SOIL MICROBIOLOGY

Sam Ruhala

CLORPT

CLIMATE

Climate shapes rock weathering, soil composition, and plant/animal distribution, impacting nutrient leaching over time.

ORGANISMS

Contribute to soil enrichment through organic matter addition and mixing and impact nutrient cycling and availability.

RELIEF/TOPOGRAPHY

Soil relief affects moisture interaction. Depressions accumulate moisture, impacting organic matter and nutrient cycling

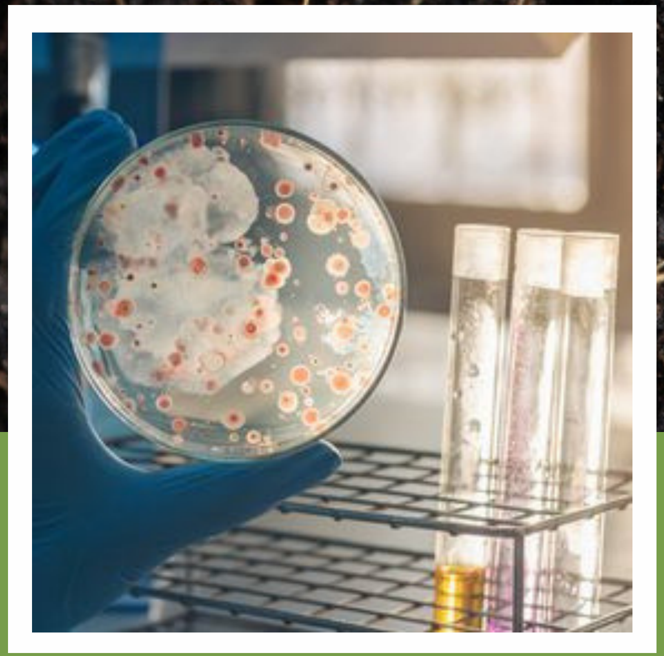
PARENT MATERIAL

Parent material determines soil texture. It includes bedrock, weathered rock, blown particles, or sediment deposited by glaciers or rivers.

TIME

Time shapes soil development through gradual processes of weathering, accumulation, and ecological interactions.

DIVERSITY IS IMPORTANT



Diversity of Crops + Diversity of Microbes

= Resilient Pathogen Suppressing Soil Ecology

DIVERSE SOIL ECOLOGY

BACTERIA

- Nitrogen-fixing bacteria
- Nitrifying bacteria
- Denitrifying bacteria
- Phosphate-solubilizing bacteria
- Cellulous-degrading bacteria
- Plant Growth-Promoting Rhizobacteria
- Cyanobacteria

ACTINOMYCETES

- Streptomyces
- Micromonospora
- Nocardia
- Actinoplanes
- Frankia
- Actinomadura

FUNGI

- Saprophytic, free-living
- Mycorrhizal
- Endophytic
- Pathogenic
- Yeasts

ALGAE

- Euglenophyta (Euglenoids)
- Chrysophyta (Golden-brown algae and Diatoms)
- Pyrrophyta (Fire algae)
- Chlorophyta (Green algae)
- Rhodophyta (Red algae)
- Paeophyta (Brown algae)
- Xanthophyta (Yellow-green algae)

PROTOZOA

- Amoebae
- Testate Amoebae
- Ciliates
- Flagellates
- Heliozoa

NEMATODES

- Bacteriverous
- Fungal-feeding
- Predatory
- Omniverous
- Plant-Parasitic

BACTERIA

Nitrogen-fixing
Nitrifying
Denitrifying
Phosphate-solubilizing
Cellulous-degrading
Plant Growth-Promoting Rhizobacteria
Cyanobacteria

Bacteria play a crucial role in soil ecosystems by facilitating nitrogen fixation and colonizing minerals, thereby influencing mineral weathering and breakdown processes.

CYANOBACTERIA

Fossil evidence suggests that microbial mats and biofilms formed by these microorganisms were present on land surfaces about 3.5 billion years ago.

Prokaryotic organisms that played a significant role in shaping the planet's early atmosphere. They are capable of oxygenic photosynthesis, a process in which they use sunlight, carbon dioxide, and water to produce organic matter and release oxygen as a byproduct.

ACTINOMYCETES

Actinomycetes are versatile soil microorganisms with both beneficial and harmful traits.

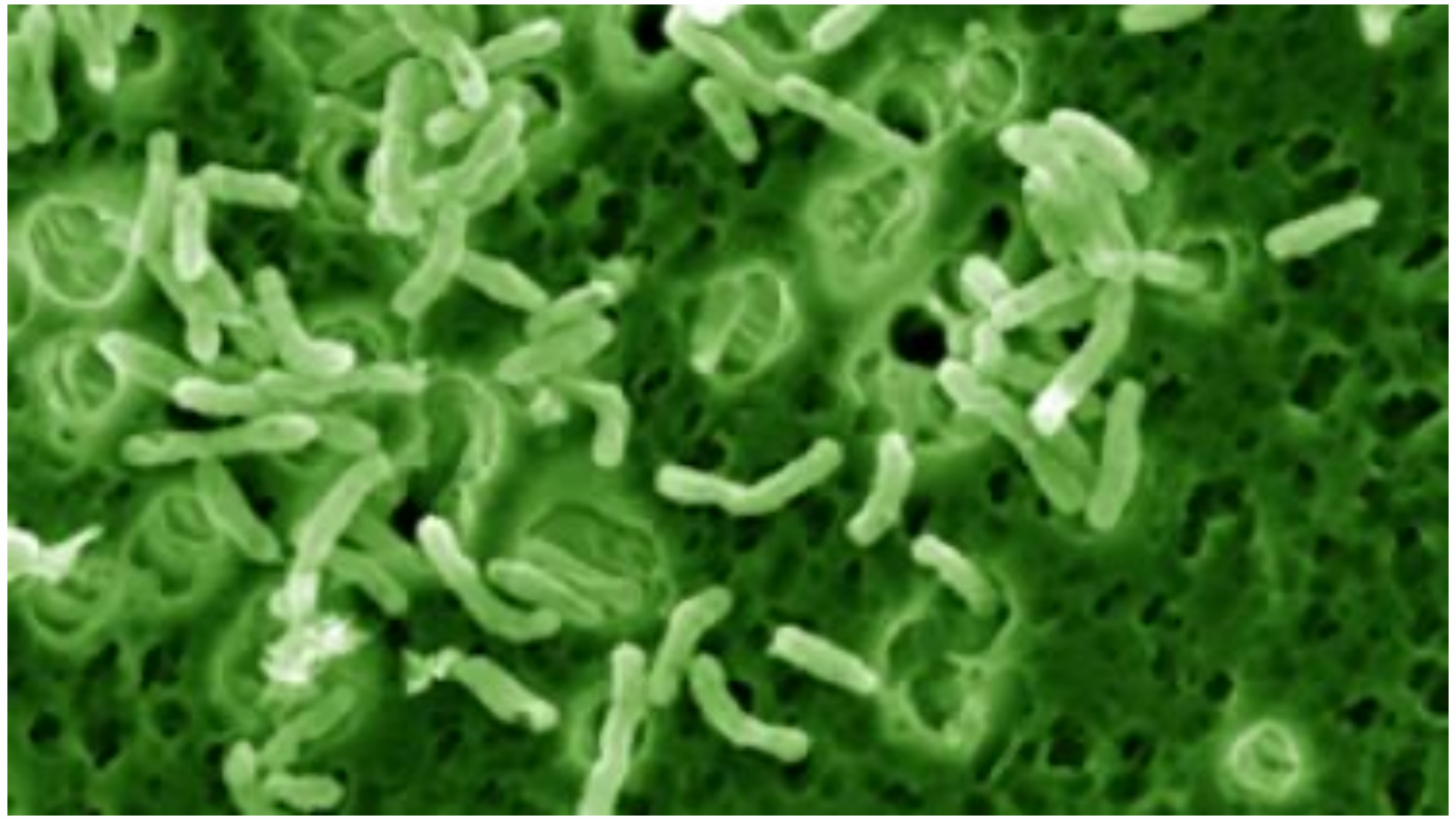
They break down organic matter, releasing essential nutrients, and contribute to soil fertility, structure, and plant growth.

Their diverse roles highlight their importance in maintaining a balanced and productive soil ecosystem.

Mycobacterium vaccae

M. vaccae increased expression of *tph2*, an enzyme involved in the biosynthesis of the neurotransmitter serotonin in the brain.

Discovered on the shores of Lake Kyoga in Uganda in the 1970s by immunologist John Stanford after recognizing that people who lived in the area responded better to certain leprosy vaccines.



FREE-LIVING FUNGI

Fungal Contributions

Fungi near plant roots aid in nutrient availability by decomposing organic matter, while their hyphal networks enhance soil structure, water retention, and nutrient cycling, promoting healthy plant growth and soil functionality.

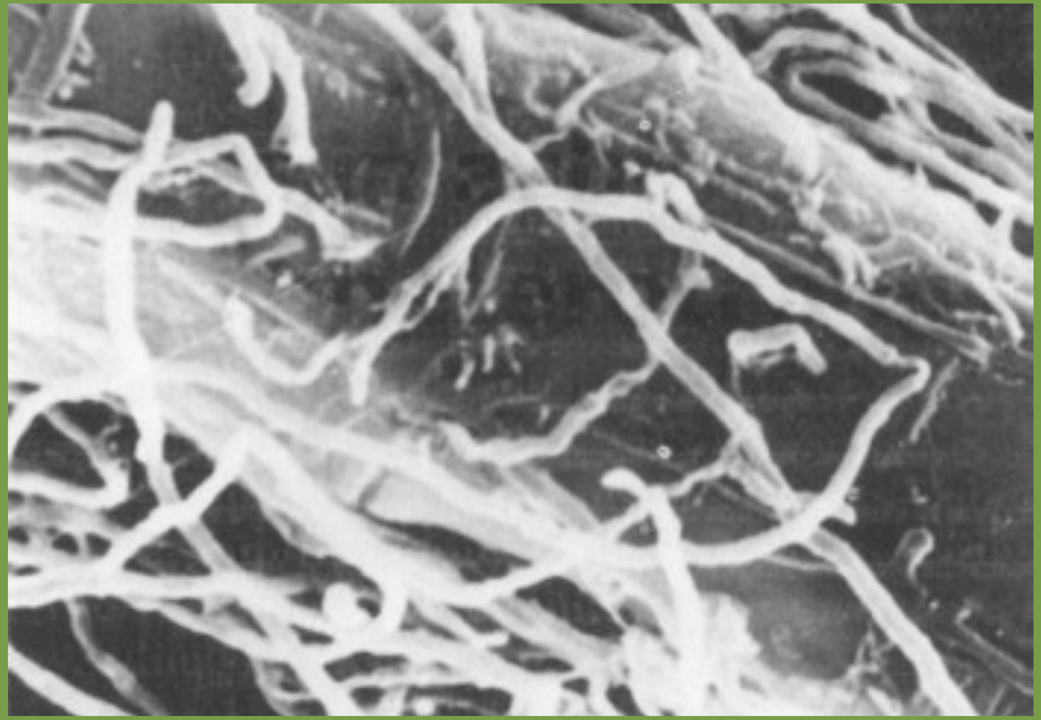
MYCORRHIZAL FUNGI

ENDOMYCORRHIZAE

Endomycorrhizae form a symbiotic bond with plant roots, boosting nutrient absorption and promoting vigorous plant growth and vitality in diverse ecosystems.

ECTOMYCORRHIZAE

Ectomycorrhizae form a dense network of hyphae around the root tips, creating a protective sheath that aids in nutrient acquisition and enhances the plant's resistance to pathogens.



ERICOID MYCORRHIZA

Symbiotic association between certain fungi and plant roots, commonly found in acidic soils. These specialized fungi help plants by aiding in nutrient uptake and enhancing tolerance to harsh environmental conditions.

ALGAE

- Primary producers, oxygen and organic matter production.
- Food source for microbes, nutrient cycling support.
- Photosynthesis releases oxygen, provides organic compounds for microbial growth.
- Enhance soil productivity, influence microorganism activity.

PROTOZOA

Harnessing soil microorganisms for healthy, resilient ecosystems.

- Predators of bacteria and fungi, regulate populations.
- Nutrient release through excretion, support nutrient cycling.
- Control slimy bacteria, improve soil structure.
- Influence microbial dynamics, enhance soil functionality.

Predators that regulate populations, release nutrients, and improve soil structure.

NEMATODES

Microscopic roundworms that mostly enhance soil health – **generally not parasitic**

- Control harmful organisms: pests, parasites, and pathogenic bacteria
- Participate in nutrient cycling: feed on organic matter
- Release nutrients back into the soil through waste
- Improve soil structure and aeration by creating channels
- Vital role in promoting plant health and sustainable agriculture

NEMATODES

Magnetosensitive neurons mediate geomagnetic orientation in *Caenorhabditis elegans*

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Abstract Many organisms spanning from bacteria to mammals orient to the earth's magnetic field. For a few animals, central neurons responsive to earth-strength magnetic fields have been identified; however, magnetosensory neurons have yet to be identified in any animal. We show that the nematode *Caenorhabditis elegans* orients to the earth's magnetic field during vertical burrowing migrations. Well-fed worms migrated up, while starved worms migrated down. Populations isolated from around the world, migrated at angles to the magnetic vector that would optimize vertical translation in their native soil, with northern- and southern-hemisphere worms displaying opposite migratory preferences. Magnetic orientation and vertical migrations required the TAX-4 cyclic nucleotide-gated ion channel in the AFD sensory neuron pair. Calcium imaging showed that these neurons respond to magnetic fields even without synaptic input. *C. elegans* may have adapted magnetic orientation to simplify their vertical burrowing migration by reducing the orientation task from three dimensions to one.

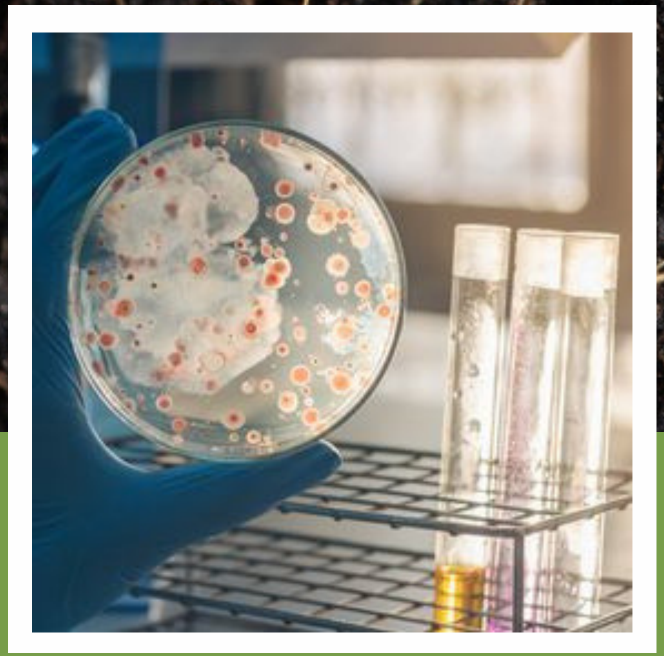
DOI: 10.7554/eLife.07493.001

Bacteria-eating nematode, C. elegens, can only move vertically in the soil horizon when in the presence of the Geomagnetic Field (GMF).

BIOLOGICAL SOIL CRUST

- Bacteria, algae, fungi, and other microorganisms
- It prevents soil erosion caused by wind and water, enhancing soil stability.
- Fixing nitrogen and cycling nutrients improves soil fertility for plant growth.
- The binding of soil particles by this community improves soil structure, facilitating water infiltration and reducing runoff.

DIVERSITY IS IMPORTANT



Diversity of Crops + Diversity of Microbes

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Pathogen Suppression

- Systemic Acquired Resistance (SAR): SAR is a defense response that occurs throughout the entire plant – activation of defense genes and the accumulation of defensive compounds. SAR involves long-distance signaling within the plant, typically mediated by a signaling molecule called salicylic acid (SA).

- Induced Systemic Resistance (ISR): ISR is a defense response that occurs when plants are exposed to beneficial microorganisms. ISR is mediated by signaling molecules like jasmonic acid (JA) and ethylene (ET).

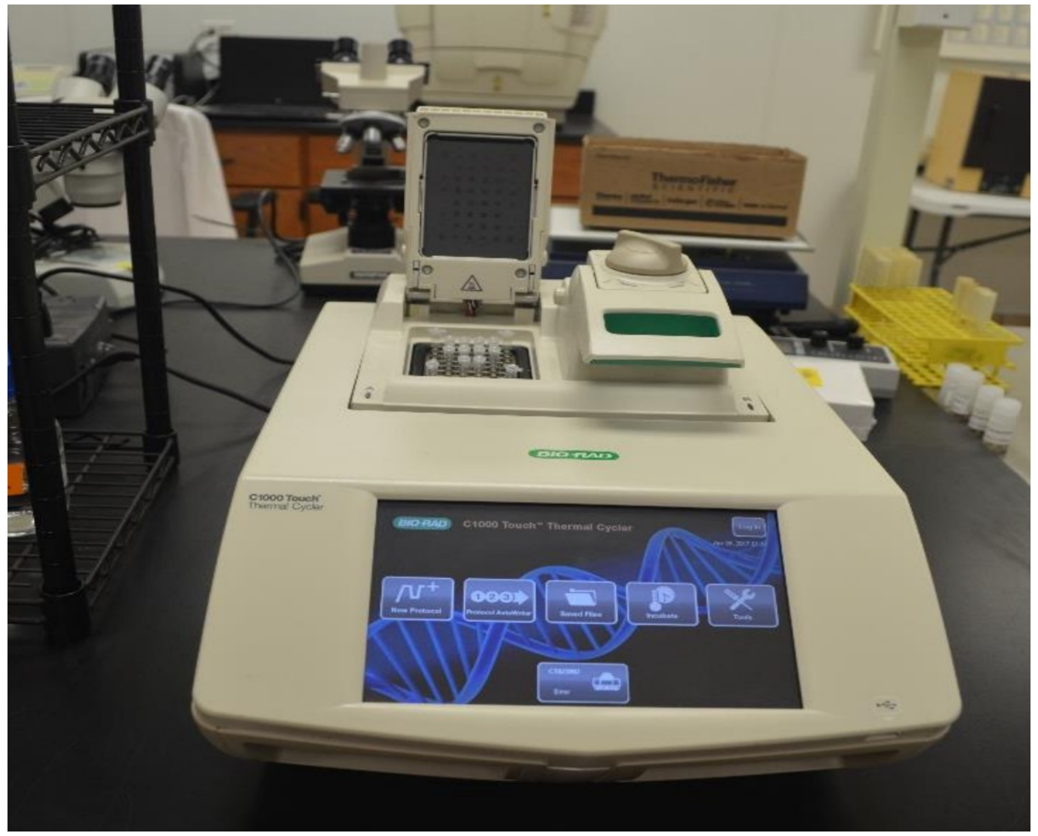
***ISR is typically faster than SAR

Species Richness Diversity Index

6 FUNCTIONAL GROUP REPORT

Purple = Sustainable   **Green** = Good   **Yellow** = Moderate   **Red** = Low

PARAMETER	ENUMERATION CFU/gdw **Grape Soils**	
	Pinot Noir Soil (40582)	**Ruby Cab Soil (40583)**
Heterotrophic Plate Count (Aerobic)	$5.8x10^6$	$2.5x10^6$
Anaerobic Bacteria	$3.0x10^5$	$1.8x10^5$
Aerobic: Anaerobic Bacteria (ratio)	19:1	14:1
Yeasts and Molds	$4.3x10^4$	$1.0x10^4$
Actinomycetes	$3.1x10^6$	$1.6x10^6$
Pseudomonads	$1.8x10^5$	$8.8x10^4$
Nitrogen-Fixing Bacteria	$2.3x10^5$	$6.7x10^4$
% Moisture (dw)	11.9%	17.5%
Total Species Richness Diversity (SRDT)[2]	**7.8**	**6.8**

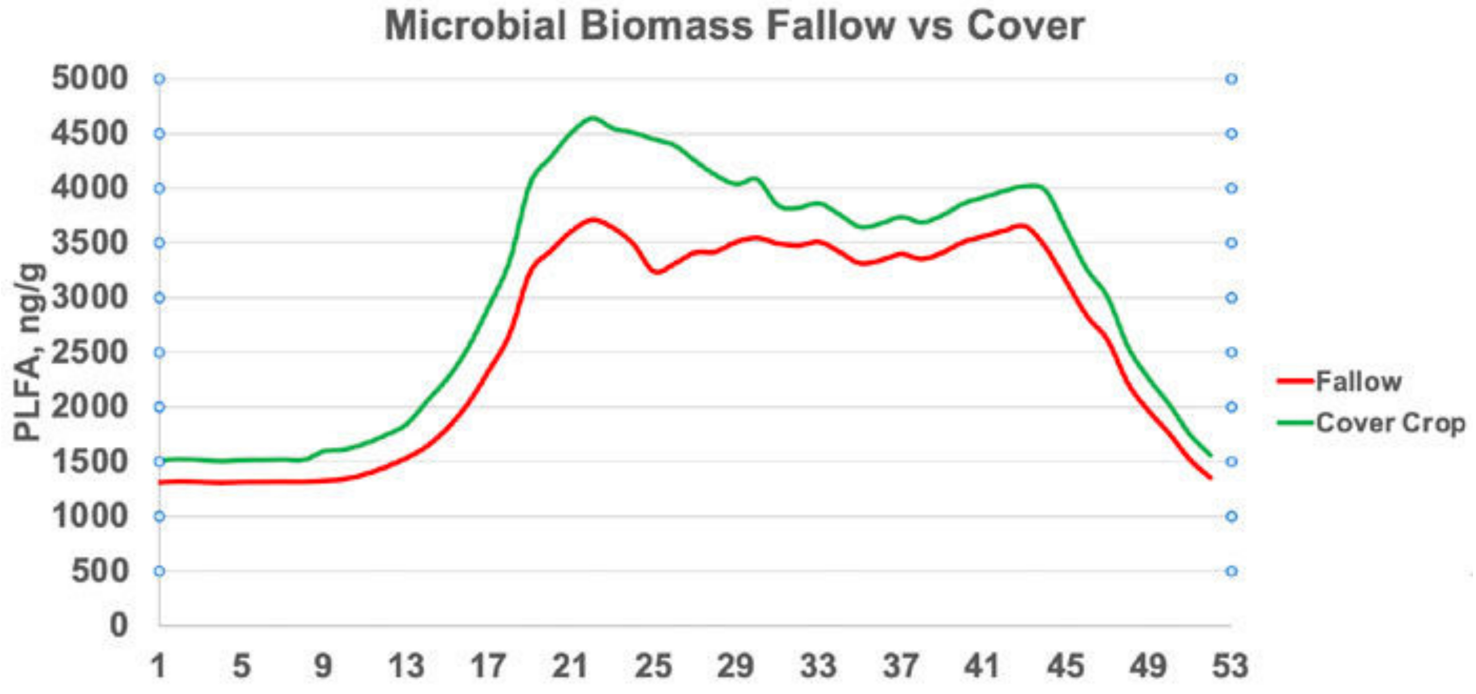


PLFA, Haney, and CO2 Burst

Lab #	Soil Health					
		H2O Extract				
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion
18523	23.4	155	15.1	7.62	7.47	50% Legume 50% Grass
Rank						

Nutrient	Traditional Soil Test *'Strong acid extractable (ppm)*	Soil Health Test *Root Exudate Extractable (ppm)*	Soil Paste Test *Water Extractable (ppm)*
Phosphorous	9	3	0.1
Potassium	100	120	12
Sulfur	14	6	6
Calcium	459	264	15
Magnesium	89	48	5

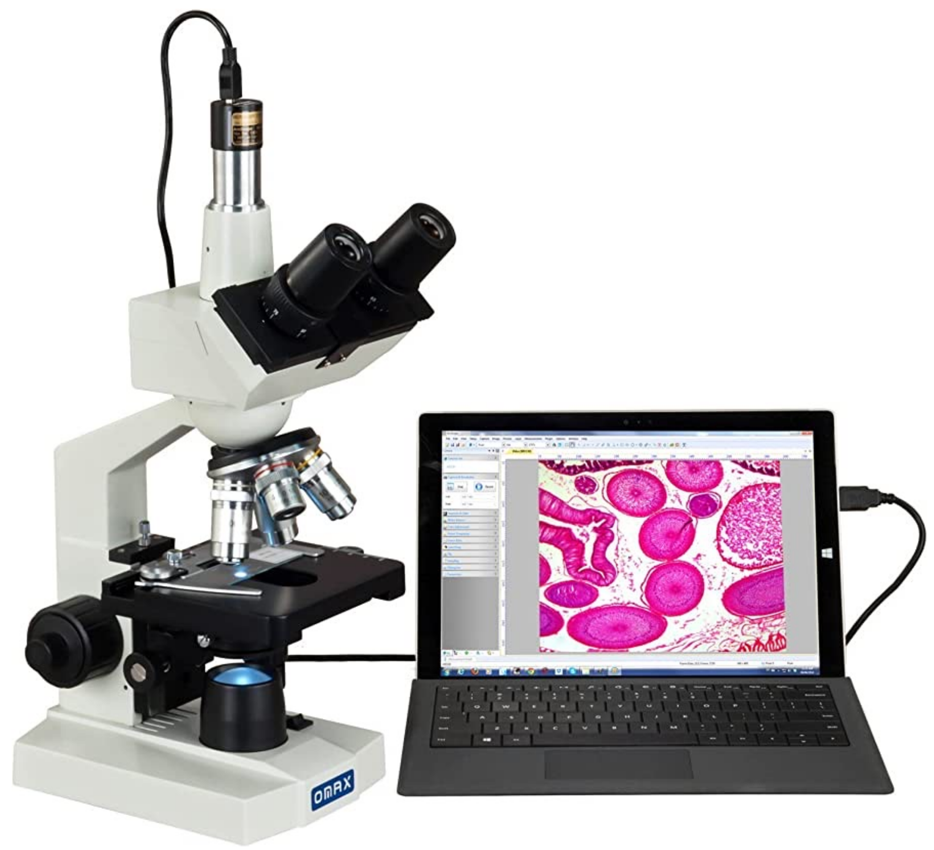
Traditional = Mehlich III Extractable
Root Exudate = H3A extractable
Water Extractable = deionized water

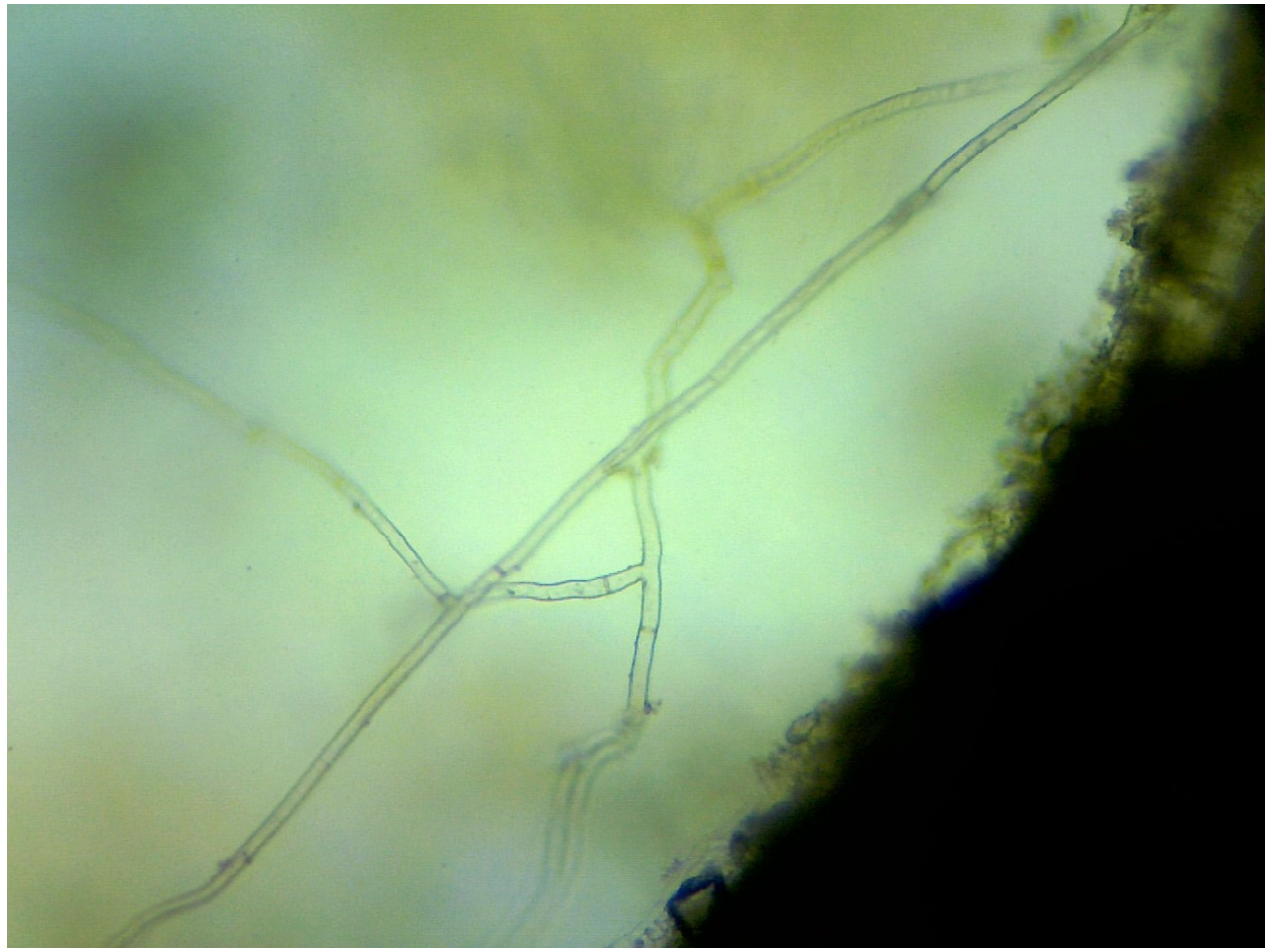


Microscopy, F:B, and bioassay…

Sample Dilution: 5

Fungi				Oomycete				Actinobacteria		Flagellate		Amoebae		Cillates	
Field	Length	Diameter	Observations	Field	Length	Diameter	Observations	Field	Length	Field	Count	Field	Count	Field	Count
1				1				1		1		1		1	
2				2				2		2		2		2	
3				3				3		3		3		3	
4				4				4		4		4		4	
5				5				5		5		5		5	
6				6				6		6		6		6	
7				7				7		7		7		7	



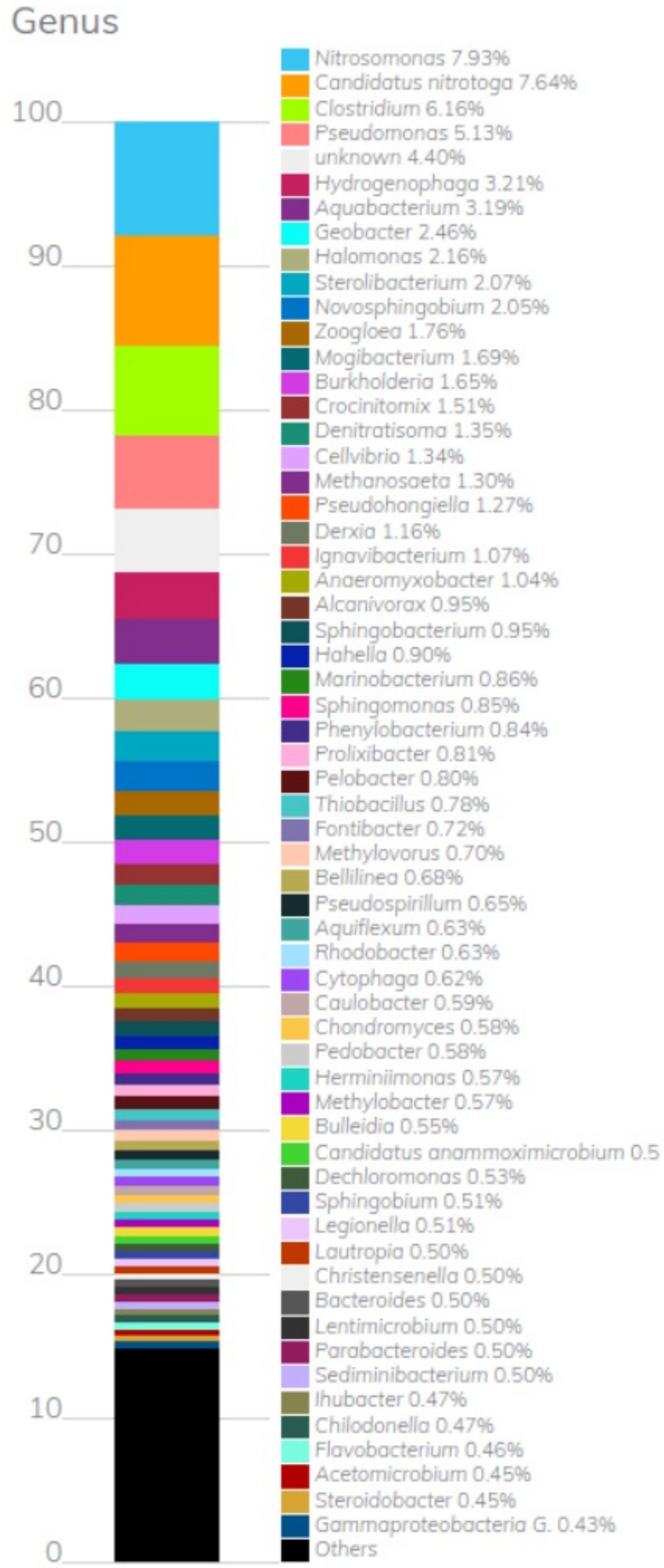


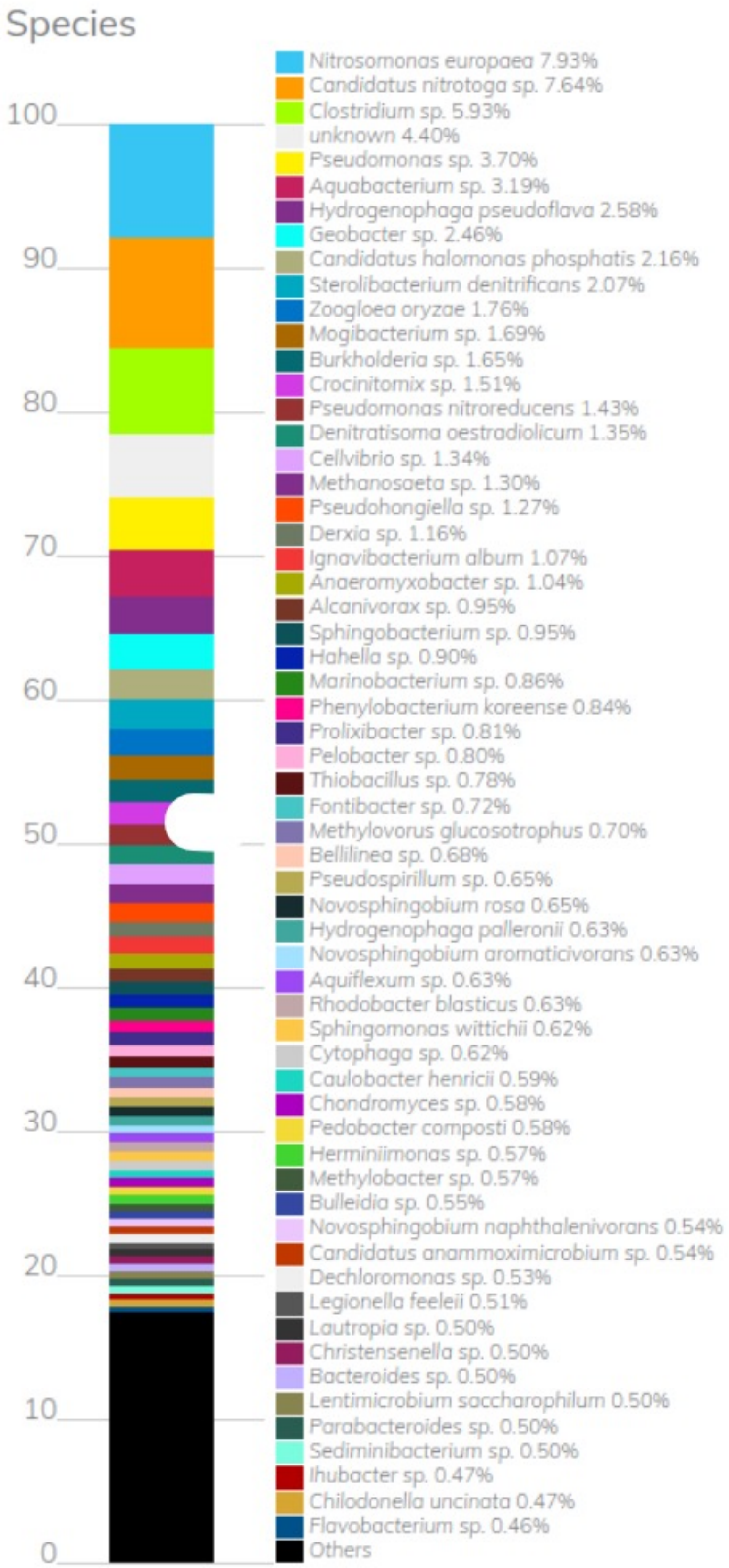
Summary

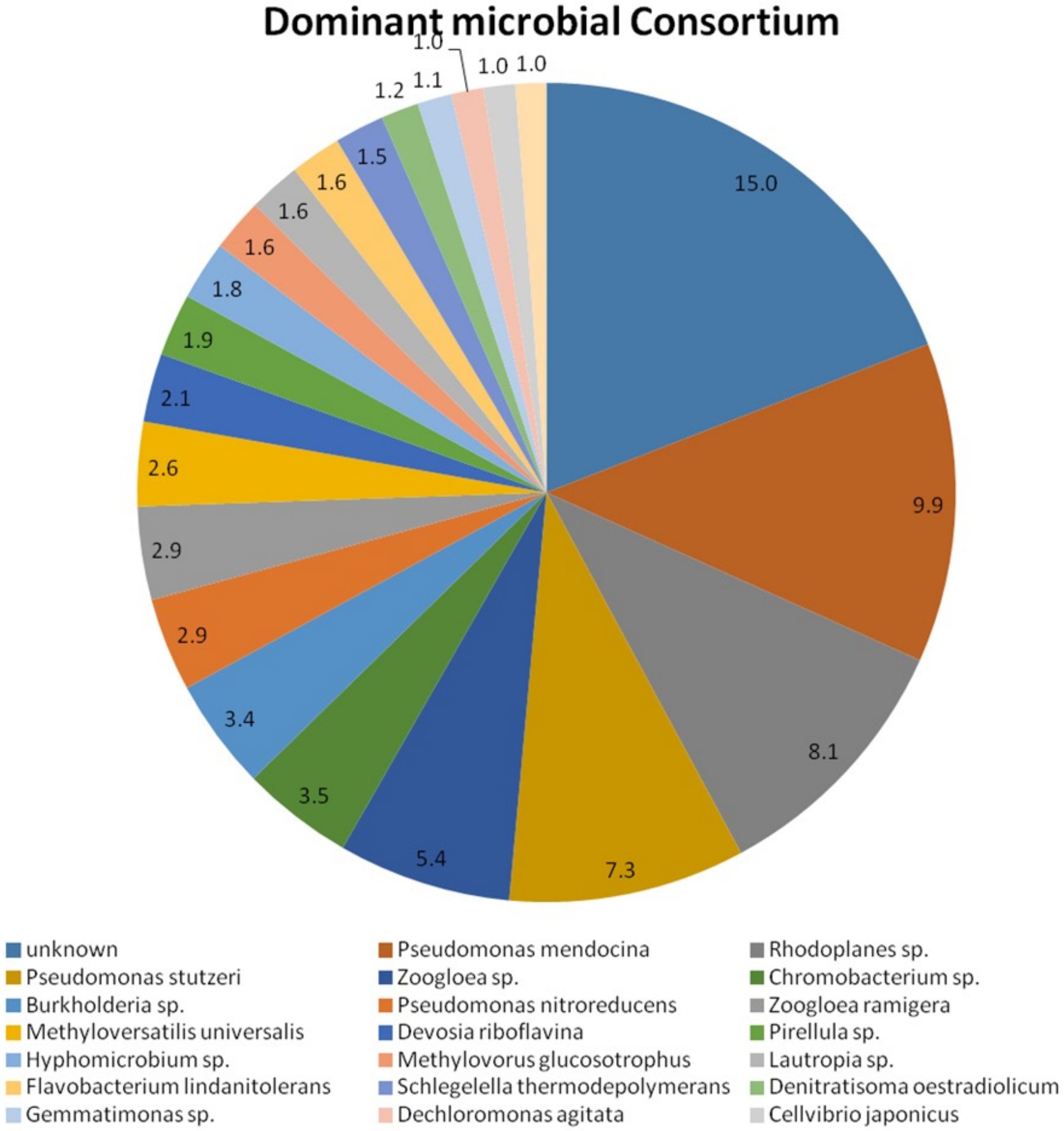
Sample F:B N/A

	Biomass (micrograms per gram)
Fungi	0
Bacteria	0
Actinobacteria	0
Oomycetes	0
	Number per gram
Flagellates	0
Amoebae	0
Ciliates	0
Nematodes	0

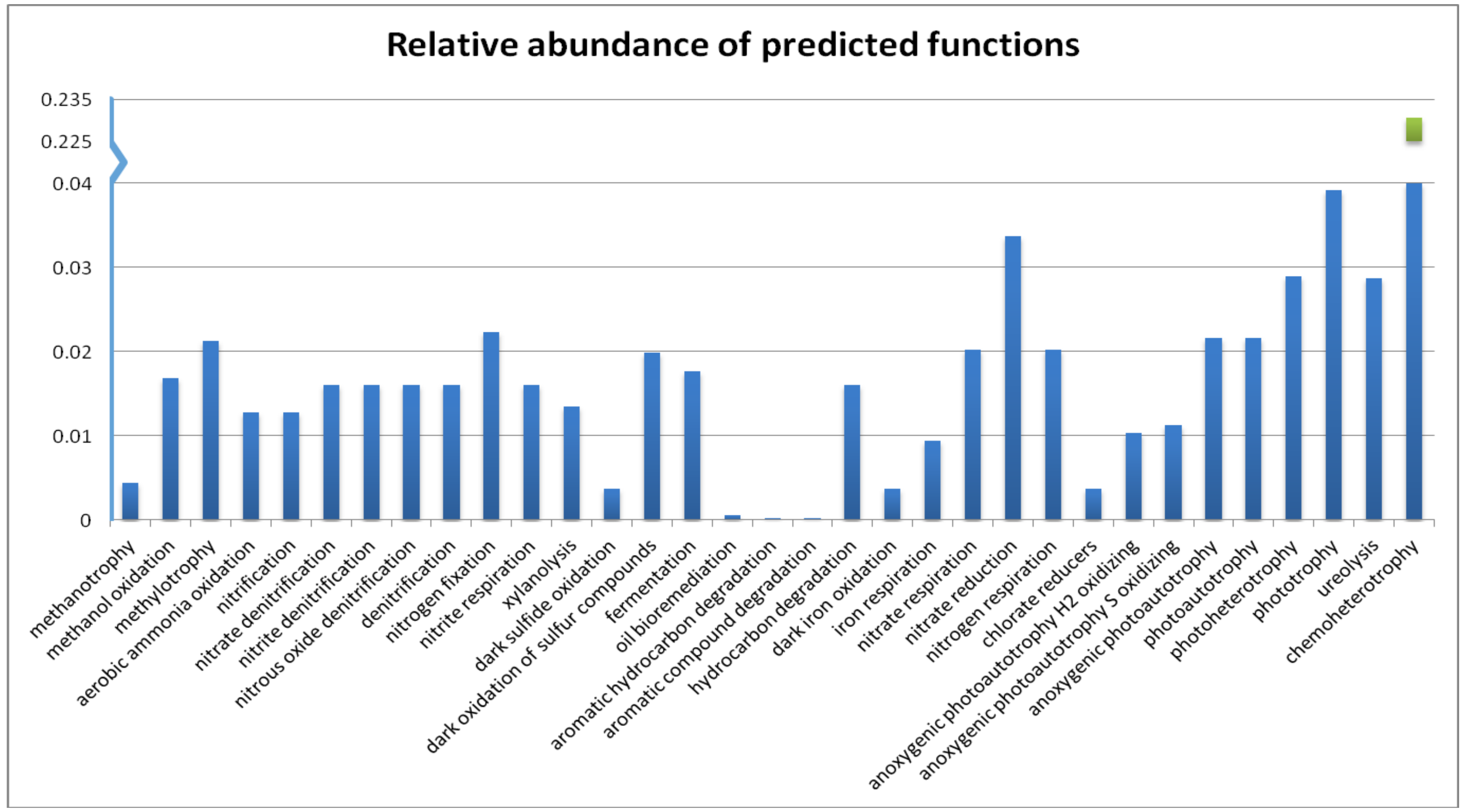
Metagenomics…

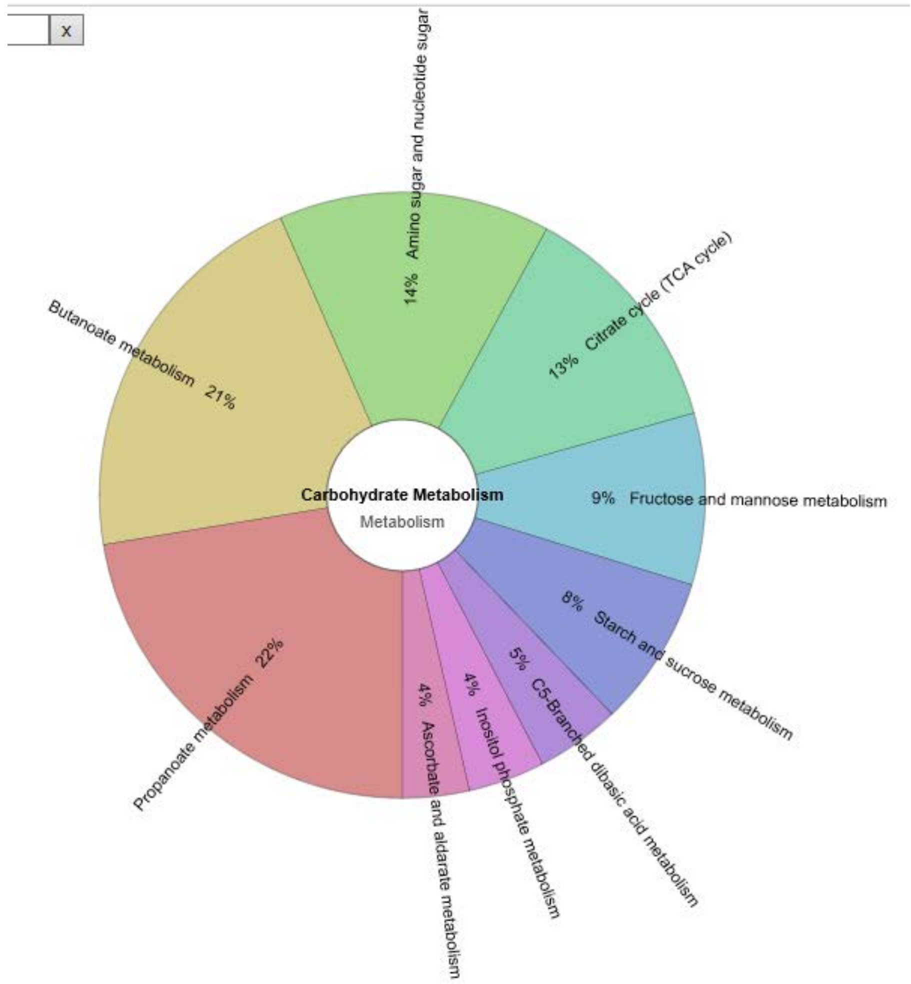


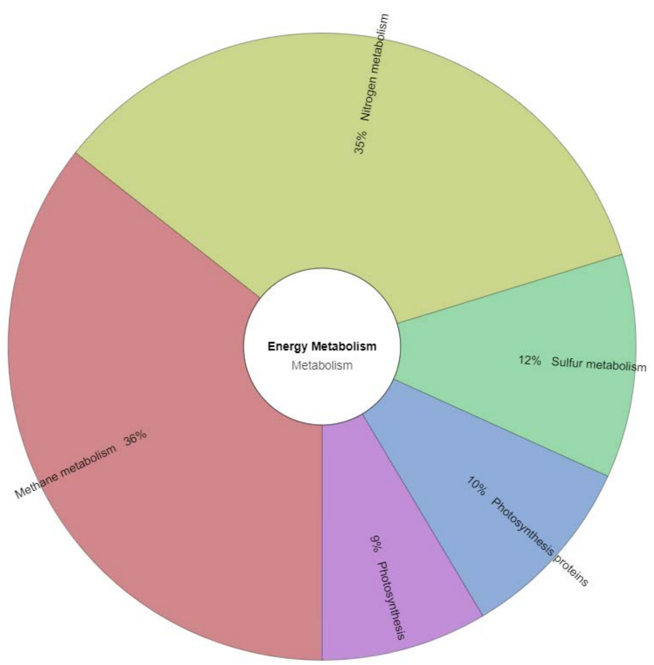


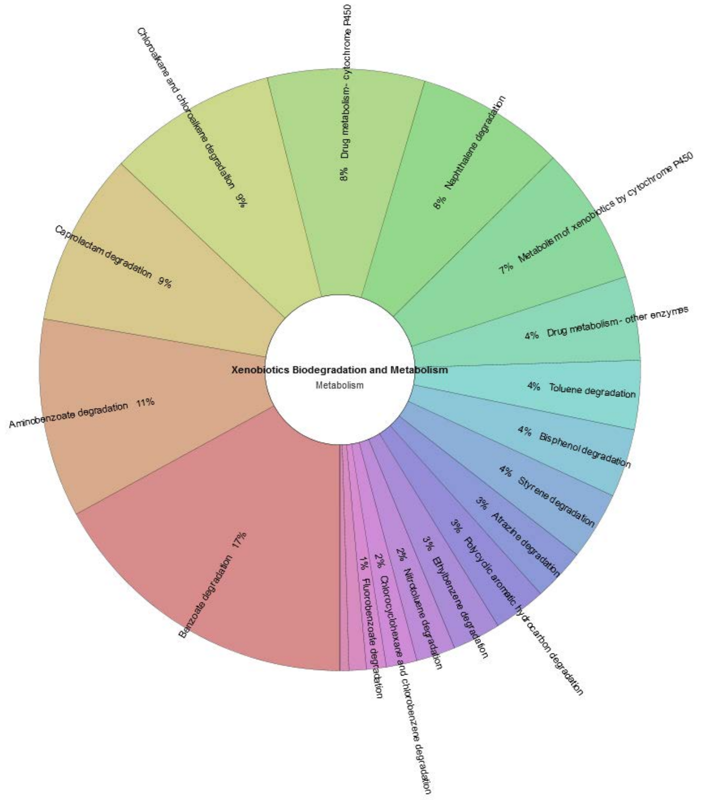


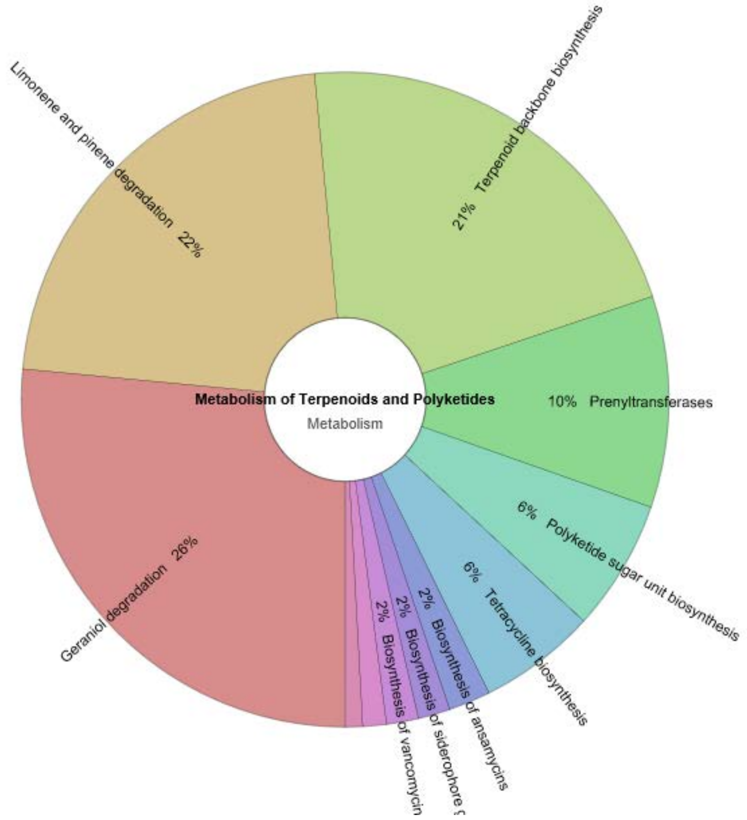
Metagenomics…

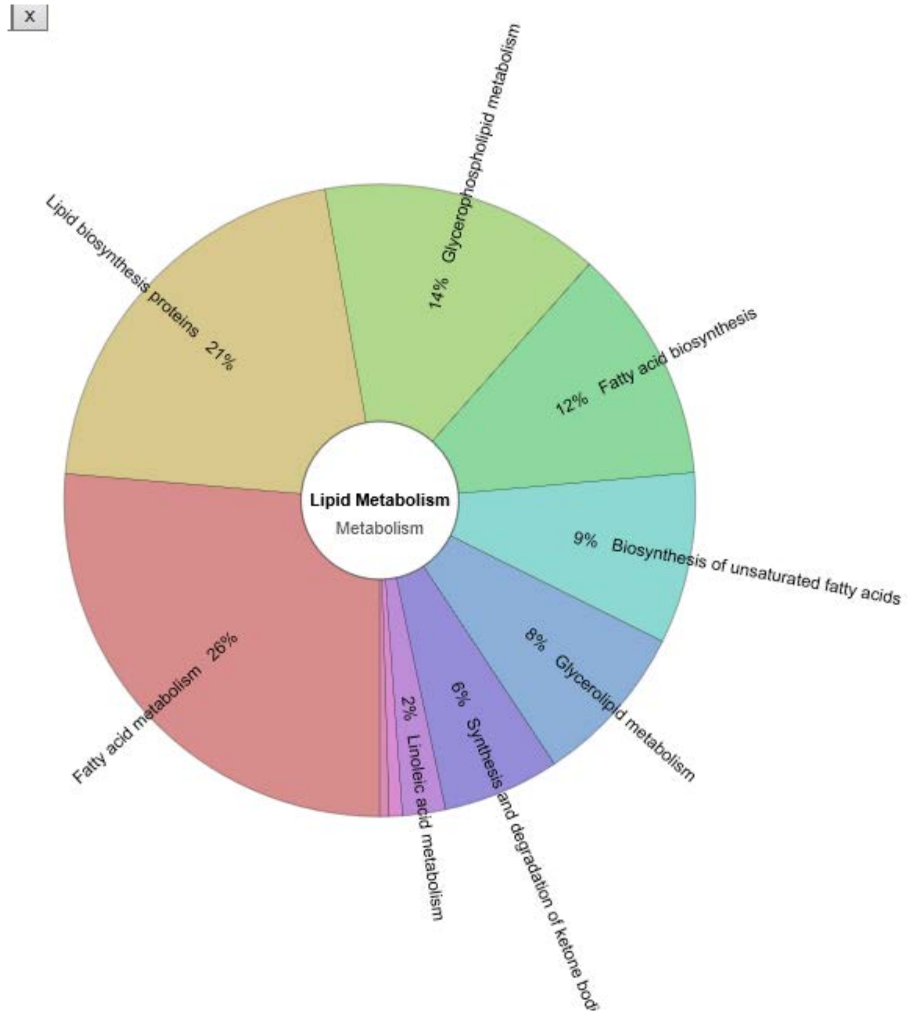












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