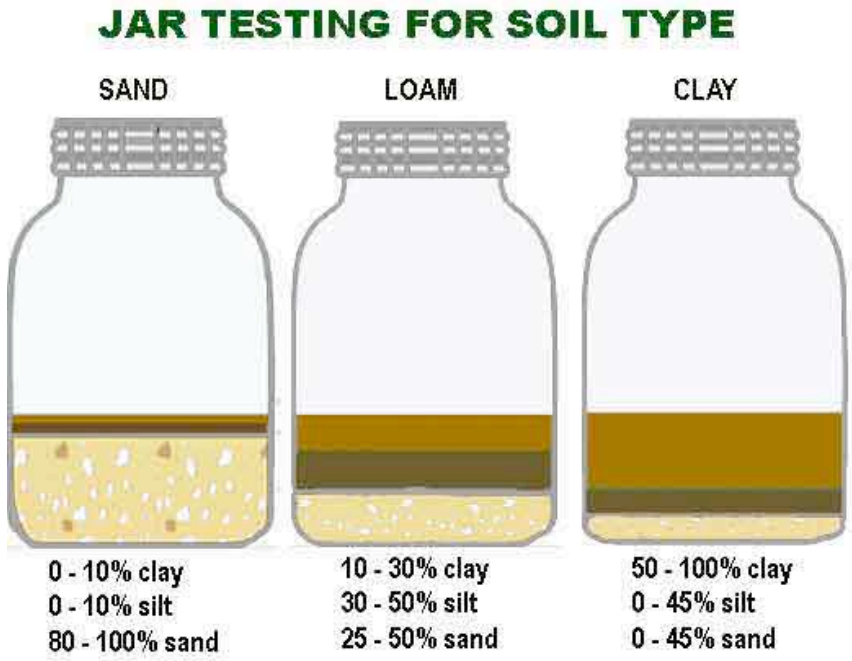


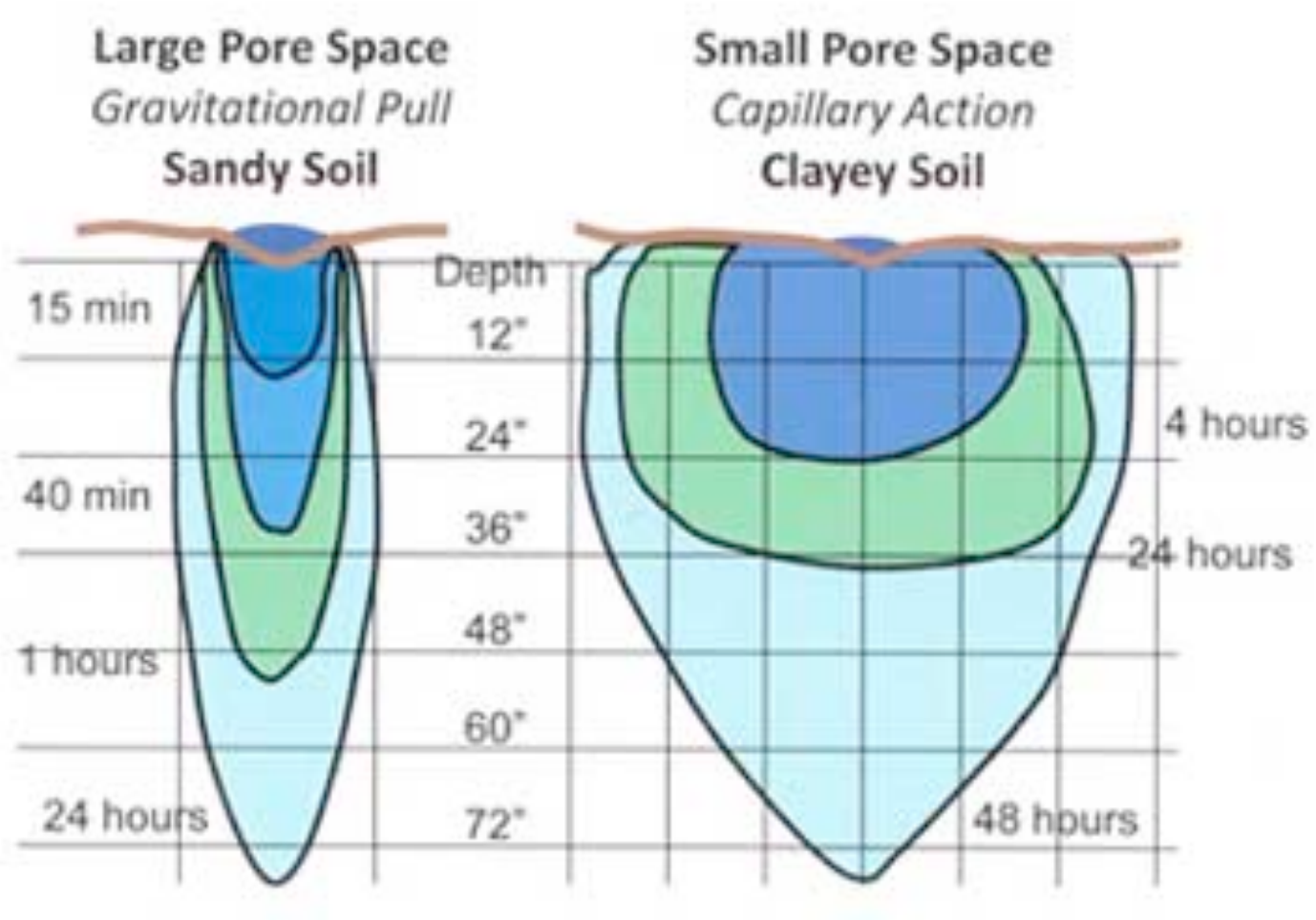
# What Kinda Dirt You Got? Easy Soil Texture Tests

SQUEEZE TEST
Clay will hold together.
Sand will fall apart
Loam will hold together, but crumble easily

JAR TEST
Fill your jar half with dirt, half with water. Shake and let sit overnight



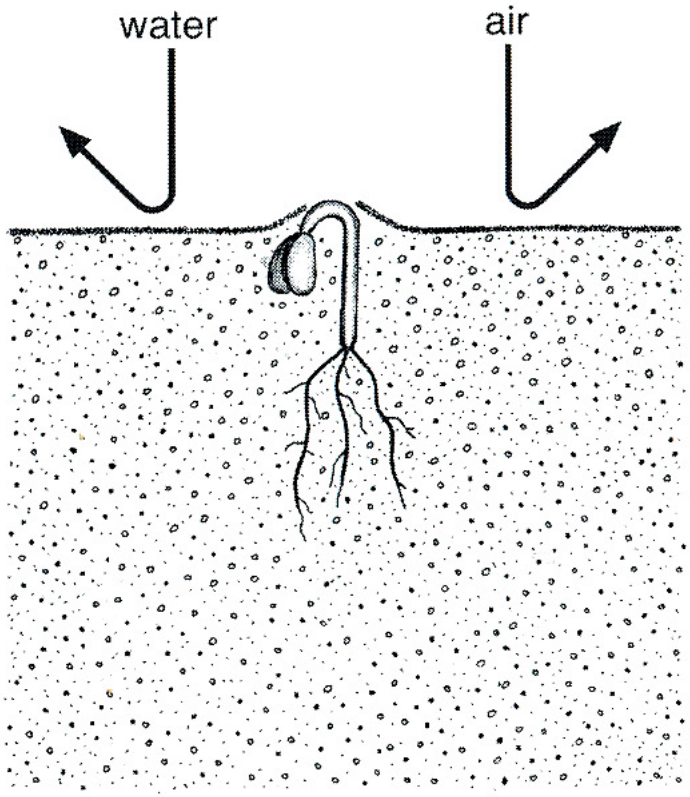
# Soil Texture: Benefits and Drawbacks



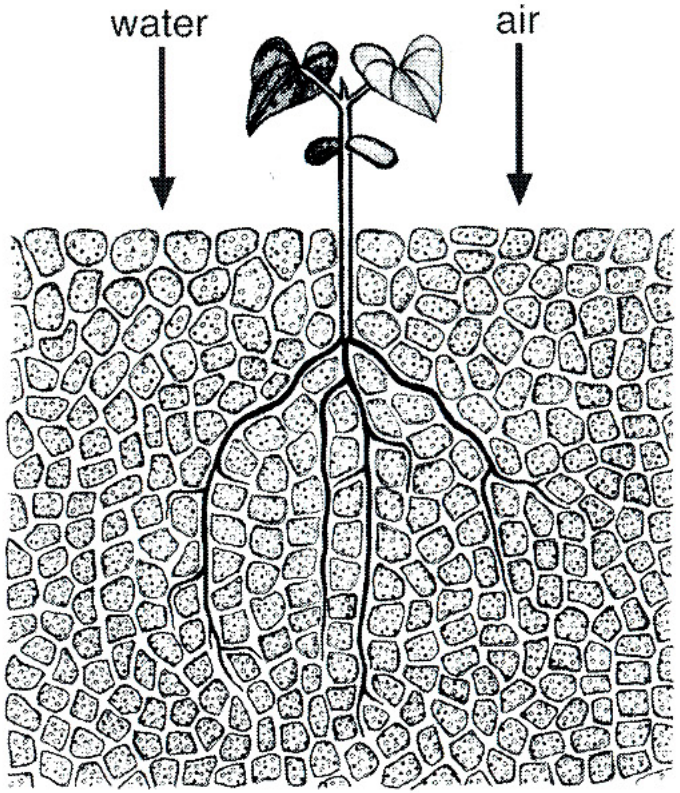
# What about lead and other toxins?

# Soil Structure

- Soil structure is  the shape that the soil particles take when grouped together. When we look soil we are always looking at aggregates, not individual particles. Good soil structure will have good drainage,good water retention and good nutrient retention.
- Soil structure is created by soil life.  Bacteria and fungi increase soil aggregation, influence soil ph, increase nutrients and increase cation exchange.
- Without soil structure plants cannot grow.
- You cannot change your soil texture, but you can change your soil structure.  Whether you have clay or sand, the process will be the same.




Poor soil structure
with dispersed
soil particles




Good soil structure
with well-aggregated
soil particles

Good soil structure can withstand torrential rain, drought, deep freeze and animal traffic. Poor soil structure results in lack of water retention and soil can collapse and wash away, even under normal conditions

# Soil Structure is created by soil life. Increase the amount of life in your soil and nature will do the rest.

A forest floor needs no tilling, fertilizer or pesticide.

Soil life will aggregate and aerate, provide water & nutrient retention, promote good drainage and disease resistance.

When in doubt, just add compost

# Soil Food Web & Disease Resistance

- Good bacteria in the rhizosphere outcompete pathenogenic bacteria
- Mycorrhizal fungi encase and protect plant roots
- Special fungi attract and then strangle plant destroying neomtodes
- Bacteria and fungi colonize plant leaves outcompeting pathogens
- Healthy plants in natural mychorrhizal associations with strong root systems and plenty of bacterial nutrition have stronger immune systems and are better able to fight disease.

## Annuals, Vegetables & Grasses

- Prefer bacterially dominated soils
- Prefers a pH around 7
- This will naturally occur in well amended *tilled* soil, as tilling inhibits fungal dominance

## Perennials & Trees

- Prefer fungally dominated soils
- pH below 7, which is created by fungal dominance

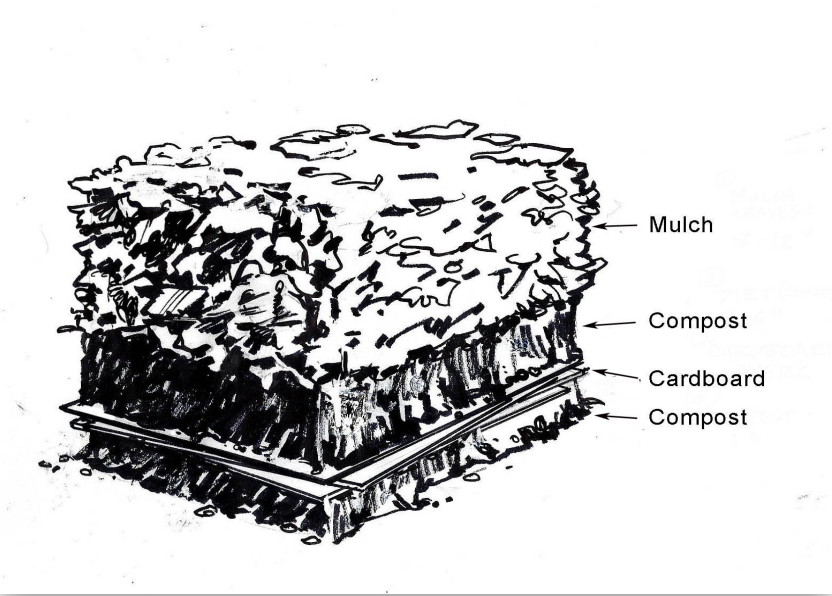
# Tools for Restoration

- TRUST nature to find balance. The forest does not need fertilizers, pesticides, amendments or tilling.
- UNDERSTAND and work with natural phenomenon to bring things back into balance
- STOP using pesticides and chemical fertilizers which disrupt or destroy the soil food web.
- INNOCULATE your soil with bacteria and fungi to feed and energize the soil food web

# Tools for Restoration

- Sheet Mulch
- Compost and/or Manure (import, make your own)
  - Hot compost, cold compost, worm bins
- Double Digging
- Green Manure/ Cover Cropping
- Crop rotation
- Fertilizers
- Compost Tea
- Biochar

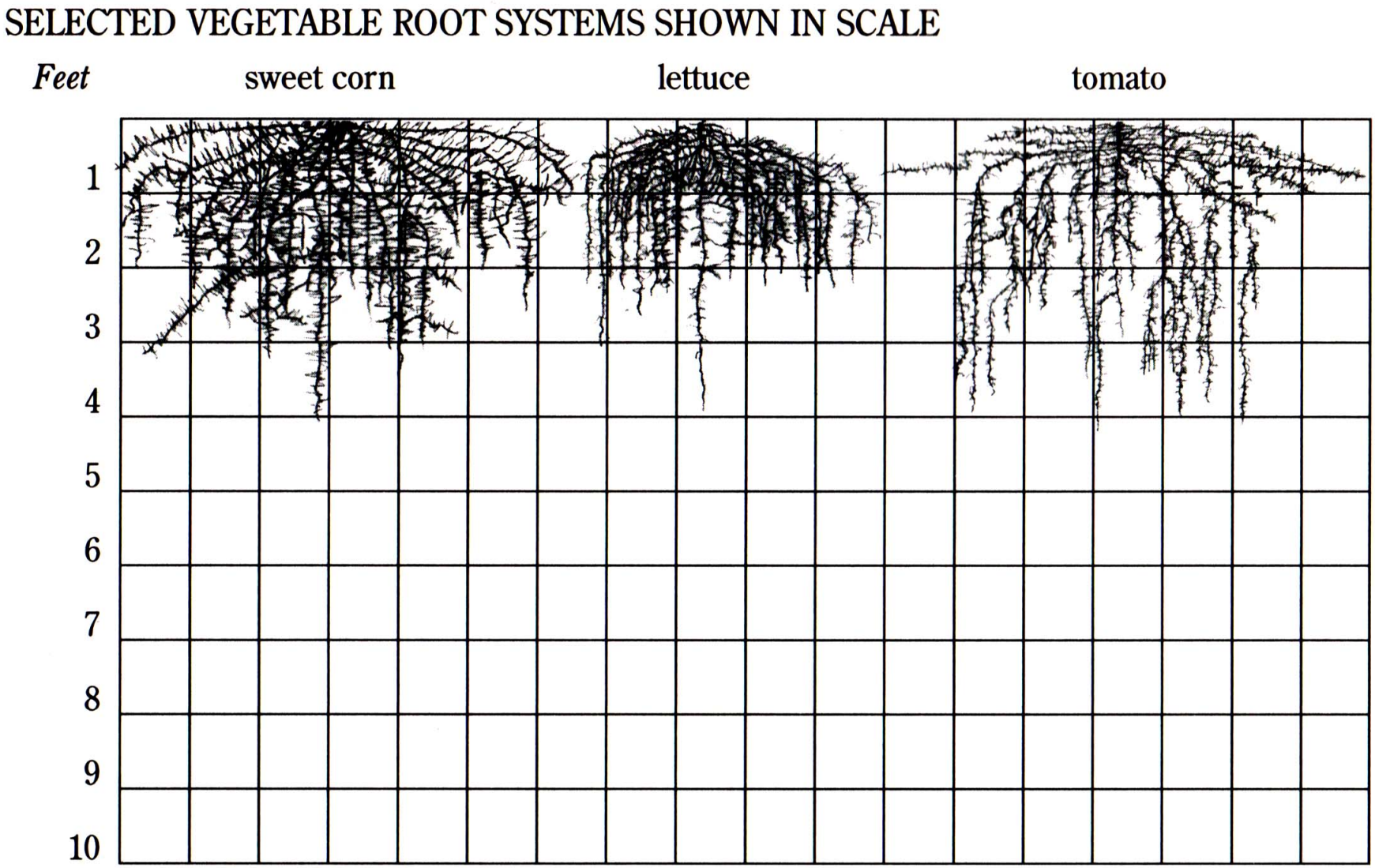
# Sheet Mulch

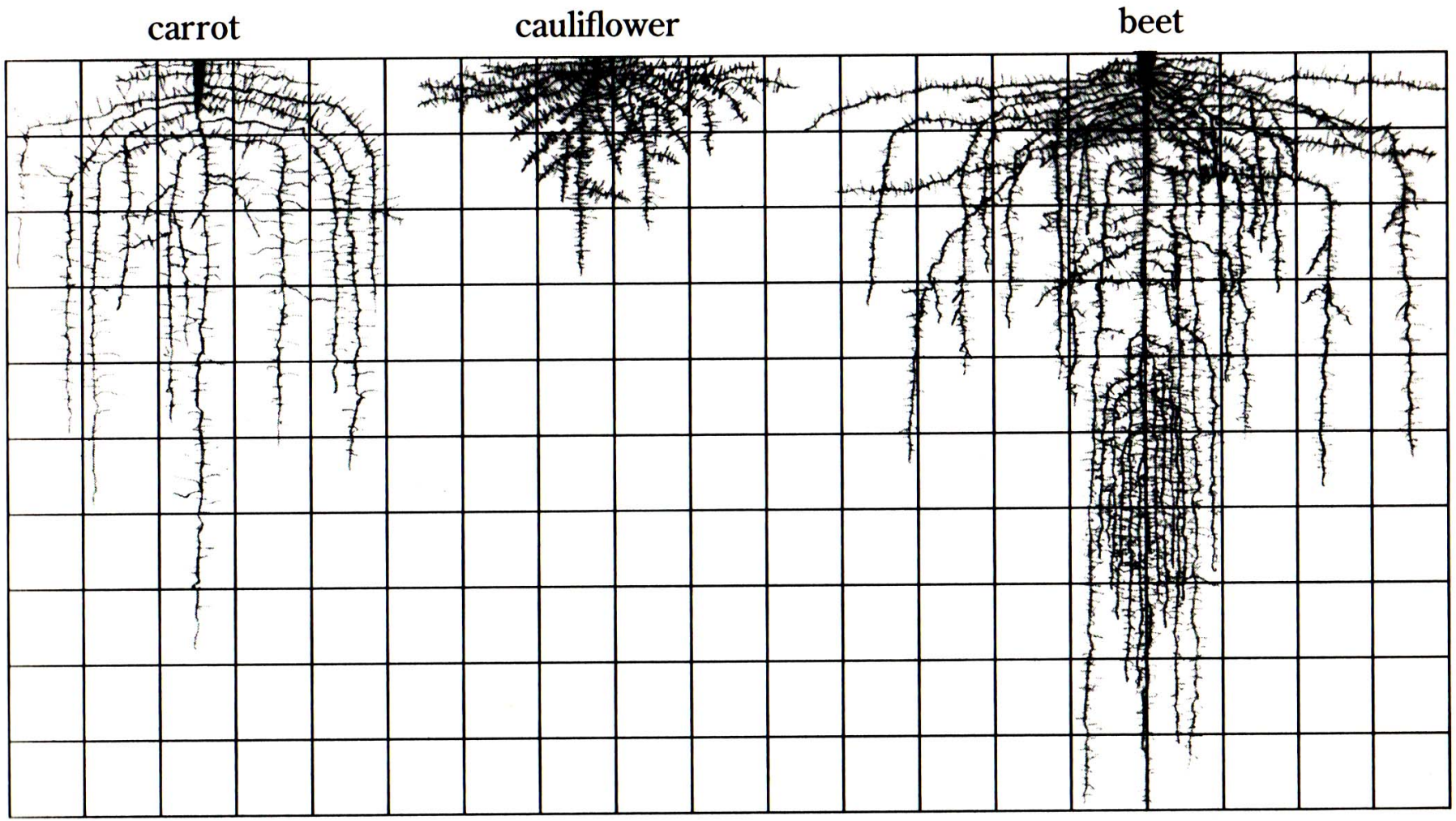



- Super charge the soil
- Let nature do the work
- 2-3 layers of cardboard
- 2-4 inches of compost
- 8-12 inches of mulch
- Let rest through one rainy season
- Turn under
- Add compost tea to innoculate
- (after 1st rains)


FRAGILE
FRAGILE
FRAGILE

Deep Bed preparation opens up the soil to allow for intensive planting




carrot
cauliflower
beet

# Double Digging aka Deep Bed Preparation

**SPREADING MANURE**
Before you start to dig, lay a good covering of manure all over the top of the bed.

**DIGGING THE FIRST TRENCH**
Starting at one end of the bed, dig a trench a spit deep. Put the soil in a wheelbarrow.

**LOOSENING THE SUBSOIL**
Dig your fork deep into the trench and wiggle it around as you loosen the subsoil.

**DOUBLE-DIGGING THE DEEP BED**
Dig a second trench next to the first one, throwing the topsoil and manure into the first trench. Work the subsoil in the bottom of the second trench. Dig a third trench and repeat the process.

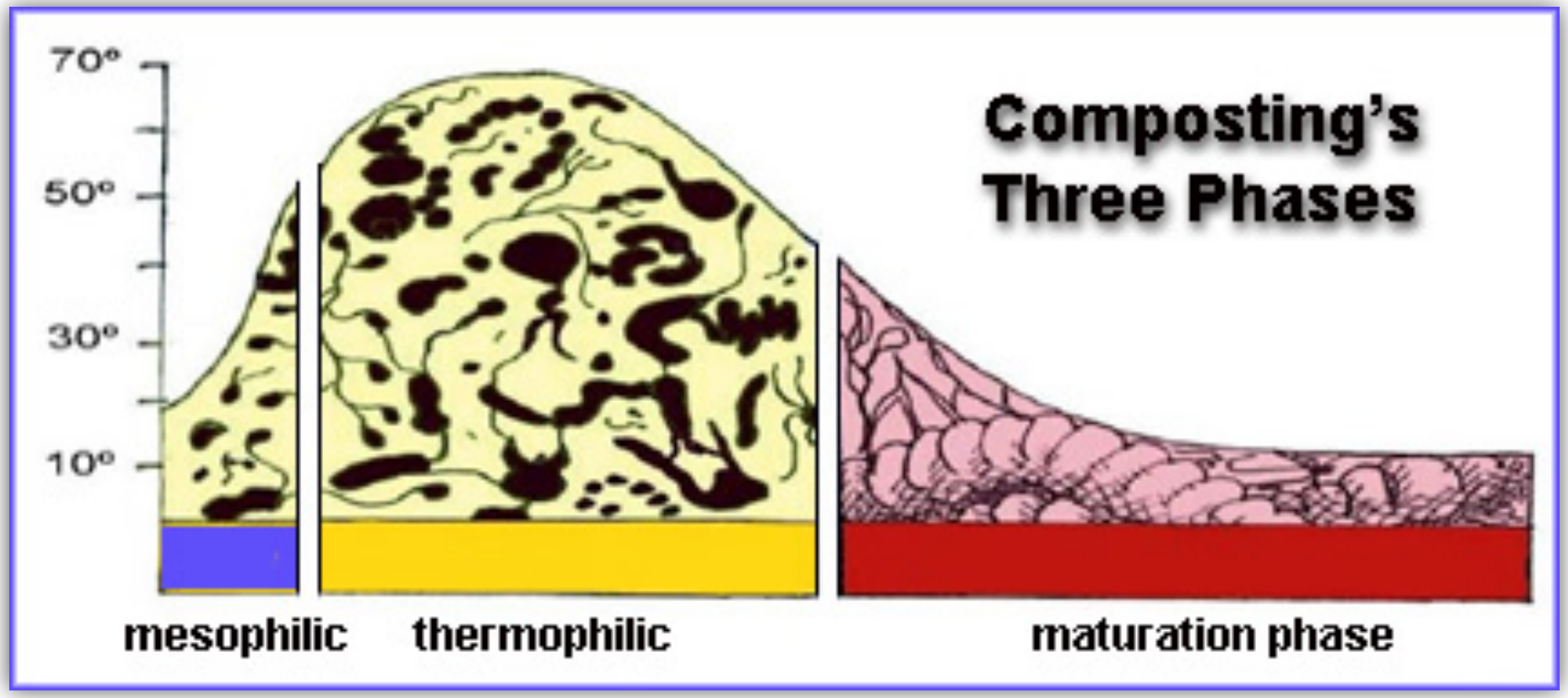
**MAKING THE PATH**
As you dig, throw all pebbles and stones to the side of the bed. When you finish, throw the topsoil from the path-to-be back on top of the bed. Spread the stones evenly over the surface of the path.

# COMPOST

- Finished compost not only adds nutrients, it innoculates the soil food web, having 3 to 12 times more micro-organisms than soil.
- Requires heat, water, air and organic materials in the proper ratio of carbon & nitrogen
- Moisture is necessary for the microbes to move around
- Air is required for the aerobic bacteria to work
- Heat comes from the metabolic activity of microorganisms
- Carbon fuels the microbes metabolism
- Nitrogen is the raw material for proteins, amino acids and enzymes critical for the decay process
- Humans need carbon and nitrogen in almost the same ration for optimal health!

# Hot Compost has 3 stages

- Mesophilic 68°-104°
  - Lactobacilli, heliospirillum
  - Cellulose, glucose
- Thermophilic 103°-150°
  - Mesophilic bacteria go dormant
  - Carbohydrates and proteins broken down
  - Heat kills seeds and pathogens
- Maturation 104°-131°
  - Mesophiles come out of dormancy
  - Fungi and actinomycetes decompose lignin
  - Macro-life is active




Mesophlic & Thermophilic stages should complete within 72 hours
Maturation phase takes 3-4 months, turn every 2-3 weeks to speed process

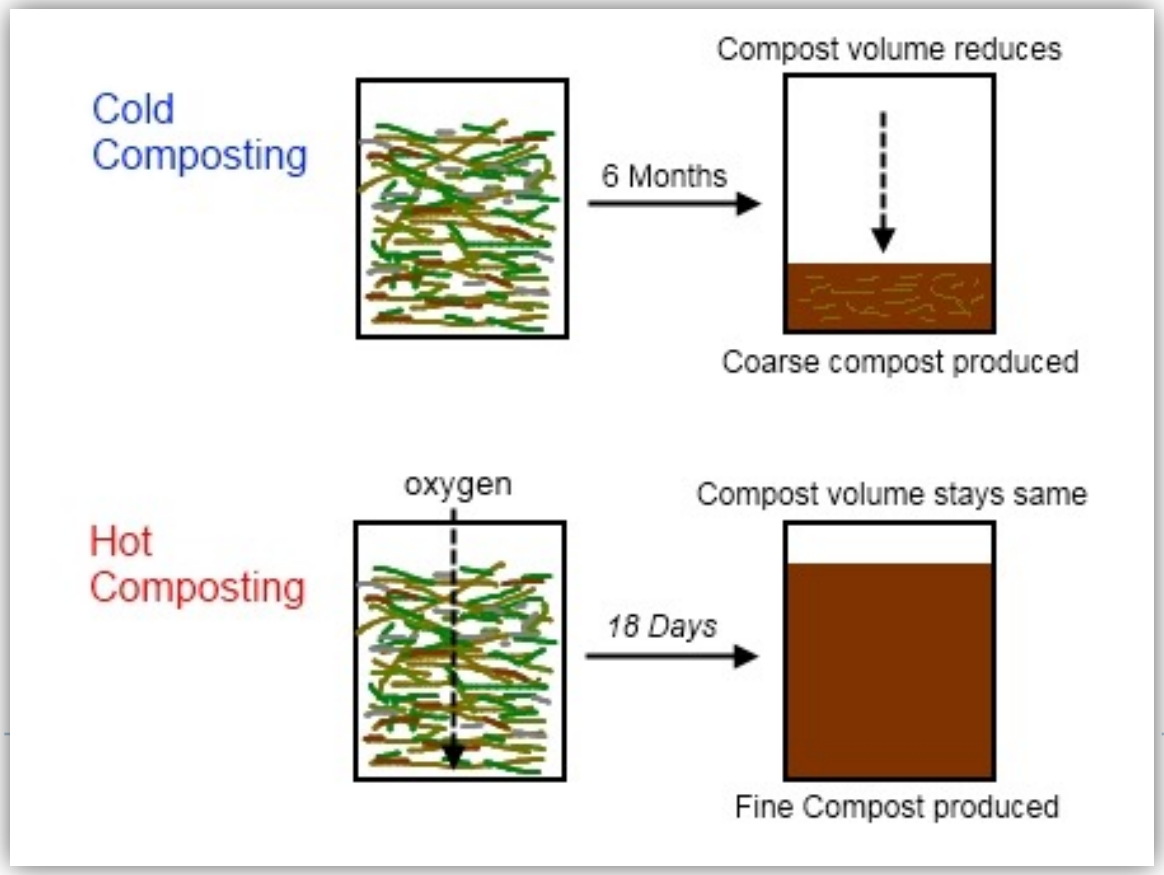
# C:N ratio

- Ideal is 25:1 or 30:1
- Brown material supports fungi, green material supports bacteria, adjust ratio for
- 2 parts brown to 1 pt green usually works
- Size of material is important, chopped, but not pulverized
- Grass clipping + brown leaves, 2:1 is ideal
- Size of pile is important

| GREEN (Nitrogen) | | BROWN (Carbon) | |
|---|---|---|---|
| Kitchen waste | 25:1 | Shredded newspaper | 175:1 |
| Coffee grounds | 25:1 | Twigs | 700:1 |
| Grass clippings | 17:1 | Shredded cardboard | 350:1 |
| Fresh Weeds | 20:1 | Leaves | 60:1 |
| Fruit waste | 25-40:1 | Pine needles | 60-110:1 |

# Lazy Composting

- Additive piles can work, but they don't always get hot
- Given enough time, all organic matter will decompose

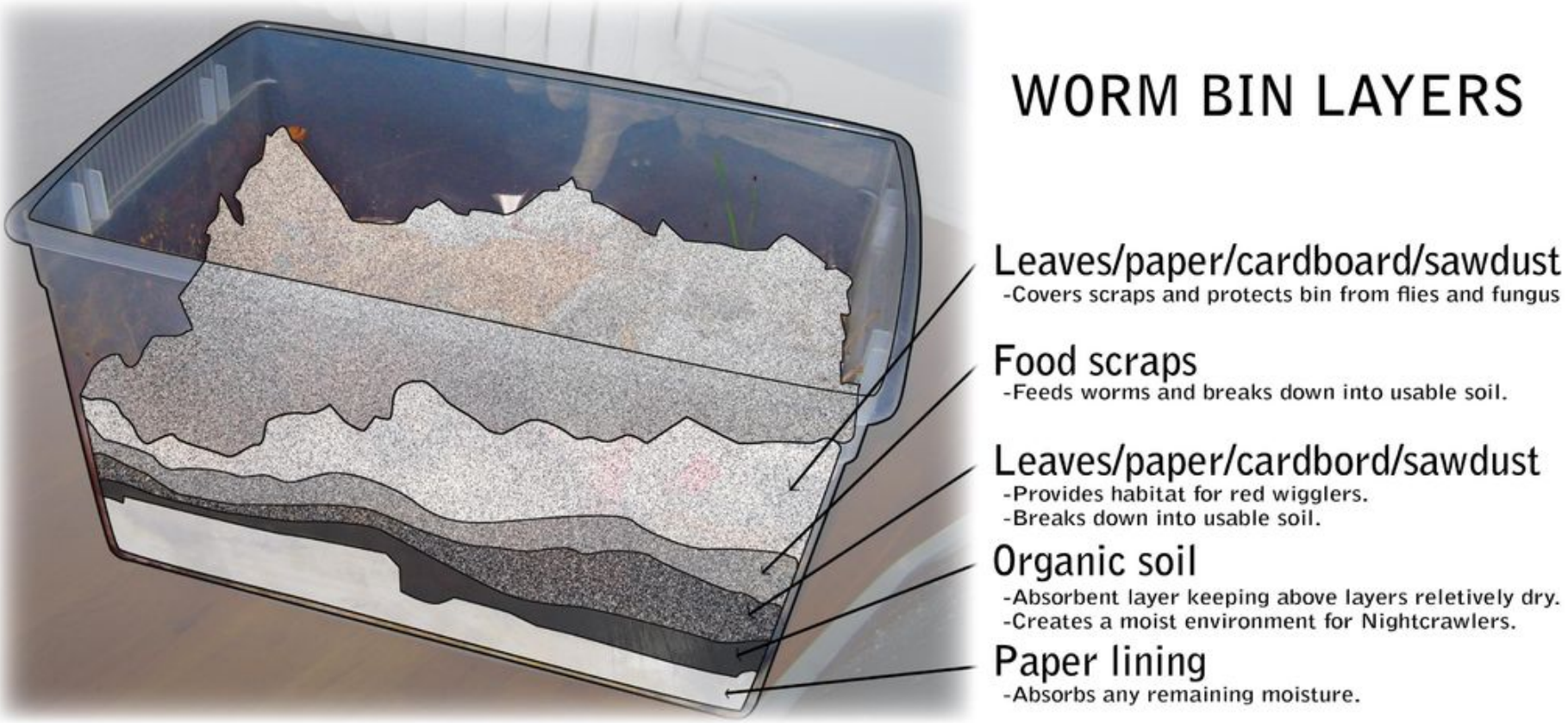


# Composting Concerns

- Things you can and cannot add
- Pathogens
- Heavy metals
- Cat, dog & human manures
- Vermin (rats & mice)
- Compost mixes and starters
- How to "fix" a stuck pile
  - Add air by turning
  - Add water
  - Add more green material

# Worm Composting

- Bacterially dominated, no heat
- Low maintenance, high yield
- Some work to harvest



# Applying Compost

- For food web innoculation you don't need much, 1" on soil surface partially dug in
- For soil aeration & restoration and for tilled soil 1 wheel barrel per 4 x 4 bed is recommended
- For perennial beds, top dressing is recommended

# Cover Cropping: Green Manures

- Winter Cover crops include legumes such as fava bean, clover and vetch as well as grasses like winter rye
- Summer cover crops include buckwheat
- Cover crops can be cut and allowed to rest on the surface of the soil as a mulch or dug  in (as part of a double digging regime for example) where they feed the plants as they decompose at root level
- For best nitrogen accumulation, cut legumes before they flower


# Crop Rotation

Soil Builder, Heavy Feeder, Light Feeder, Soil Builder
Or
Soil Builder, Light Feeder, Heavy Feeder, Soil Builder

| SOIL BUILDERS | HEAVY FEEDERS | LIGHT FEEDERS |
|---|---|---|
| Fava bean | Basil | Carrot |
| Pea | Beet | Leek |
| Soybean | Broccoli | Mustard |
| Snap Bean | Cabbage | Onion |
| | Corn | Parsnip |
| | Cucumber | Pepper |
| | Lettuce | Potato |
| | Squash | Chard |
| | Tomato | Turmip |

# Fertilizers

- NPK
- Nitrogen, Phosphorous & Potassium
- Shoots, Roots, Fruits
- Use a low numbers, organic fertilizer where the ingredients sound like they come from real stuff.
- Do not address soil deficiencies with fertilizer. Compost should cover it for most plants.
- Container plants need more fertilizer
- Fruit trees may need micro nutrients to produce well (nails, eggshells and ash)

# Compost Tea

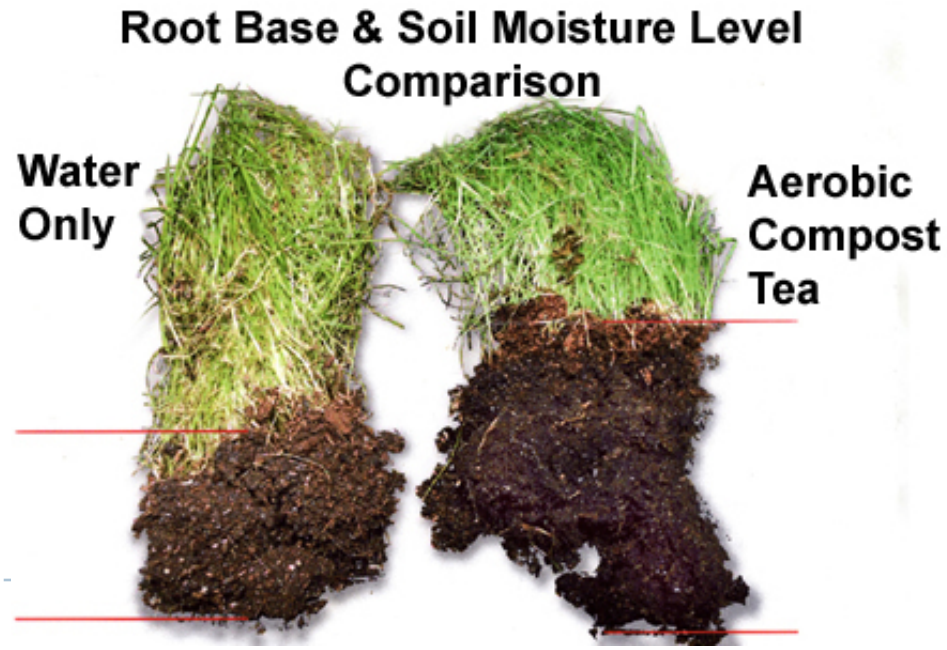
- AKA Actively Aerated Compost Tea (AACT)
- Most efficient way to get soil life to the rhizosphere
- Quick & easy to make—no turning or carting of compost
- Can be used as a soil drench or for foliar feeding
- Different than compost leachate, worm leachate or manure teas (which all have their place)

# Making Compost Tea

- 5 gallon bucket
- 1 gallon finished compost
- 3 gallons pure water
- ½ cup – 2 cups sweetener
- Aerator
- Paint strainer bag (optional)
- Best at room temperature
- Brew 12-36 hours
- Larger batches do not require exact scaling
- For bacterial teas add more sweetener
- For fungal teas, add kelp, fruit pulp or aloe vera or pre-propagate fungi

# Using Compost Tea

- You cannot use too much
- Soil drench in Spring
- Foliar feed at first bud-out
- Foliar feed at 1st sign of disease and repeat every 5-7 days



# BIOCHAR: Long Lasting Soil Amendment

- Terra preta
- Clean Fuel which can replace fossil fuels
- Sequesters carbon back into the earth
- Removes agricultural materials from the waste stream.
- Does everything that compost does, but needs only 1 application
- Enhances cation exchange
- Enjoyed by earthworms
- Porous structure holds air, water and nutrients in the soil
- Provides habitat for micro-organisms
- Reduces the need for chemical fertilizers
- Should be innoculated for best results

Biochar before & after

Biochar gasifier stove

# Tools for Restoration

- COMPOST
  - To restore the soil food web a top dressing of 1" is enough!
- MULCH
  - Use grass clippings and rotted straw to increase bacterial populations on annual vegetable beds
  - Use wood chips and brown leaves to support fungal populations around trees and perennials
  - Sheet mulch for restoration of larger areas
- COMPOST TEA
  - Use as a soil drench to innoculate the soil food web or as a foliar spray for improved disease and pest resistance

# Soil Maturation

## from hard pan clay to no-till gardening in 5 years

Year 1 Fall, Sheet Mulch & Cover Crop
Spring, Double Dig & amend with compost, drench with compost tea
Mulch with aged manure or rotted straw

Year 2-4 Fall/Winter, Cover crop with fava beans & winter rye
Spring, double or single dig with green manure, top dress with compost,
Add innoculated Biochar
Drench with compost tea and mulch with rotted straw

Year 5 + Cover crop with winter rye
Drench with compost tea , plant and mulch with green manure