Sloat Seminar - Healthy Soil

Joan Pont, Avid Gardener
March 18, 2023

The Upside Down Garden

Soil, not dirt, needs to:

Hold plants in place

Welcome water and hold it in the root zone

Welcome air so that root cells can breathe

Welcome all sorts of organisms that provide nutrients & water for plant growth

Food Makers and all Us Eaters

We don’t eat sunlight

Photosynthesis: Plants combine water and carbon dioxide, with power from sunlight, to produce sugar as the initial building block

From there, all sorts of other molecules are formed. Apple/pear/peach each have a unique flavor profiles

Vitamins, carbohydrates, proteins and fats make up our food requirements, and that of all other animals, fungi & bacteria

Fiber for clothing and wood for shelter

And regulate the planet’s weather to boot!!

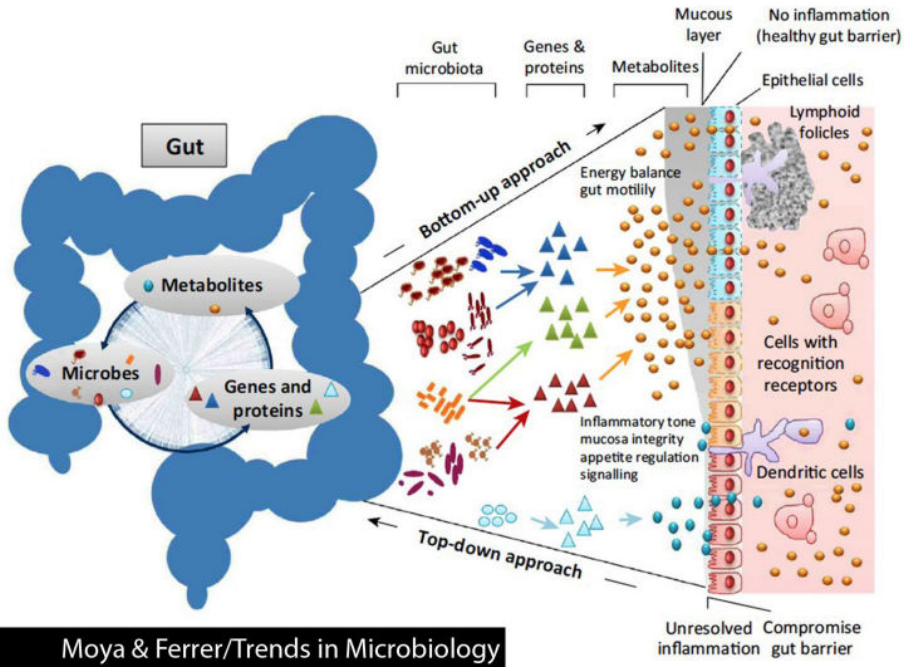
Spoiler Alert

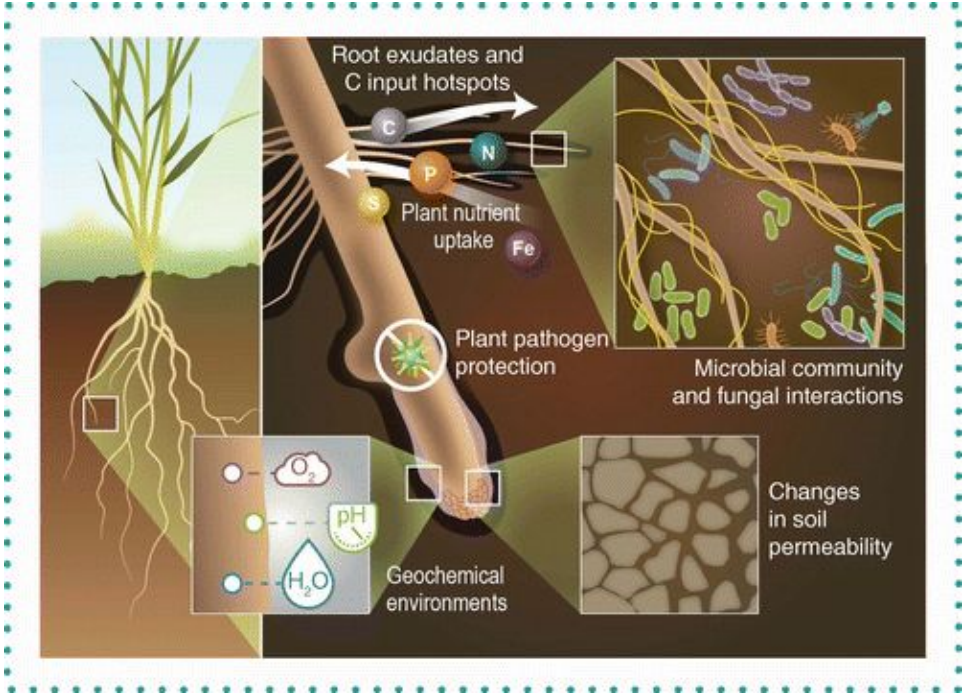
Purchased soil products are just the start. You have to add plants

That is because healthy soil is a living ongoing relationship between plants which provide root exudates into the soil to feed organisms which, in turn, help plants

Consider this a kickstarter, since all of Sloat's E.B. Stone fertilizers contain mycorrhizae

Gut Microbiome vs Plant's Rhizosphere





Gut bugs help us. Root zone bugs help plants. Rhizosphere is the plant's external gut.

An Acre of Soil, 208x208 feet

5000 pounds bacteria & fungi

800 pounds arthropods

300 pounds protozoa including ciliates, flagellates and amoeba

100 pounds of nematodes

Totals 6,200 pounds, equal to the weight of a female African elephant!

What? There is an Elephant in my yard?

Yes, the equivalent of an elephant is in your yard, eating 45% of the plant's products pumped into the soil

Carbohydrates and other chemicals are called root exudates

Not the same as an old leaky pipe, but controlled exudates feed and communicate with the
SOIL FOOD WEB

InnCoCells - collecting root exudates for the very important cosmetics industry

Meet your neighbors

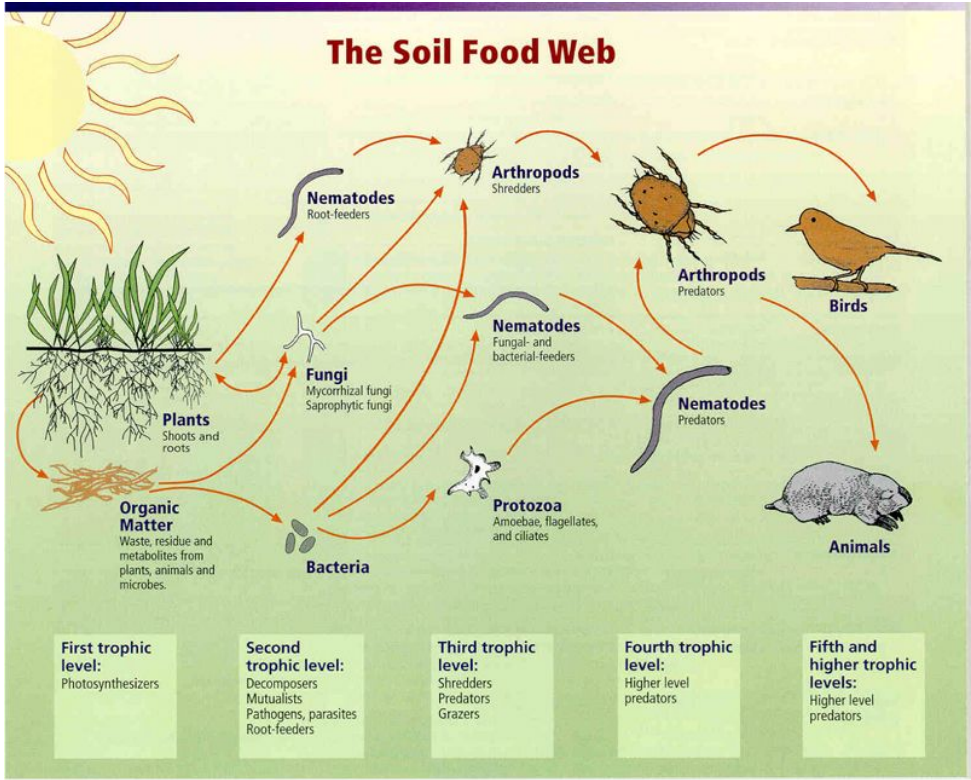
A quarter of a teaspoon of soil contains

3 billion bacteria, 75,000 different species

1 million protozoa

500 nematodes

Miles of fungal hyphae, 25,000 different species



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

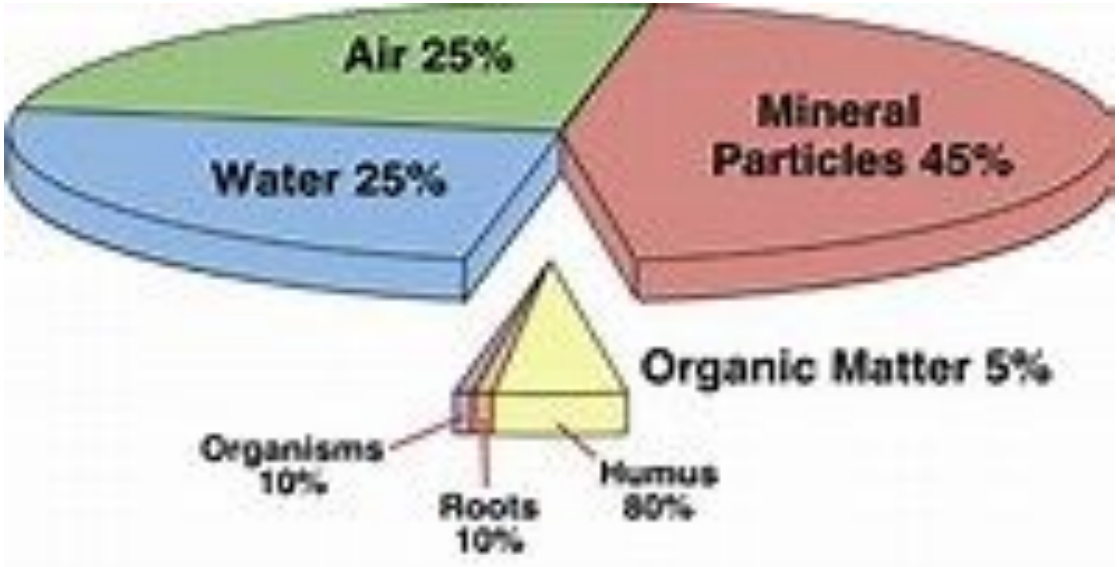
The Ingredients

Ground up rocks %45

Water %25

Air %25

Organic material %5



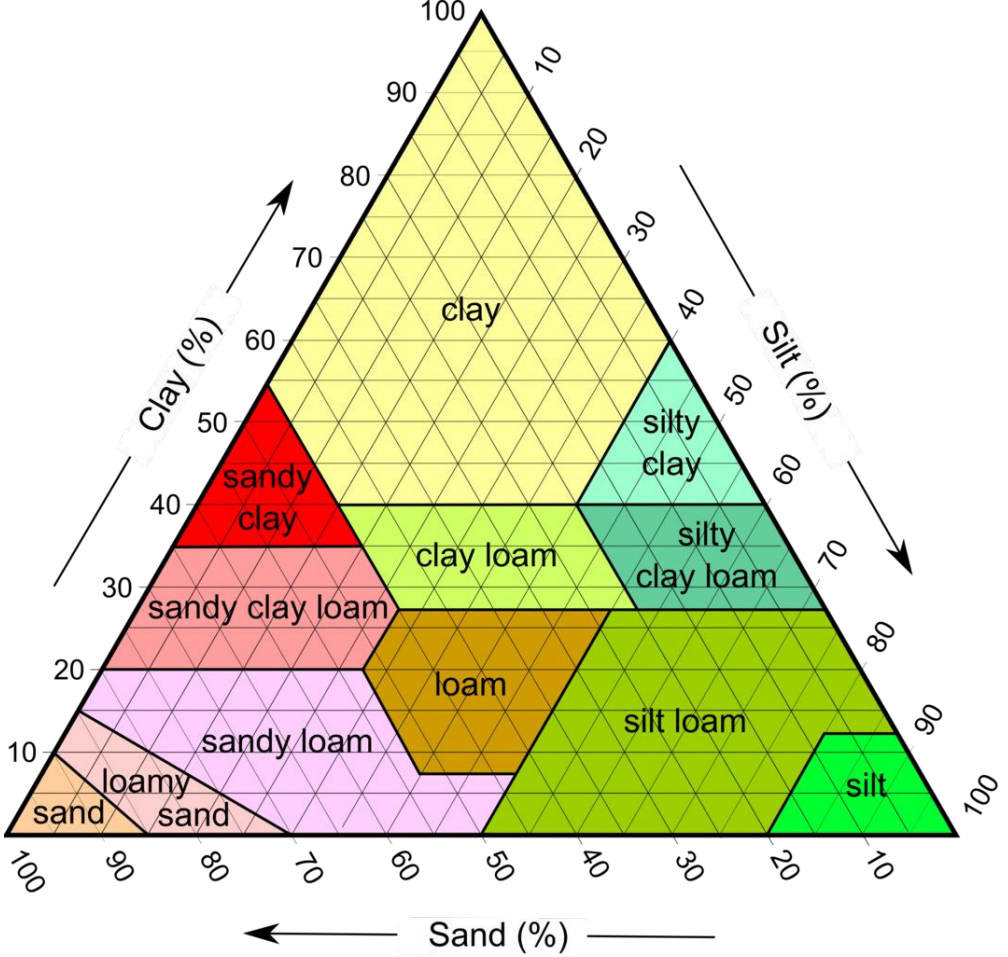
Ground up Rocks

Tiny particles: **clay**

Medium particles: **silt**

Largest particles: **sand**

Combinations: **loam**



Loam is a mixture of all three

Plant Grocery List - The Dead Stuff

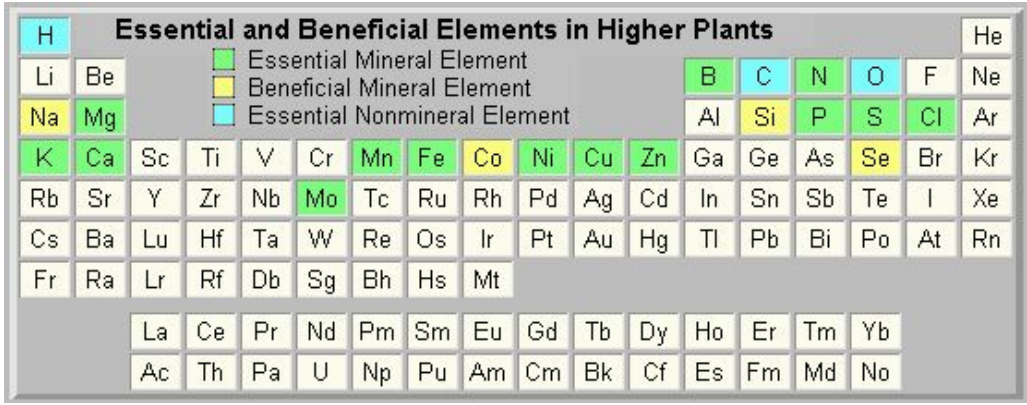
Sunlight (red and blue wavelengths)

Water and carbon dioxide (Hydrogen, Oxygen, Carbon,)

Nitrogen/Phosphorus/Potassium=NPK

Boron, Calcium, Chlorine, Copper, Iron, Magnesium, Manganese, Molybdenum, Nickel, Sulfur, Zinc are essential trace elements

Silicon, sodium, cobalt, and selenium are beneficial elements



Essential elements need to be converted to plant available forms, largely by soil organisms

Now forget all that and Support the Soil Food Web instead

Move to “Regenerative Agriculture”

Essentially copy Nature

No tilling

No synthetic chemical fertilizers

No “cides”

Lots of different cover crops & plants

Support microorganisms in the soil that support plants by creating soil aggregates and fetching water and minerals

2018 Documentary follows the transformation of an abandoned farm

Mycorrhizal Fungi (Spelling challenged, do we really need that extra r &h?)

Myco=fungus

Rhiza=root

Fungal threads extending out from live plant roots

Discovered in 1881 but present in the fossil record for 400 million years

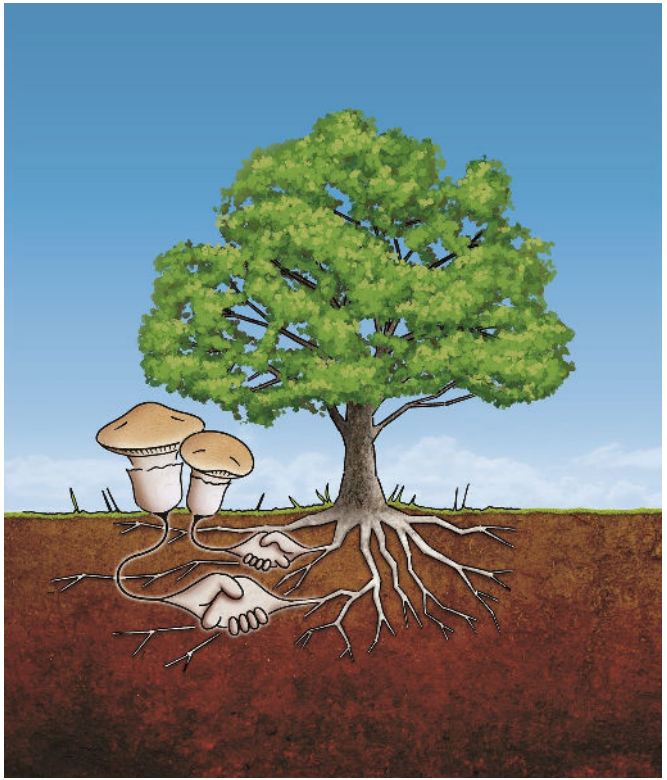
In 1885, Professor A.B. Frank reported that oaks and beeches had fungi attached to their roots, discovered while trying to improve truffle productivity

Giant white truffle auctioned off for a whopping $118,000, 21st World White Truffle Auction, Italy

Good Fungus?

Professor Frank surmised that the tree and fungus were mutually beneficial; the fungus aiding in the absorption of water and nutrients

His publication created great consternation. The thinking was that all fungi were parasites and always bad for the plants



Symbiosis: interaction between two different organisms living in close physical association, typically to the advantage of both.

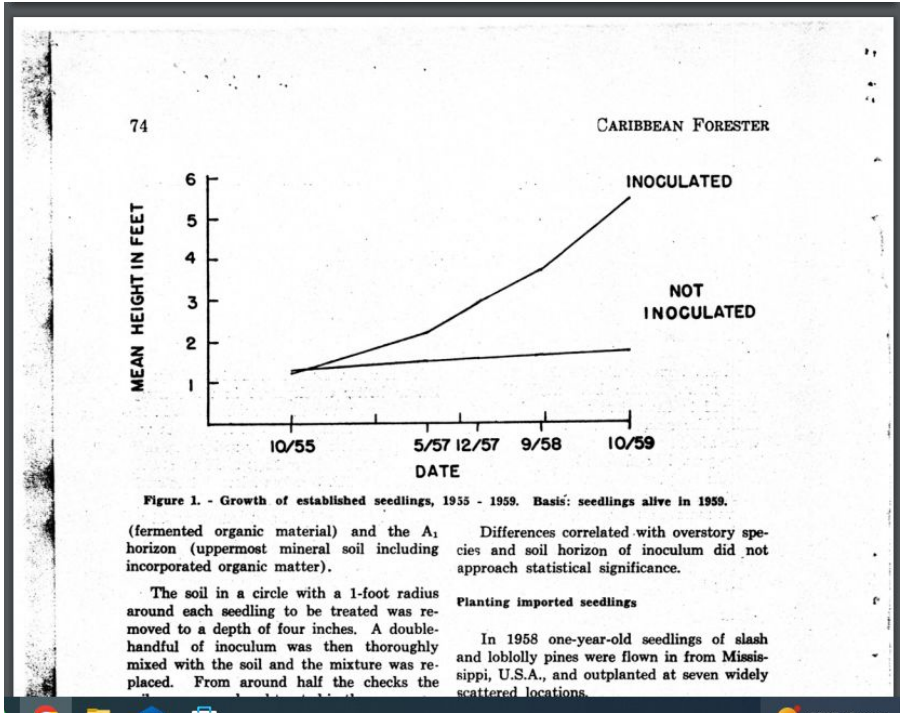
Fast [sic] Forward to 1955, Puerto Rico

This time, pines not truffles

Attemp to grow pines in Puerto Rico resulted in paltry 4” seedlings which usually died

Soil brought from North Carolina was added to 32 plants, with control groups

Wait for this: A year later, the treated trees were **5 FEET tall**, control group largely dead



74 CARIBBEAN FORESTER

Figure 1. - Growth of established seedlings, 1955 - 1959. Basis: seedlings alive in 1959.

(fermented organic material) and the A_1 horizon (uppermost mineral soil including incorporated organic matter).

The soil in a circle with a 1-foot radius around each seedling to be treated was removed to a depth of four inches. A double-handful of inoculum was then thoroughly mixed with the soil and the mixture was replaced. From around half the checks the

Differences correlated with overstory species and soil horizon of inoculum did not approach statistical significance.

Planting imported seedlings

In 1958 one-year-old seedlings of slash and loblolly pines were flown in from Mississippi, U.S.A., and outplanted at seven widely scattered locations.

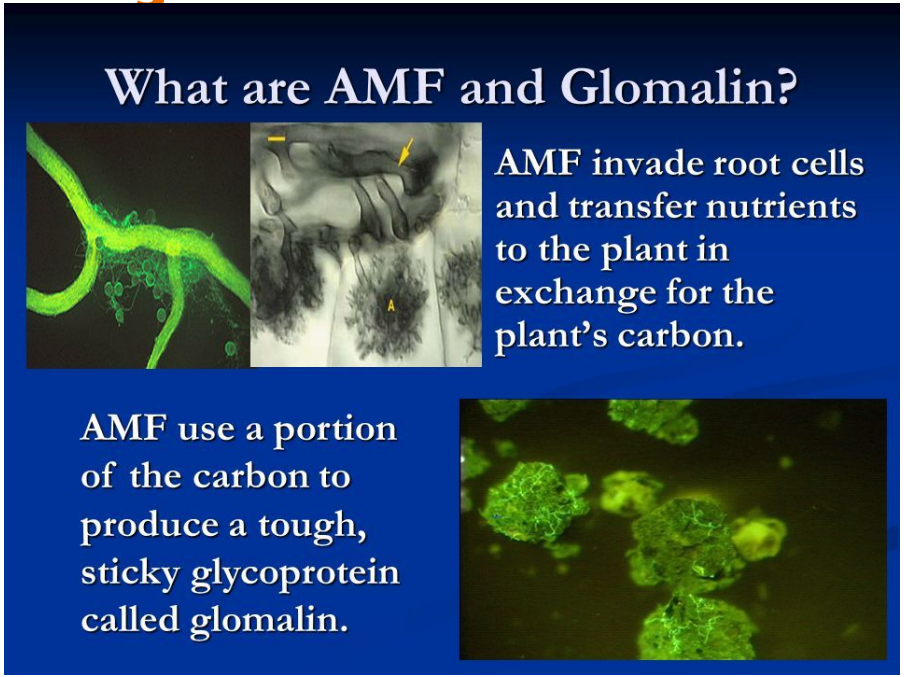
https://www.srs.fs.usda.gov/pubs/ja/1959/ja_1959_briscoe_001.pdf

Mycorrhizae make Glomalin = Fungal Glue

Arbuscular mycorrhizal fungi (AMF) make glomalin to coat hyphae and prevent leakage

Gets sloughed off the hyphae and glues together soil aggregates

Insoluble in water, lasts 50 years, makes up 20% of soil organic carbon (SOC)



Naturally brown, stained green for images, Dr Sherry Darabi

Glomalin Advantages

Protects hyphae from nutrient loss

Glues together and stabilizes aggregates

Aggregated soil has pores to store water, provide air passage, and room for root growth

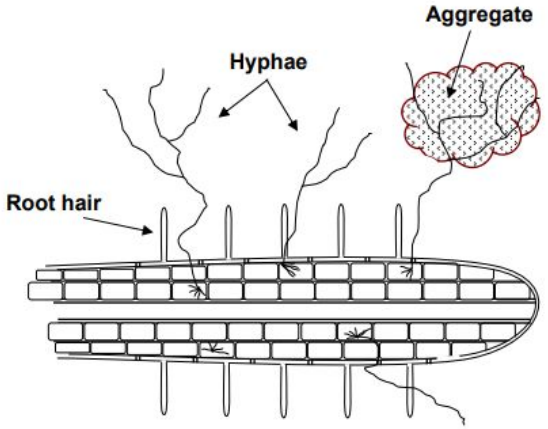


Fig. 1. Hyphae of arbuscular mycorrhizal fungi grow beyond nutrient depleted zones found around roots and root hairs. Hyphae form a frame for soil particles to collect into aggregates which are coated with glomalin.

Kris Nichols USDA-ARS-Northern Great Plains Research Lab

Bacterial Slime - Alternate Glue for Soil Aggregates

Skipped brushing your teeth this morning? Yuck, that slick coating is bacterial slime created overnight

Soil has tons of bacteria which make slime for their defence and mobility

Slime also glues together tiny rock fragments and organic material to create aggregates

Charles Paradis, at Los Alamos National Laboratory, holds a soil core sample. Credit: Lance E. King/Y-12 National Security Complex

Stable Soil Aggregates - Built by the Live Stuff

Glue together clumps of mineral particles and organic matter to create stable soil aggregates for **perfect soil**

Reduces wind and water erosion

Increases water infiltration and retention near roots

Reduces compaction for roots

Sequesters carbon in the soil

Improves nutrient cycling

Habitat for organisms

Stores **plant available** nitrogen

Didi Pershouse: Soil Sponge Demo using Flour vs bread

How do you get stable aggregates?

Tilling rips up hyphal networks

No Till/ No Dig/No fallow periods

No synthetic fertilizers

No “cides” (pesti/herbi/insecticides)

Include many different plants or cover crops to maintain living roots

A smiling Charles Dowding has books, courses and encouragement for no dig gardening

Bumble dating profile for annuals

Many annuals and some other plants do not form relationships with AMF, and use bacterial friends

Imagine the post: looking for short term, no “strings” attached relationship. I am an annual who must germinate, grow, flower, get pollinated (that means sex!), make seeds and split (euphemism for die)

Bumble dating profile for 2,000 year old Redwood

Heck, I’m only middle aged, very tall and a redhead

Looking for LONG TERM relationship that is mutually beneficial. I am a superb provider of sugars and other nutrients. All I ask for in return is for you to fetch me water and leach out minerals from tiny rock fragments

Don’t add Synthetic Fertilizers??? Are you Crazy?

Beyond creating soil aggregates, the “elephant” in your garden delivers NPK and all the other minerals mined from rock fragments

If you add NPK and minerals via synthetic fertilizers, plants stop feeding their friends and you have to continue the synthetic stuff

Sloat sells organic fertilizers

Lupines, once thought stole nutrients, adds nitrogen by harboring nitrogen-fixing bacteria in root nodules

Why do plants need Nitrogen? (We need Nitrogen also)

It’s in all amino acids to build proteins and enzymes and chlorophyll for photosynthesis

It’s in DNA and RNA which directs the building of proteins and provide blueprint for inheritance

It's in hormones and neurotransmitters

All the nitrogen we need comes from plants in our diet, or animals that eat plants

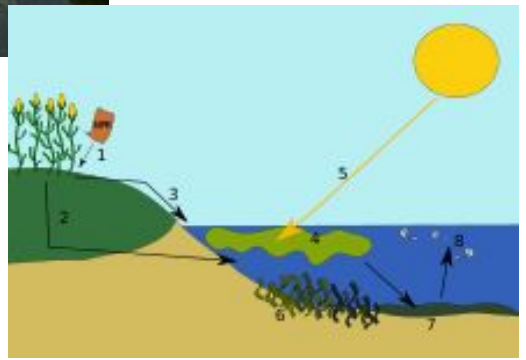
Meats provide all 20 amino acids, vegan options can have high protein also

Why not just add it? Whoops, Eutrophication

Nitrite and Phosphate runoffs create algal bloom

The bloom smothers and kills plant life underneath

The bloom eventually dies, then bacterial decomposers consume oxygen and then fish die too

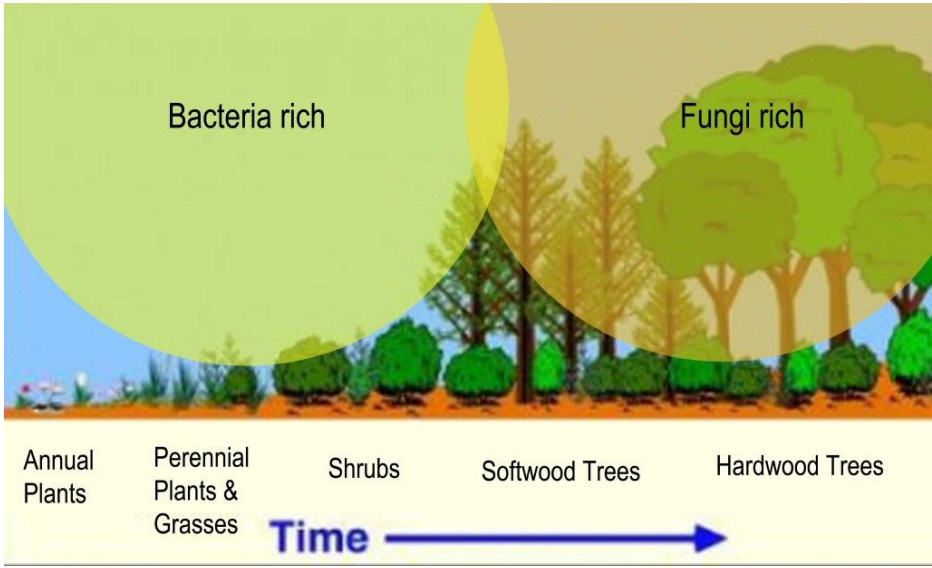


N2 in the atmosphere is useless to plants

The 2 Nitrogen atoms are attached by a triple bond that plants can't break

Bacteria and fungi form ammonium (NH_4^+) and nitrate (NO_3^-) that plants can access

Curiously, the soil organisms comport with the nitrogen form the plants prefer



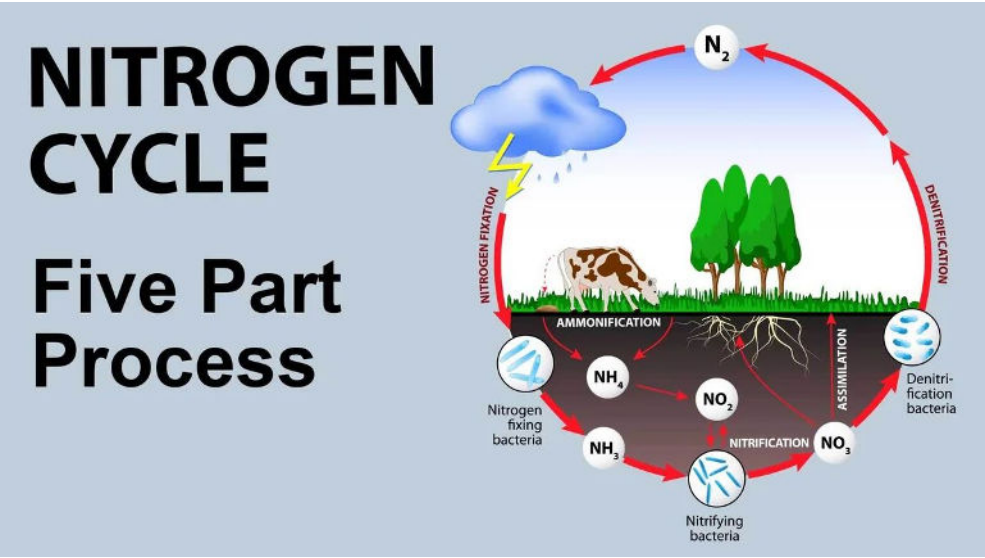
Soil organisms vary along with plant succession after a disturbance, and provide the Nitrogen form they prefer, co-evolution in action!

Multiple Ways Plants get Available Nitrogen

Plucked from the atmosphere by nitrogen-fixing bacteria

Recycled from dead plants, bacteria and animals, or manure and urine

No sheep in your yard? Earthworm casts are earthworm manure



Nitrogen-fixing bacteria convert atmospheric nitrogen to nitrates
Bacteria of decay convert decaying nitrogen waste to ammonia
Nitrifying bacteria convert ammonia to nitrates/nitrites
Denitrifying bacteria, which convert nitrates to nitrogen gas
Fungi also convert dead plants and animals and their wastes into ammonia in the soil

But didn't tillage work?

Yes, for 7,000 years

But we have used up almost all the SOM/SOC (soil organic matter/soil organic carbon)

That means no wonderful soil organisms to get nutrients for plants or form aggregates

To grow crops, it's dependant on us to add everything…forever.

Or build back soil instead

The Dust Bowl, Ken Burns, PBS

Just Once, Pleeeeeze

Plow, till, disc, harrow, cultivate, dig, double dig, more terms than Inuit's have for snow

One pass can break up aggregates physically

Also, bacteria get a blast of oxygen and chew up the glue, releasing CO2 into the atmosphere

Figure 1. Grassland soil fractionated into water-stable aggregate size classes.

A large macroaggregate is bigger than a sand particle. A microaggregate has the thickness of one or two human hairs. A macroaggregate lies in between. Agvise Laboratories

Ode to a Small Garden

But my garden is tiny; can it house an elephant?

Terrarium sealed for 50 years implies YES!

Oxygen, Carbon Dioxide, Water, and all other molecules recycled

Just add Sunshine

Gardener David Latimer with his sealed 10 gallon carboy, created in 1960, watered once in 1972

Action Items

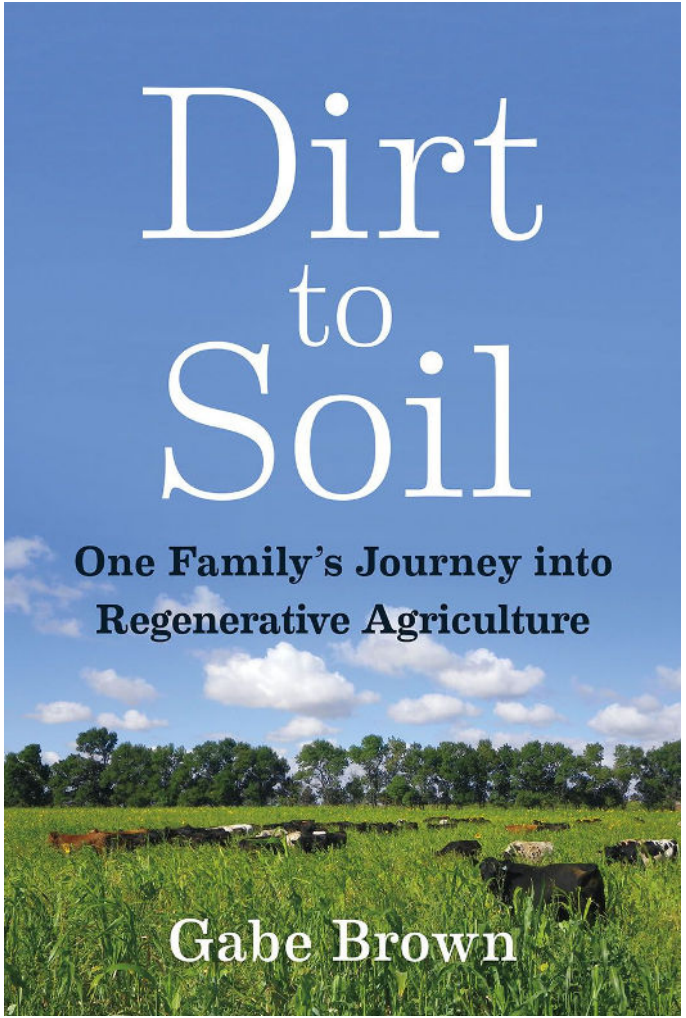
Planted areas:

Leave the leaves, stay on paths
Top Dress with compost & mulch (use your weeds)
Eliminate “cides” and synthetic fertilizers
Insects are delicious bird food and pollinators
Edit plants to be site-appropriate
Native plants (most supportive to native organisms)

New areas:

Sheet mulching, compost & mulch
cover crops
place research (Calscape.org)
and Native plants
reading!

Multi-species
Right plant right
Lots of diversity
Keep



References

Grow your soil: Harness the Power of the Soil Food Web to Create Your Best Garden Ever, Diane Miessler

Dirt to Soil, Gabe Brown

Teaming with Microbes, Jeff Lowenfels & Wayne Lewis

The Grapes or Wrath, John Steinbeck

Nature's Best Hope: A New Approach to Conservation That Starts in Your Yard, Douglas Tallamy

https://calscape.org/

https://www.theguardian.com/environment/2022/may/07/secret-world-beneath-our-feet-mind-blowing-key-to-planets-future, George Monbiot

https://www.the-compost-gardener.com/mycorrhizal-fungi.html