Introduction to Soil Health

Glenn McGourty, Winegrowing and Plant Science Advisor

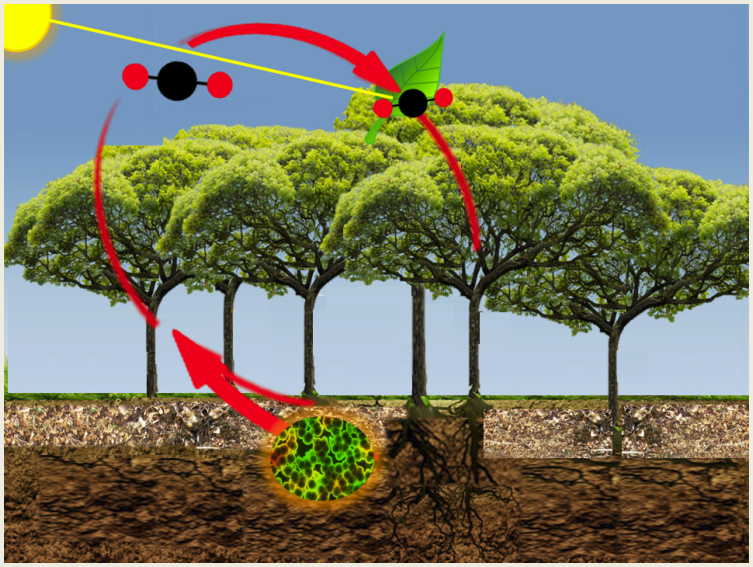
University of California Cooperative Extension

Mendocino and Lake Counties

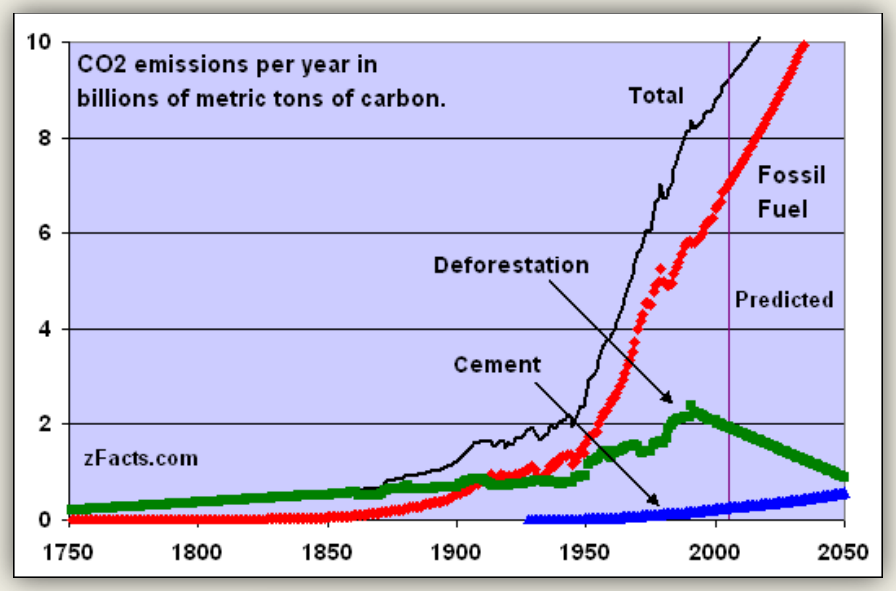
UC CE | University of California
Agriculture and Natural Resources | Cooperative Extension

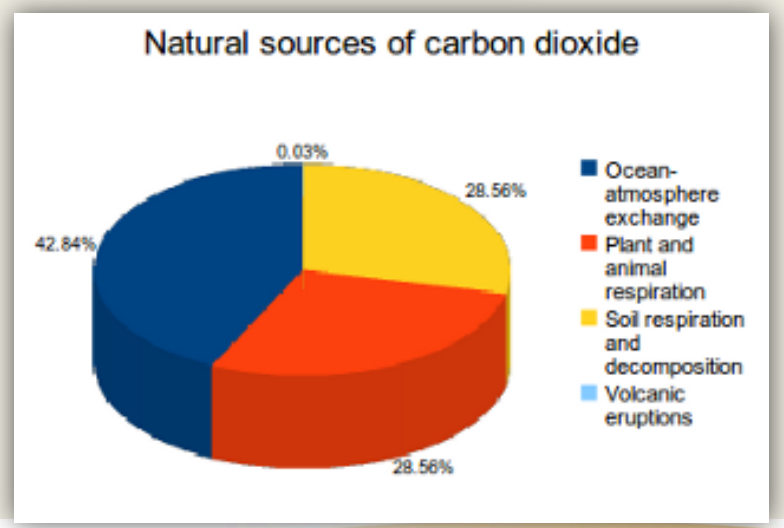
Regenerative Agricultural Systems

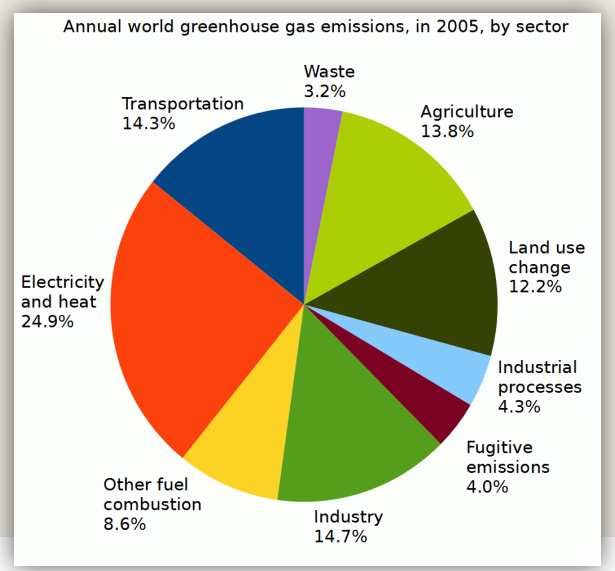
- Seek to promote soil and plant health by using photosynthesis for the removal and retention of atmospheric carbon dioxide into stable soil carbon.



What is the big CO^2 picture?







Is Climate Change Inevitable or Can it Be Mitigated?

Rethinking the Role of Farms: Ecological Services

Watershed: protecting soil and water ways, storing water

Beneficial Insects and Pollinators

Habitat for Diverse Species

Sequestering Carbon

Sustainable, Biodynamic and Organic Farming Systems embrace these practices

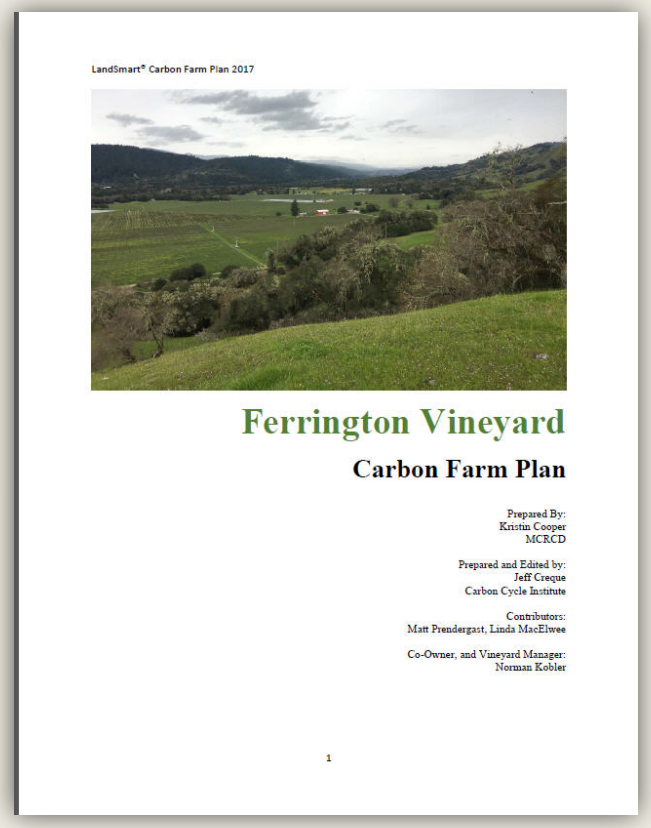
The Concept of Soil Health

- Includes all aspects of soil quality
- Also includes carbon sequestration
- Active soil microbes
- High water infiltration rates and retention
- Protection of soil against erosion

Going in the Right Direction

- Keep soil covered
- Minimize tillage and soil disturbance
- Diverse plant species to increase biotic diversity below ground
- Keep living roots in the soil as long as possible throughout the year

New Techniques and Products



Organic and Biodynamic Agriculture: Require Addition of Organic Matter

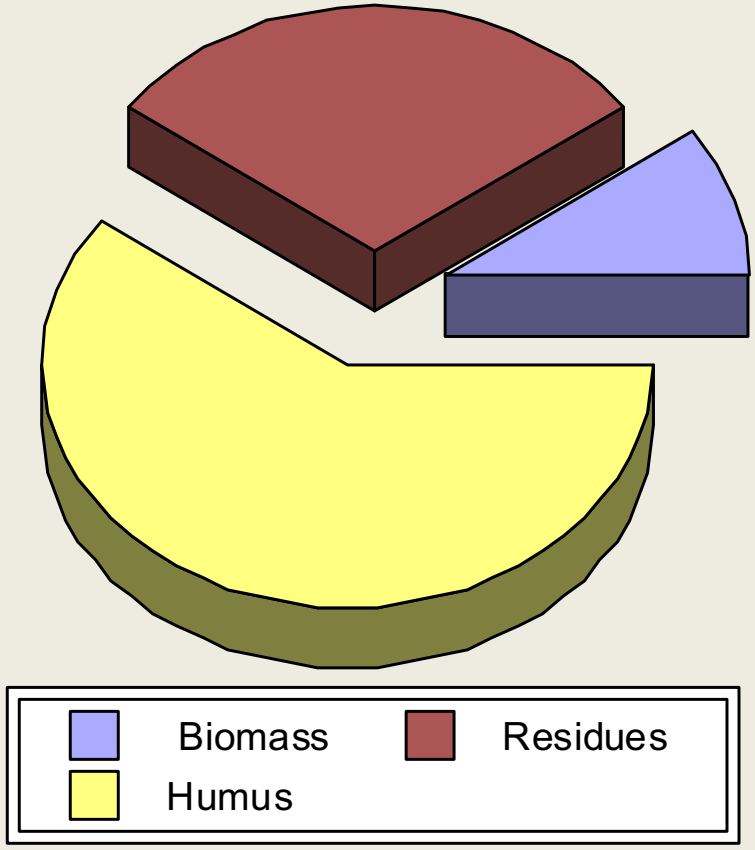
- Compost
- Cover Crops
- Conservation Tillage

Energy Consumption: Chemical Fertilizers Vs. Compost

Material	Joules required to synthesize	BTU's required to synthesize	Amt. of water heated by 1 degree F*
1 kg of N—chemical	78,914,000	75,000	9,350 gallons
1 kg of N—Compost	527,500	1,100	136.5 gallons

*1 BTU= 1055 joules = amount of energy to raise one gallon of water by 1 degree F

Soil Organic Matter by Percentages



Organic Matter and Water

- One lb of organic matter (humus) can hold 40 lbs of water (5 gallons)
- Increasing soil organic matter by 1% can store an additional 21,000 gallons per acre
- Potential to increase water storage by 1/3 in moderate textured soils
- Plant cover can increase infiltration rates by 200% compared to tilled soils

Soils: Stomach of Our Ecosystem

Component (grass land system in a humid climate)	Kg/ha	Population Numbers
Organic Matter all	120,000	
Organic Matter non living	105,000	
Microbes	5,000	10×10^{18}
Nematodes	20	2×10^{9}
Earthworms	100	7×10^{3}
Arthropods	100	4×10^{17}
Vertebrates	42	4×10^{5}

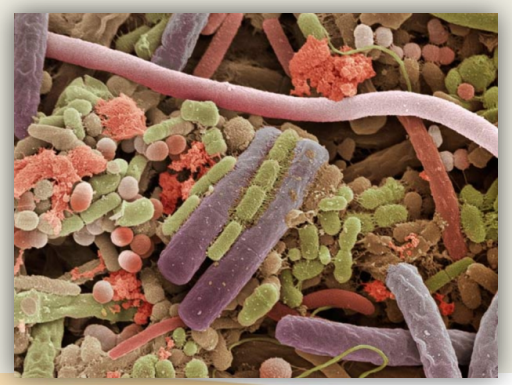
From H. Foth: Fundamentals of Soil Science, 7th Edition

Beneficial Activities of Soil Microbes

- Decomposition of plant residues for energy and growth
- N cycling as fertilizers and organic matter are decomposed
- Increase availability of P, Fe, So, K and others
- Humus formation, C cycling
- Aggregate formation
- Suppression of pathogens
- Mycorrhizal relationships

Immediate Effects of Cover Crops

- Plant tissue is the primary source of SOM
- Soil life is stimulated
- Cover crops serve as food source for vertebrates, invertebrates and microbes
- Soil respiration rates and microbe numbers increase



Soil Protection With Cover Crops

- Cover crop foliage shields soil from rain splashing, slaking of aggregates
- Water infiltration rates stay elevated
- OM conserved by preventing erosion
- Mulching effect keeps soil cool in summer, protects OM from oxidation



Grass Roots

Cover Crop Types

Grasses

Legumes

Soil Carbon Builders

Insectary, disease suppression

Legumes

Legume Roots

What Can You Expect From Cover Crops In Terms of Nitrogen?

Cover Crop Type	Lbs N per Planted Acre
Vetches	50--200
Medics (bur clover)	50-100
Sub clovers	30-100
Rose clover	50-100
White clover*	50-150
Strawberry clover *	50-150
Berseem clover	100-300

* Perennial—expect gophers, too!

Soil Carbon Builders

Insectary Cover Crops and Plantings

Looking Close: The Microbiome

The microorganisms in a particular environment, or the combined genetic material of the microorganisms in a particular environment.

“Understanding the microbiome—human, animal, and environmental—is as important as the human genome"

The Microbiome of Grape Vines:

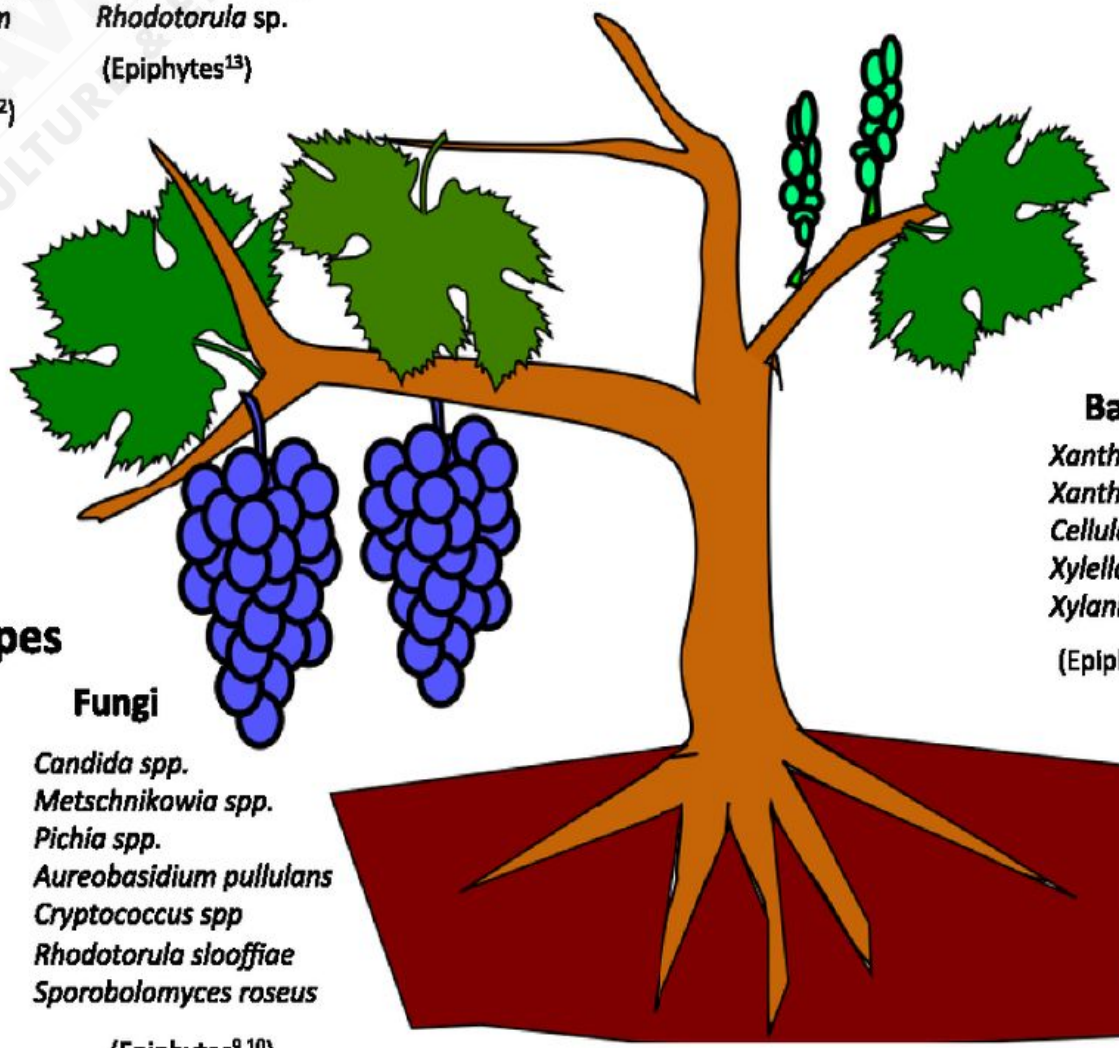
- *Phyllosphere*: Leaf surfaces
- *Fructosphere*: Fruit
- *Rhizosphere*: Roots and soil
- Traditional methods of isolating individual species in pure culture will be assisted by genomics
- New science that will rapidly change how we view farming systems ecology

Leaves

Bacteria	Fungi
Sphingomonas	*Aureobasidium pullulans*
Pseudomonas	*Cryptococcus laurentii*
Bacillus	*Cryptococcus uniguttulatum*
Methylobacterium	*Cryptococcus ater*
Curtobacterium	*Rhodotorula* sp.
Skermanella	
(Epiphytes[6,12])	(Epiphytes[13])

Flowers

Bacteria	Fungi
Pseudomonas sp.	None identified.
Bacillus ssp.	
(Endophytes[3])	



Bark

Bacteria	Fungi
Xanthobacter	*Aureobasidium pullulans*
Xanthomonas	*Cryptococcus uniguttulatum*
Cellulomonas	*Candida zeylanoides*
Xylella	*Filobasidium capsuligenum*
Xylanimonas	*Rhodotorula sp.*
(Epiphytes[12])	(Epiphytes[13])

Grapes

Bacteria	Fungi
Pseudomonas	*Candida spp.*
Achromobacter	*Metschnikowia spp.*
Flavobacterium	*Pichia spp.*
Cellvibrio	*Aureobasidium pullulans*
Massilia	*Cryptococcus spp*
Micrococcus	*Rhodotorula slooffiae*
Bacillus	*Sporobolomyces roseus*
(Epiphytes [6,12])	(Epiphytes[9,10])

Bulk soil

Bacteria	Fungi
Clostridium	*Filobasidium capsuligenum*
Bacillus	*Aureobasidium pullulans*
Rhizobium	*Hanseniaspora uvarum*
Acinetobacter	([13])
Streptococcus	
Paenibacillus	
([12])	

Currency of the Microbiome: Exudates

- Plants communicate with microorganisms to to alleviate stresses, such as pathogen attack, drought-limiting nutrient acquisition, and metal toxicity to name a few
- Microbes benefit from plant exudates by using them as a resource, in many cases carbohydrates but also other nutrients.

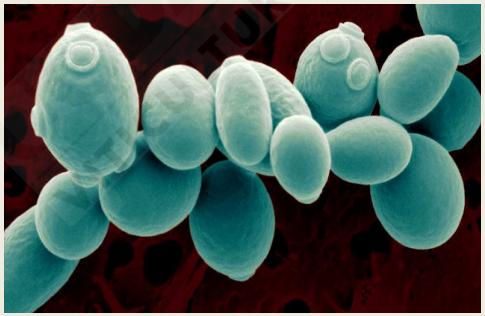
Phyllosphere of Grape Vines

- Generally, grape vine leaves don't seem to support large numbers of diverse species, or populations
- Ice nucleating bacteria affect freezing, research ongoing on controlling populations
- Bacteria most likely migrate from cover crops and neighboring vegetation

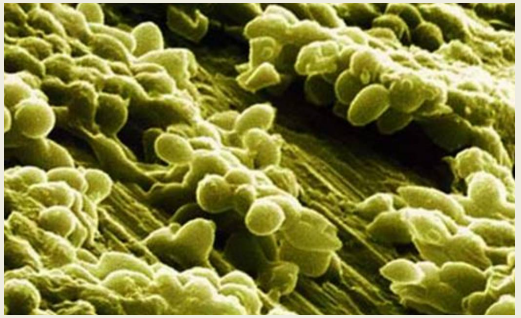
Phyllosphere, Plant Surfaces

Samoray et al, 2016

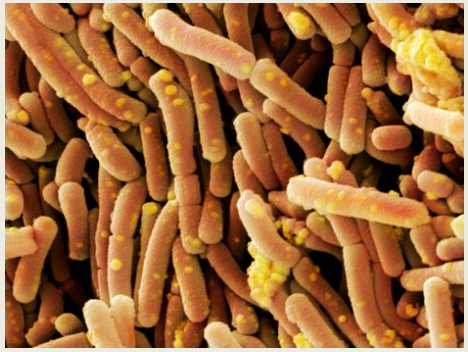
Fructospehere: Microbes on Grapes Can Be Specific to Vineyard Sites



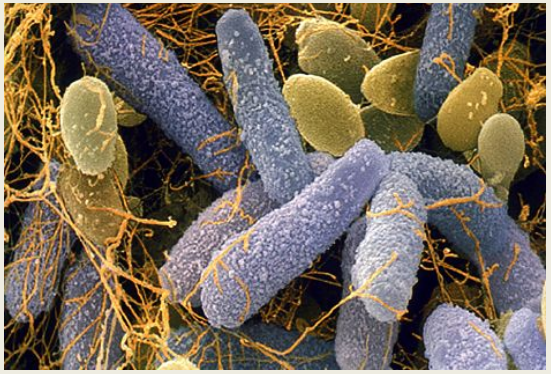
Saccharomyces cerevisiae



Sacchromyces on fruit



Lactobacillus

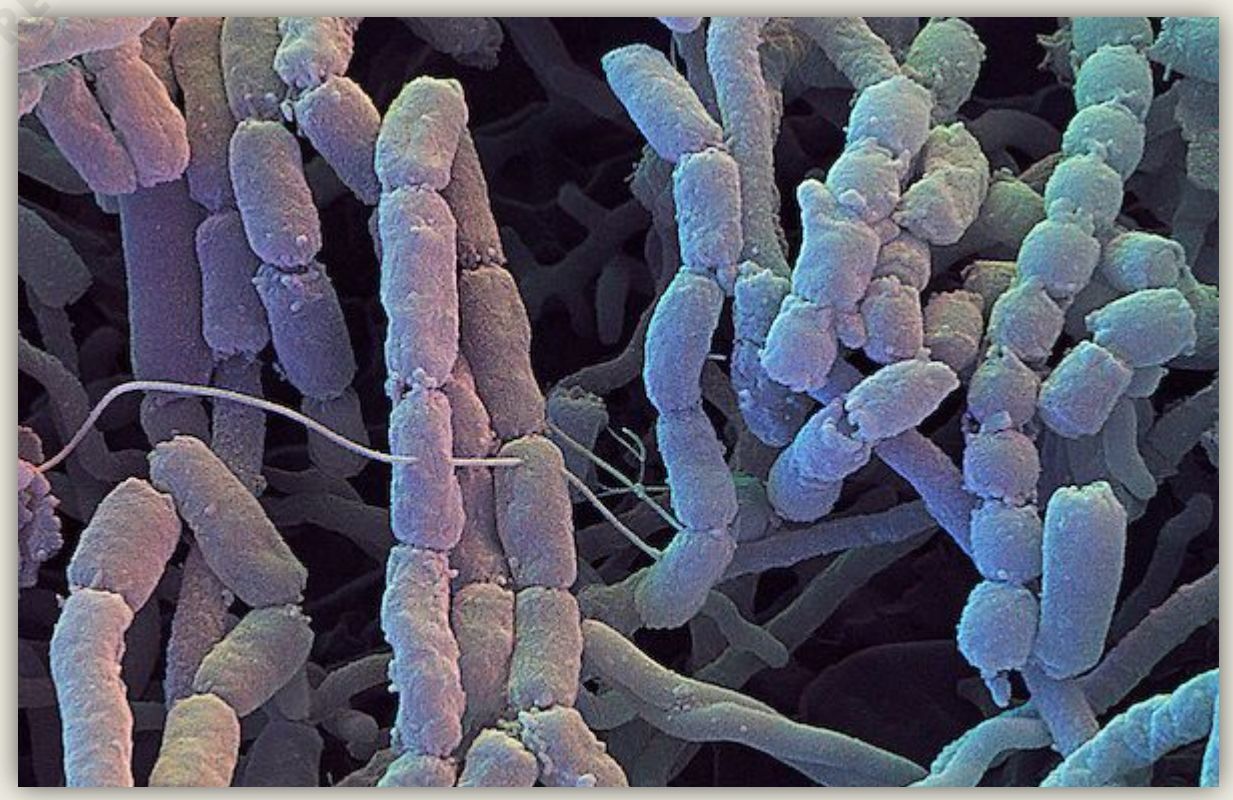


Schizosaccharomyces and Acetobactor

Rhizosphere

Trends in Plant Science

Actinomycetes

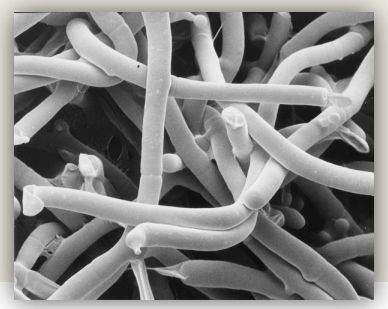


Fungi

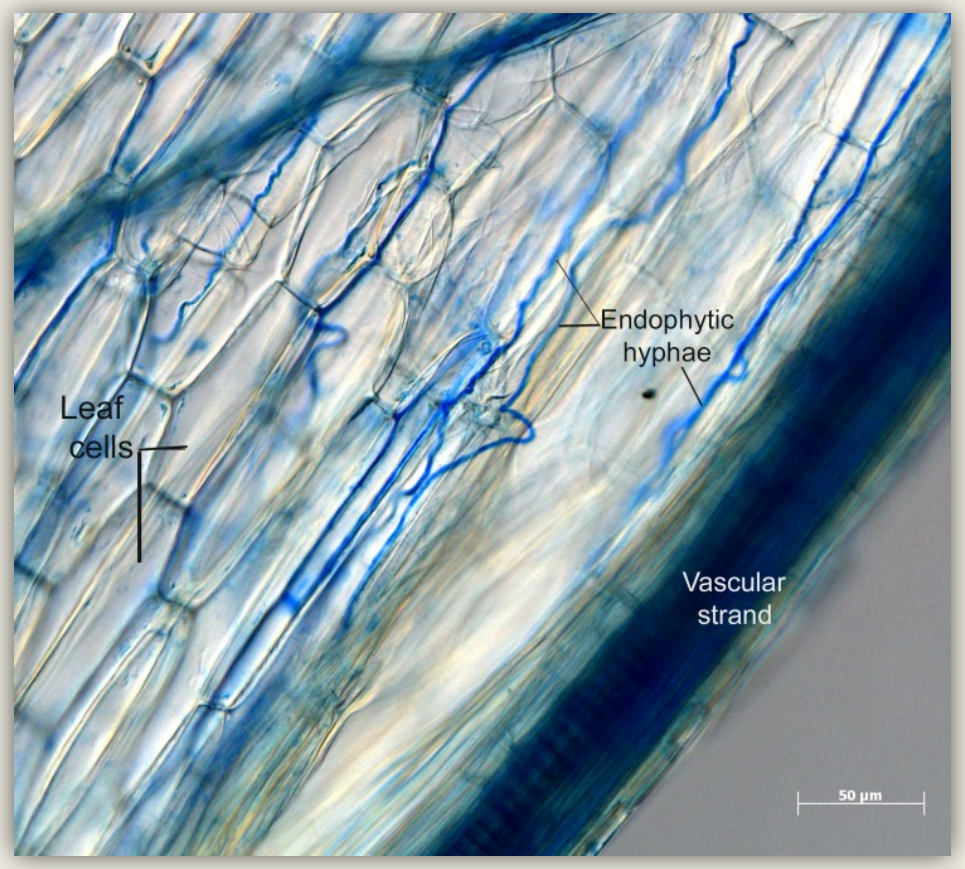
- Decomposers
- Mutualists
- Pathogens

Fungal Decomposers

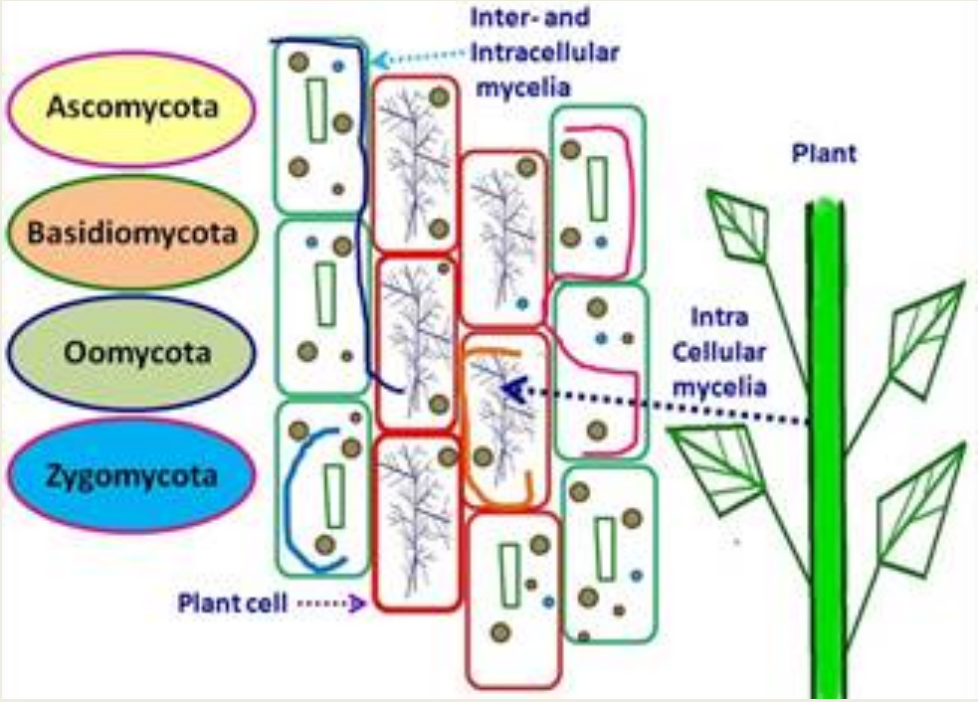
- Can live in dryer conditions and lower pH than bacteria
- Decompose cellulose and lignin
- Unlike bacteria, fungi can form hyphae that penetrate substrates



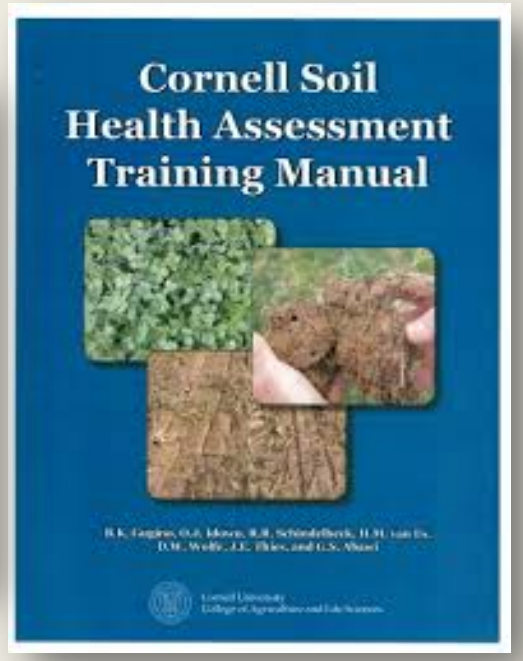
Fungal Mutualists: Endophytic Fungi



Endophytic Fungi



Soil Health Assessments



Soil Health Tests

Soil Analysis	Description	Relationship to Soil Processes
Physical		
Texture	% of sand, silt, clay, gravel content	Inherent soil property that influences ability to increase soil organic matter, form stable aggregates, retain/infiltrate/drain water.
Bulk density	Weight of dry soil in specific volume	Indication of compaction, allows calculation of soil C, N, other nutrients on area/volume basis
Aggregate stability	% of aggregates stable to simulated rain	Related to soil water infiltration capacity, nutrient retention. Changes relatively rapidly with soil management changes because of the role of living organisms in soil aggregation (e.g. fungal hyphae, earthworm casts, bacterial compounds stabilize aggregates).

Chemical Testing

Chemical	Relationship to process
pH	Soil pH can influence nutrient availability, soil biology and plant health
Phosphorus (P)	Important to cover crops more than grape vines
Calcium (Ca)	5:1 ratio of Ca to Mg
Magnesium (Mg)	Excesses an issue for aggregate formation and stability
Cation exchange capacity (CEC)	Should build over time with organic matter increases

Biological Testing

Biological	Description	Relationship to process
Total organic carbon (TOC)	% of soil as C by weight, carbonates removed with acid treatment	TOC is an accurate indicator of soil organic matter (SOM), which is important for water holding capacity, as CEC, in aggregation, as nutrient supply. Soil microbes are part of SOM, and SOM is their food supply.
Active carbon	Permanganate oxidizable carbon (POC)	POC is a measure of labile carbon, and therefore is related to microbial biomass and changes more rapidly than TOC following management changes.
Total organic nitrogen (N)		
Potentially mineralizable N (PMN)	Nitrogen released from organic matter during a ___week incubation	Indicator of soil fertility, organic matter quality

What is the End Game?

- Personal effort to address climate change and build resiliency into your vineyard
- CDFA Healthy Soils Incentive Program: may start paying for carbon credits
- New sections for Code of Sustainabilty, SIP, Lodi Rules, etc.
- We would like to work with Oregon LIVE

Resources

- North Coast Soil Health Hub: soilhub.org/
- Cornell Soil Health Assessment:
  https://soilhealth.cals.cornell.edu/

CDFA- Climate Smart Ag Grants

- **State Water Efficiency and Enhancement Program (SWEEP)**
  - Max $100k
  - Must reduce GHG emissions AND save water
  - Deadline to apply March 8th

- **Healthy Soils Program (HSP)**
  - Incentives Program max $75k
  - Demonstration Projects max $250k
  - Eligible practices proven to improve soil health, sequester Carbon, and reduce GHGs
  - Deadline to apply March 8th

- **Alternative Manure Management Program (AMMP)**
  - Incentives Program max $750k ($2million additionally available for Demonstration Projects)
  - For Dairy/Livestock Operators who wish to implement non-digester manure management practices resulting in a reduction of methane emissions
  - Deadline to apply April 3rd

For more information, visit CDFA'S website: https://www.cdfa.ca.gov/oefi/

CDFA- Climate Smart Ag Grants

UC Cooperative Extension's

<u>Technical Assistance Providers</u>

- University/CDFA partnership
- 10 Community Education Specialists hired throughout the state to assist interested applicants

- Britta Baskerville- UCCE Ukiah
  - SWEEP & HSP
  - (707) 463- 4158
  - blbaskerville@ucanr.edu
- Randi Black (Dairy Advisor)- UCCE Santa Rosa
  - AMMP
  - (707) 565- 2648
  - rablack@ucanr.edu

Thanks for your attention!