# Beyond Organic Matter: Unlocking the Power in the Soil Microbiome

Presented by Bob Reeves from
Earth Alive Clean Technologies



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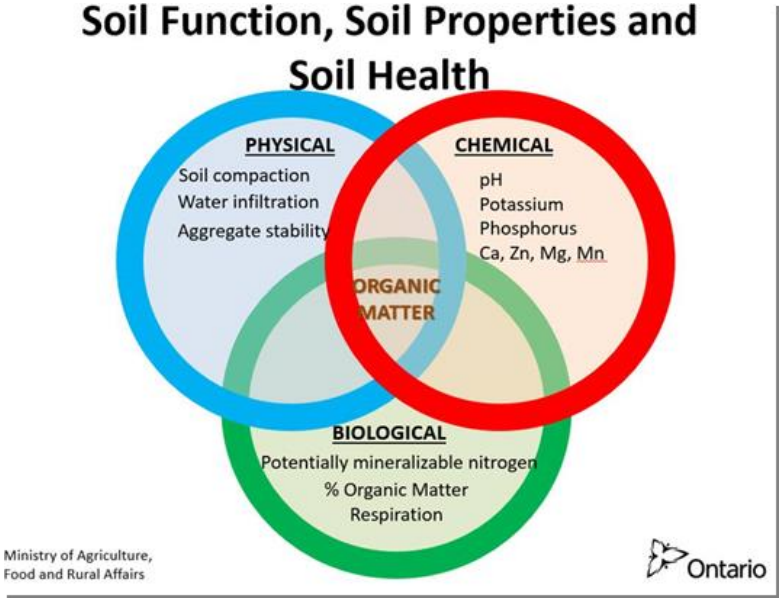
# Nature in Balance

Image of Wolf Lake (Temagami ON) by Rob Nelson | http://www.savewolflake.org/ | http://www.robnelson.ca/

- Nature is a self-powered, self-balancing, self-correcting system
- The foundation of this durability is the intimate relationship between green plants and soil
- Life is incredibly durable
- Recovery and Adaptation are limited by only One Factor: Time

- Soil Organic Matter (SOM): we will explore the Green Ring below, and reveal its importance.
- Dynamic Microbial Communities, and a cascade of Micro and Macro-Fauna Foragers play a key role in soil (and plant) health.
- These are a vital part of SOM in healthy soils



# The 5 Essential Elements in Balanced, Undisturbed Soil Ecologies

1. Photosynthetic Plants (a Green Plant Community)
2. Mycorrhizal Fungi (Symbiotic Root Partnerships)
3. A Mix of Soil Biota (Bacteria, Protists, and Beneficial Foragers)
4. Plant and Other Organic Residues (Soil Respiration / Water Cycling / Increase CEC)
5. Soil Parent Material (the Mineral Nutrient Supply Reservoir)

# Essential to Soil Health: 1. Green Plants

1. Photosynthetic Plants (a Green Plant Community)
2. Mycorrhizal Fungi (Symbiotic Root Partnerships)
3. A Mix of Soil Biota (Bacteria, Protozoa, Beneficial Foragers)
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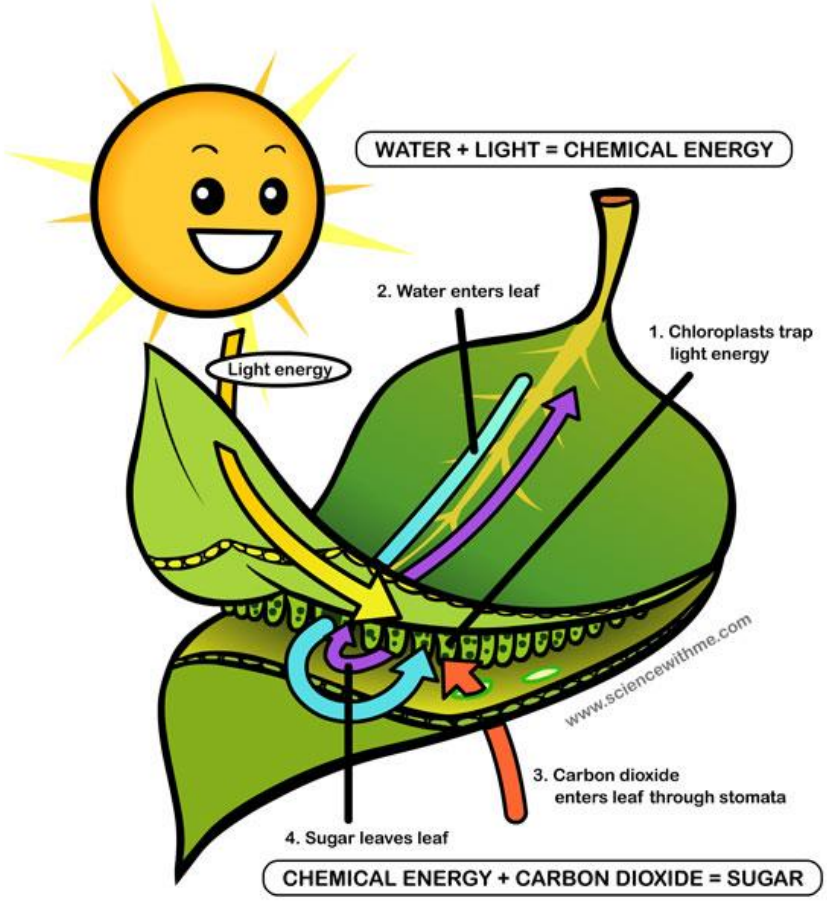
# The Power of Green Plants

## The Engine that Powers All Life on Earth (Including The Unseen Life In Soils)



# Ancient Earth – Rock, Oceans, and Tidepools

## And in those tidepools, single-celled organisms begin competing for food - and dominance

- A winner would emerge from the primordial soup

# The Primordial Leap Forward

## It all began - with a Bad Case of Indigestion

- Captured and protected inside an ancient cell, the Clorophyta flourished (and so did it's captor)
- The hitchhiker gave the cell the ability to feed itself – **Bingo!**
- World domination was just around the corner

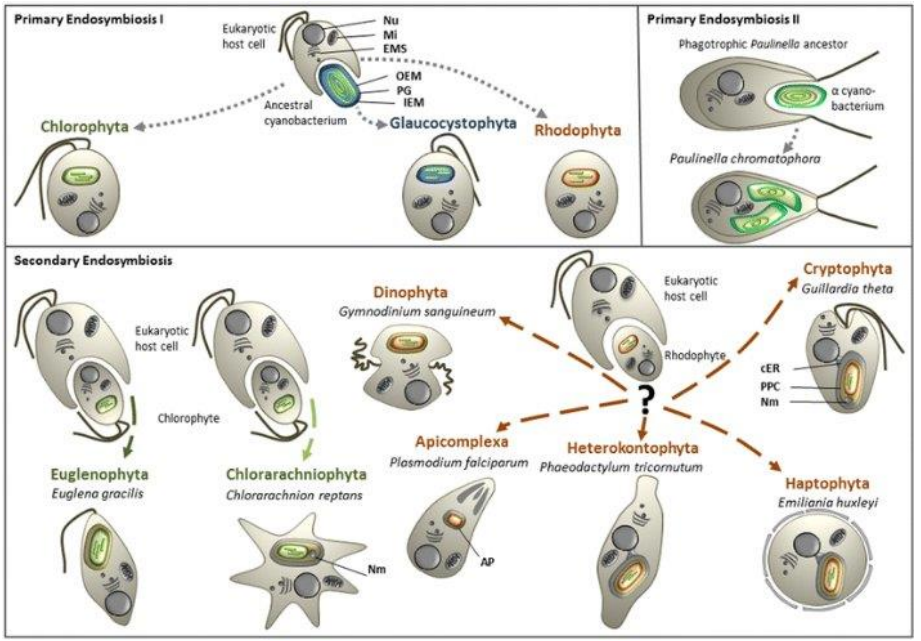



Image by: Gentil, J., Hempel, F., Moog, D. et al. Protoplasma (2017)

# Blue-Green Algae Changes our Earth

## The Chlorophyta Hitchhiker inside the ancient Cyanobacteria propels this microbe to planet-wide dominance.

- But – its waste product (Oxygen) would ultimately drive it to near-extinction

# Planet Earth becomes Green

## Photosynthesis Changed the World

- The captured Chlorophyta eventually became part of the DNA of its host cell
- Today we call these amazing organelles inside of all green plant cells ‘Chloroplasts’
- Green Plants continue to supply the atmosphere with a very important waste product - Oxygen

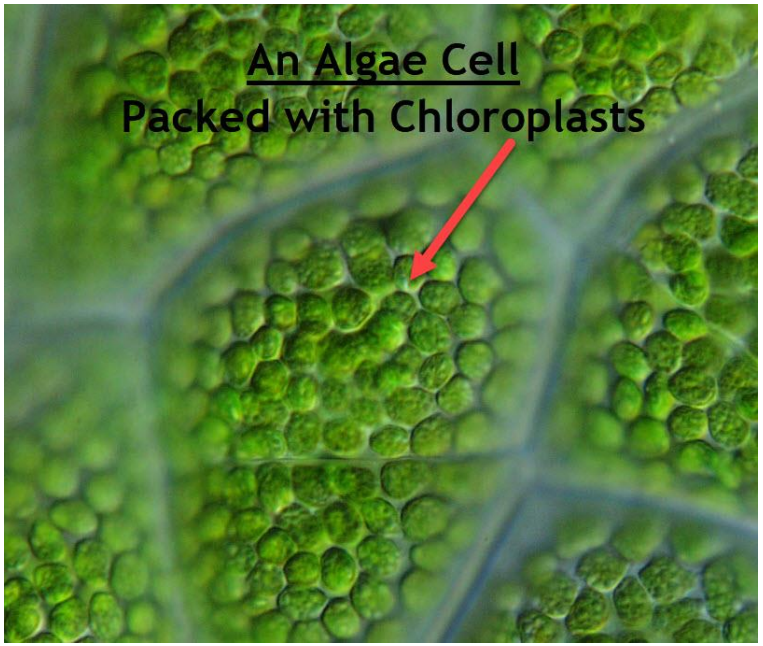
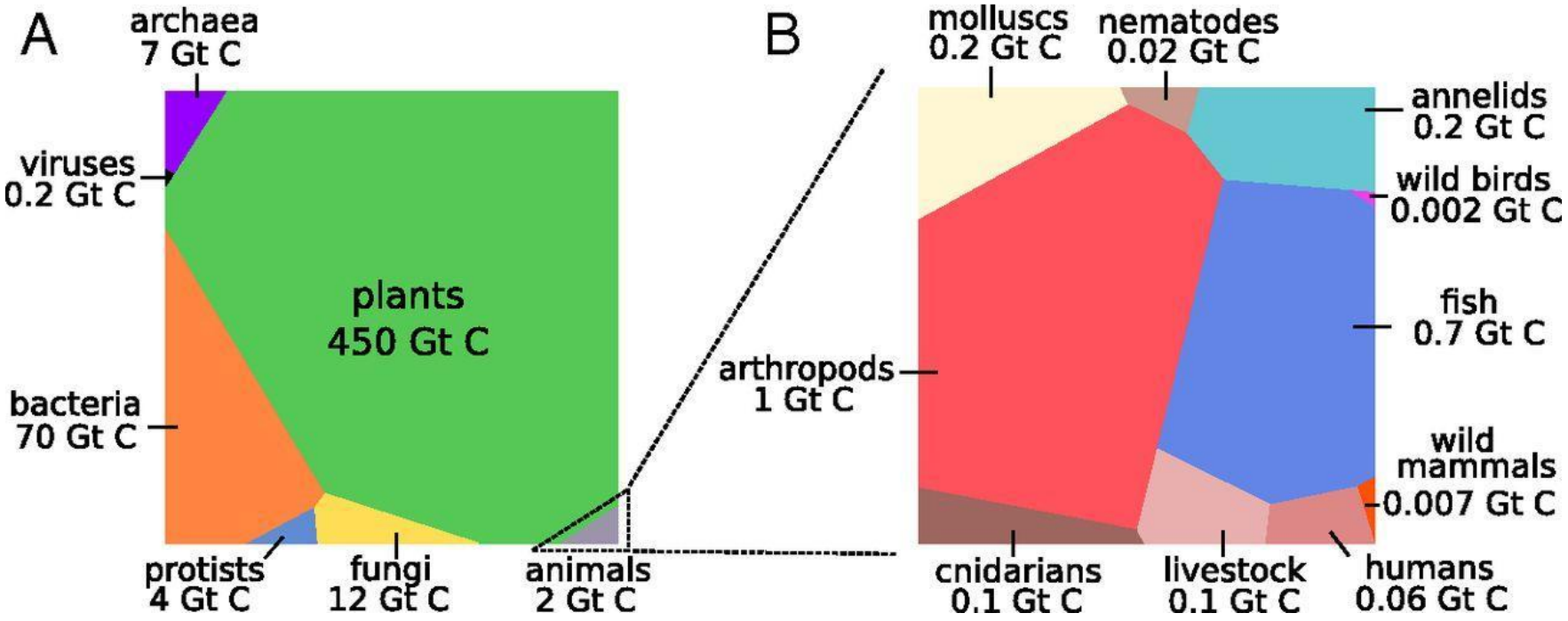



Image by: Gentil, J., Hempel, F., Moog, D. et al. Protoplasma (2017)

# Which Lifeform Dominates Earth?

## Photosynthetic Plants: **80%** of Earth's Biomass

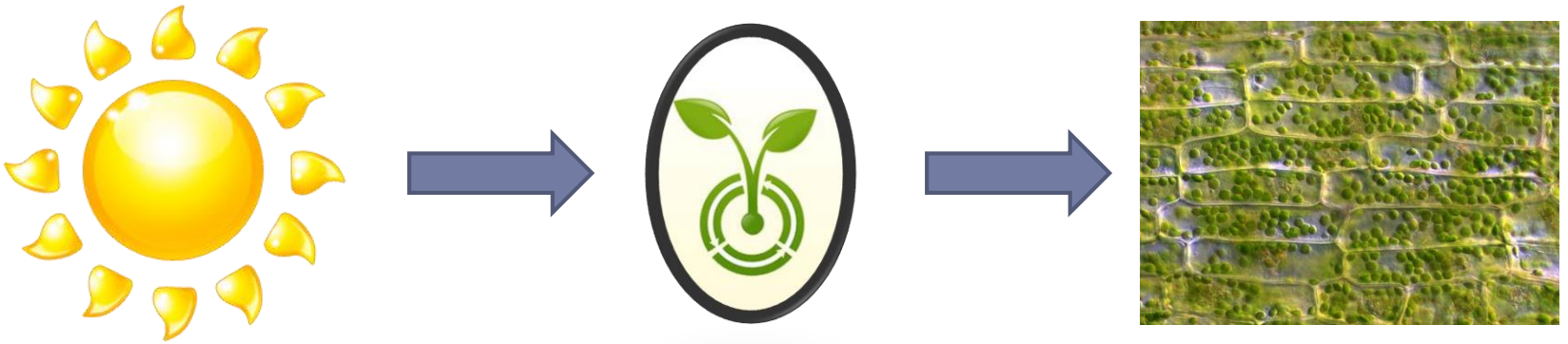



**"Gt C" = Gigatons of Carbon**

Diagram courtesy of: The Smithsonian Institute

# Exudates – The Fuel That Powers Life In Soils

- **Chloroplasts produce 40% More Sugars than a plant needs to grow**



**Carbon Compounds Produced Through Photosynthesis**

**60%**

Used to Grow

**Used by the plant to grow and reproduce**

**40%**

Exuded to form Partnerships

**Traded to beneficial soil microbes in exchange for nutrients, water and other work**

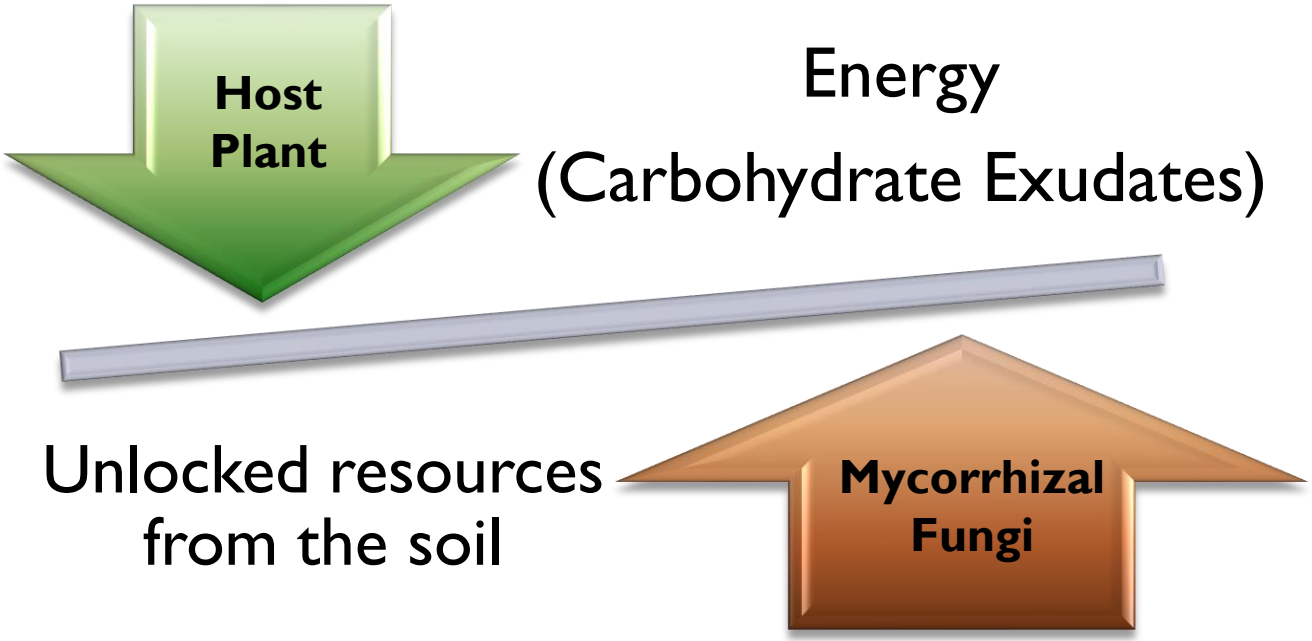
Elodea canadensis image by: Dr. Ales Kladnik

# How Do Plants Spend Their Carbohydrate Surplus?

- Why do plants exude their surplus of carbon photosynthates (sugars etc.) into the soil environment?
- What soil organism benefits most directly from the carbohydrate surplus?
- What do plants get back in return?

# The Natural Trading Partnership

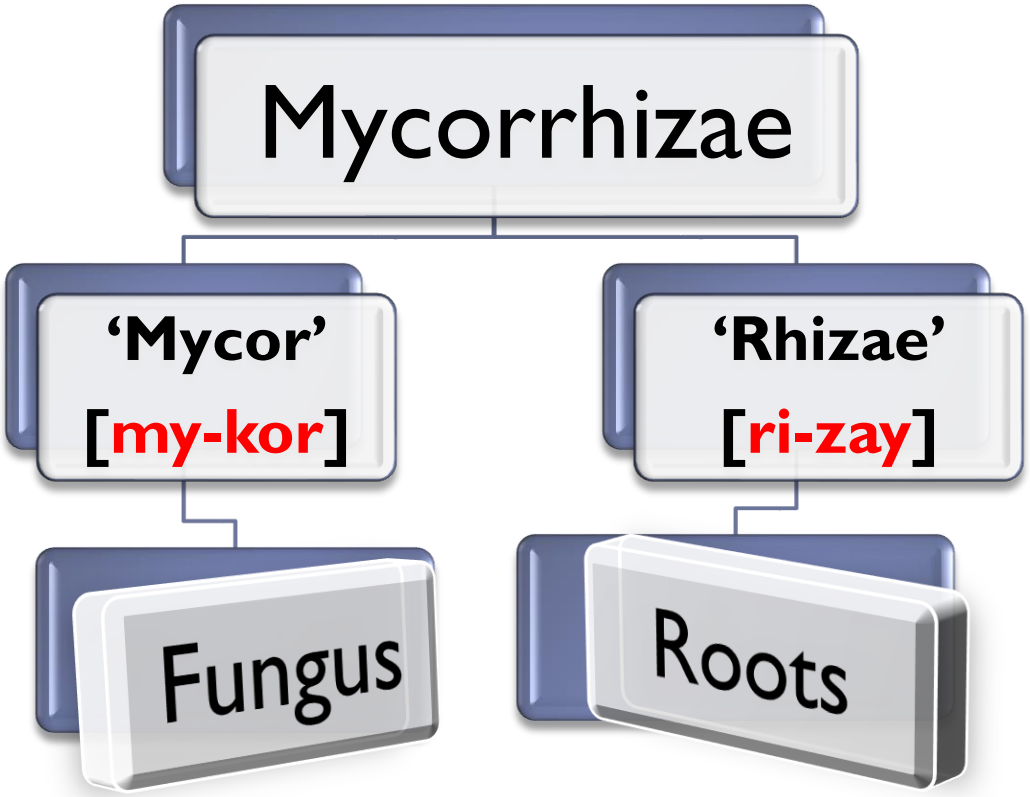
- **1/3** of all Photosynthates are given to **<u>Mycorrhizal Fungi</u>**
(via various carbohydrate exudates)



# Essential to Soil Health: 2. Mycorrhizal Fungi

1. Photosynthetic Plants (a Green Plant Community)
2. Mycorrhizal Fungi (Symbiotic Root Partners)
3. A Mix of Soil Biota (Bacteria, Protozoa, Beneficial Foragers)
4. Plant and Other Organic Residues (for Nutrient Cycling)
5. Soil Parent Material (a Mineral Nutrient Supply Reservoir)

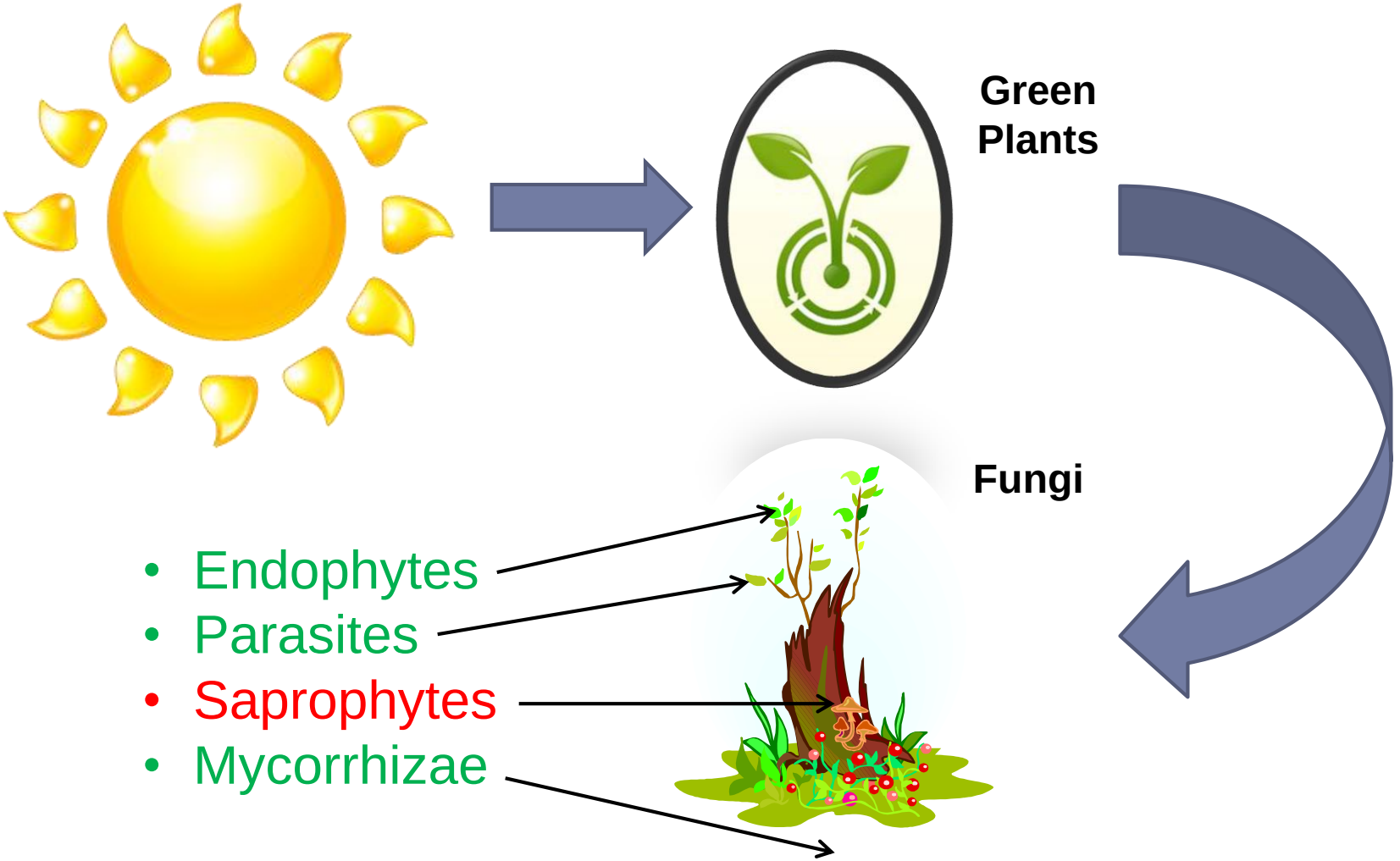
# How do you say that?




- **In undisturbed nature, 95% of plants form a unique partnership with ancient fungi. Mycorrhizae help plants find water and nutrients in soil (and more).**

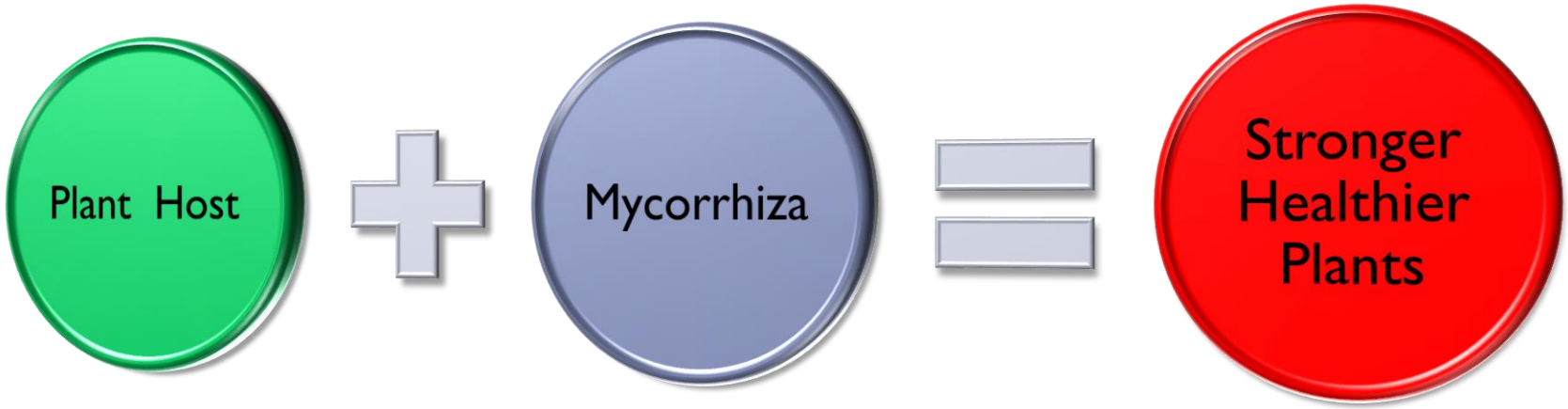
# Energy (Carbon) Acquisition by Fungi

- Fungi acquire carbon energy from either Living or Dead hosts



# Symbiosis = Success

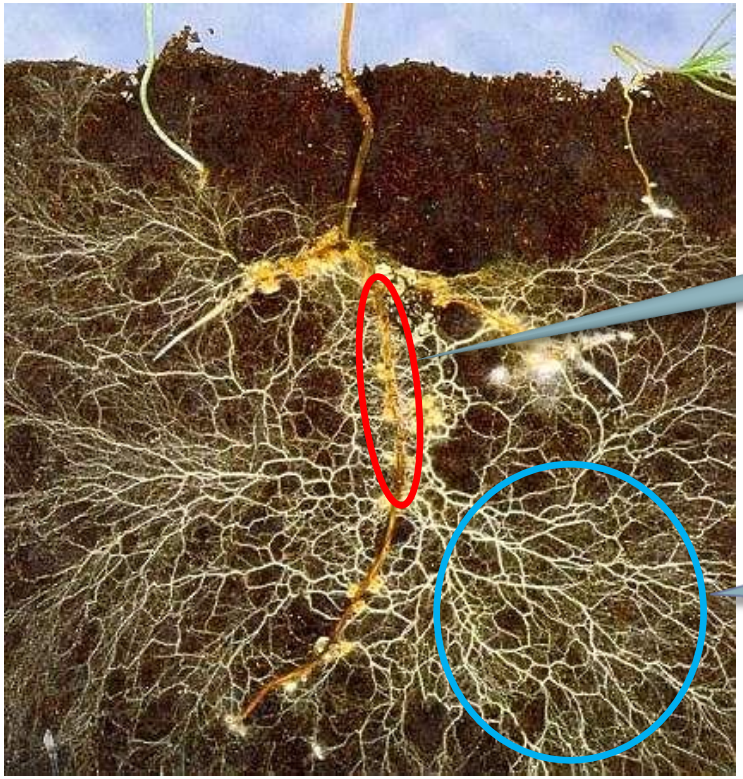
**symbiosis** (noun) "the living together of two dissimilar organisms, as in mutualism…"
**mutualism** (noun) "a relationship between two species of organisms in which both benefit from the association."




**Achievement Through Co-operation**

# Let's Look Closer…

- Only **1** to **3** % of soil volume is roots
- Mycorrhizal hyphae can increase this density to **20%**



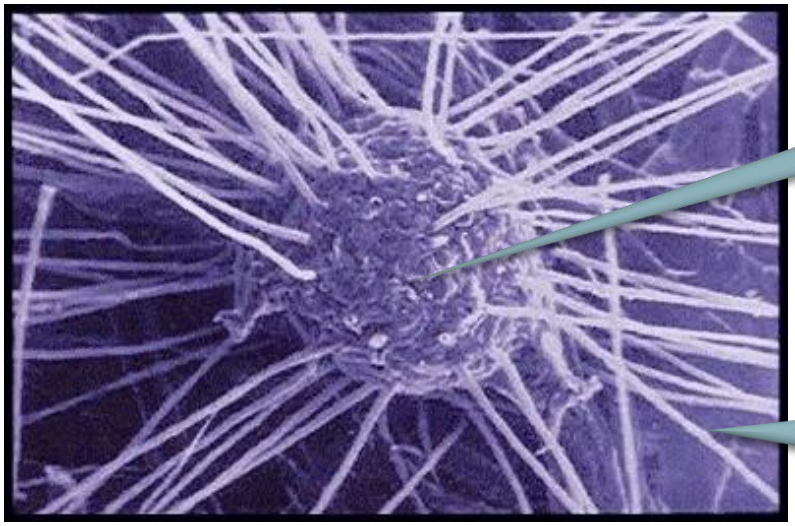
Host Root

Mycorrhizal Web (Hyphae)

Pinus sylvestris & Suillus [ECM]
Image c/o S.E. Smith / D.J. Read

# Looking Even Closer…

Now that's small!



A Root Hair Tip

Mycorrhizal hyphae

- The only absorptive surface that a root has is the root tip

# The Nutrient Depletion Zone is Expanded 100 to 1000 Times Over by Mycorrhizae

- Mycorrhizal mycelium increase the absorptive surface of roots by adding the Mycorrhizosphere to the Rhizosphere

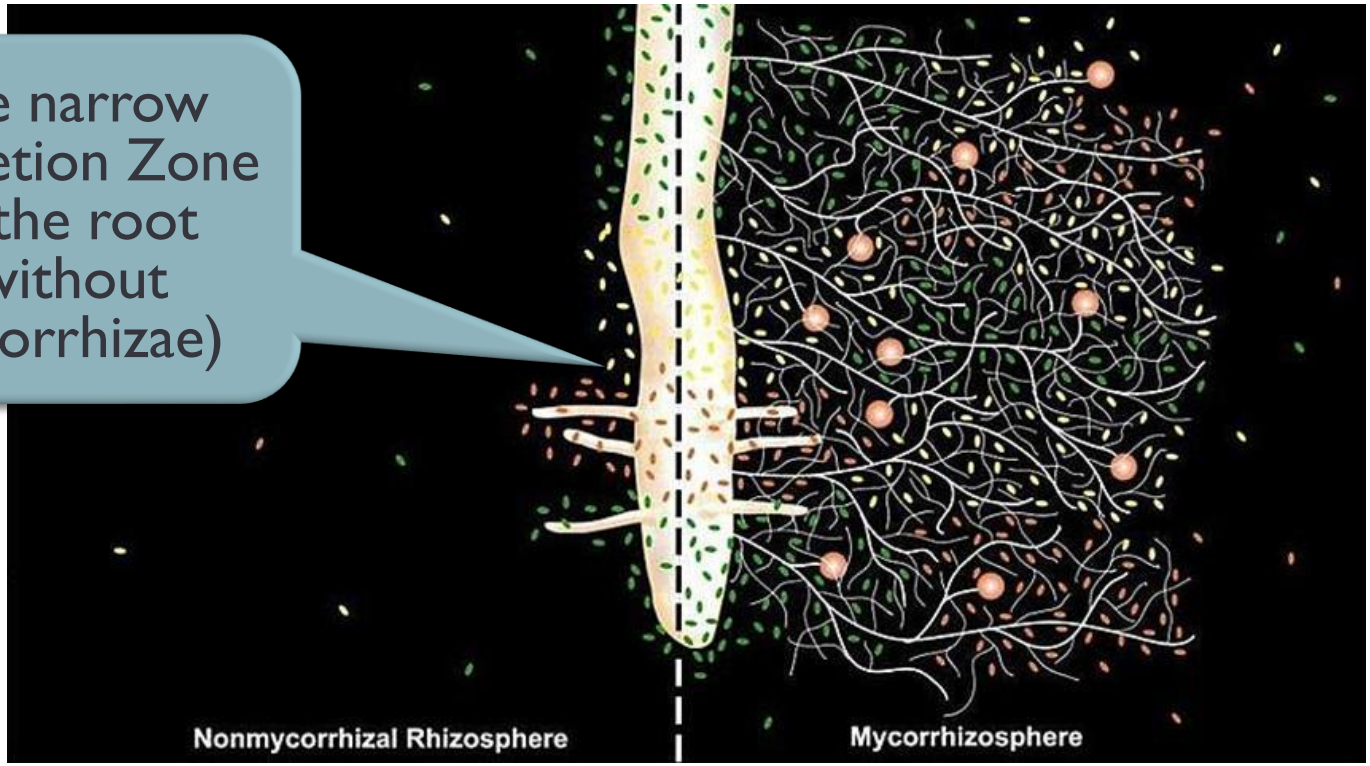
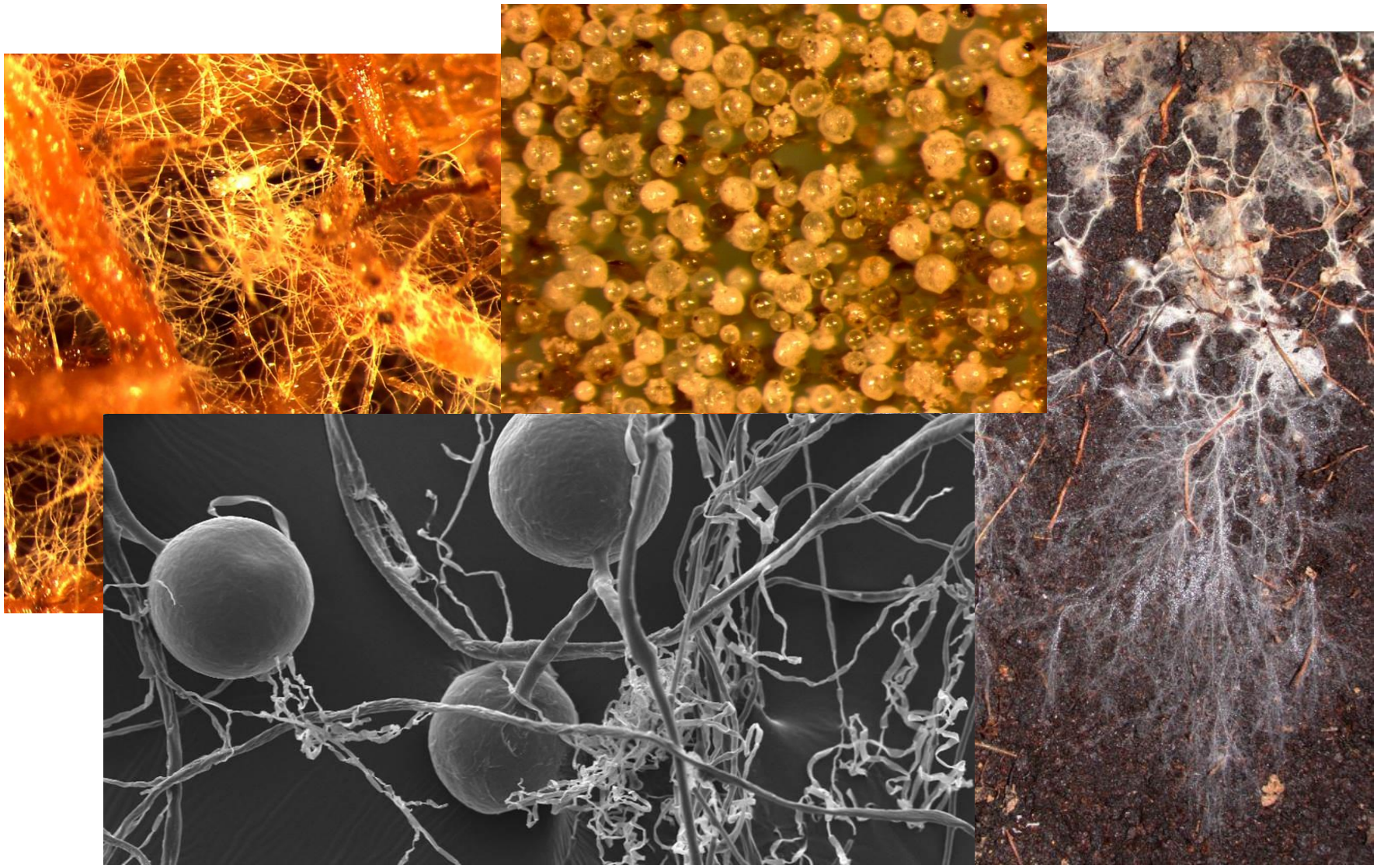
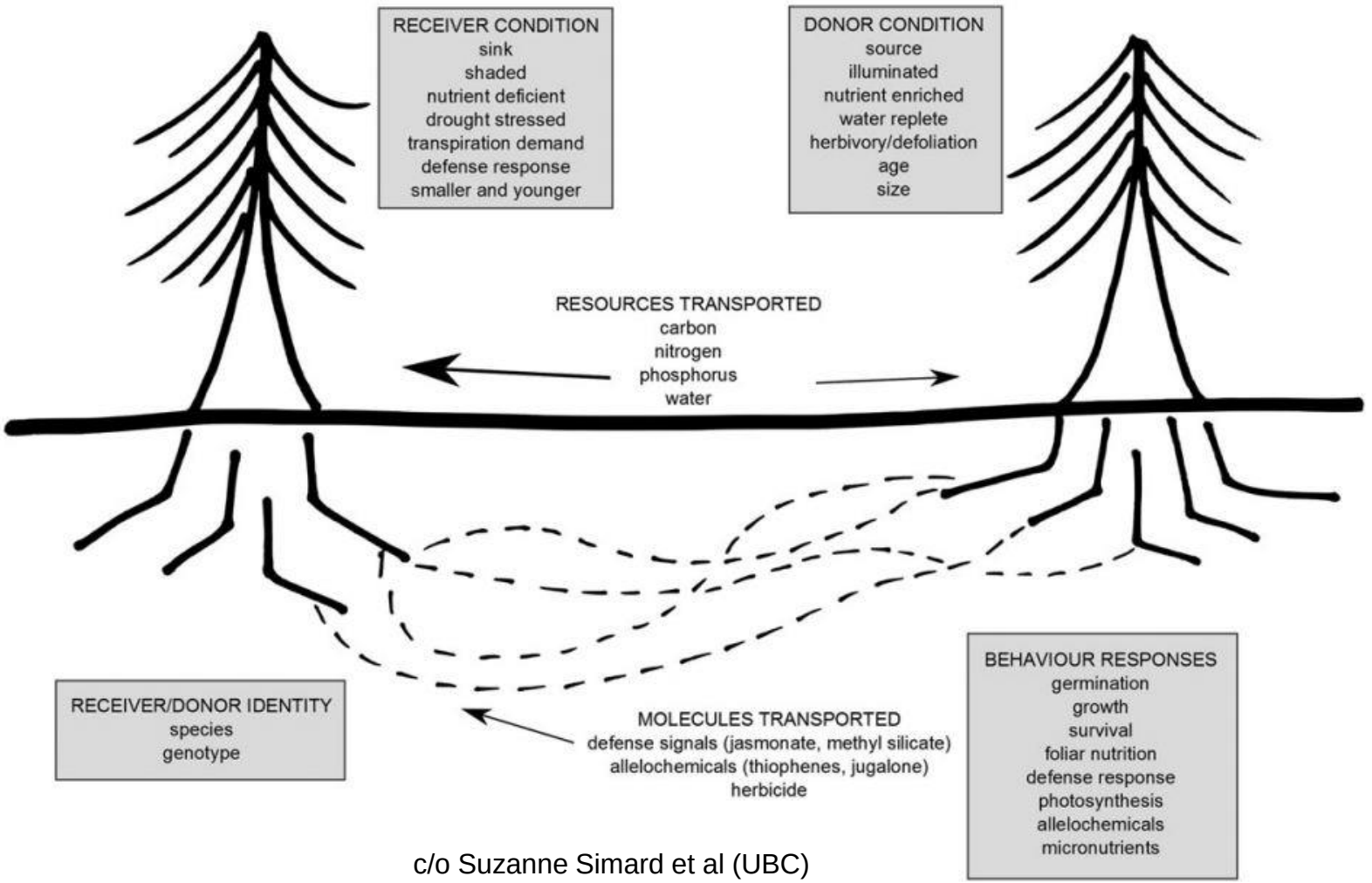



Image c/o Paul Kuttner 2015 / www.culturalorganizing.org

# The Root's Fungal Workforce



# The Sharing of Assets (and Information) through the Mycorrhizal Network




c/o Suzanne Simard et al (UBC)

# A Plant Chooses Its Mycorrhizal Partners

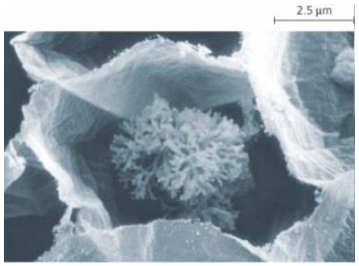
95% of landscape plants associate with 2 classes of mycorrhizae:

**Endomycorrhizae**

**Ectomycorrhizae**

# Endo vs. Ectomycorrhizae

An Arbuscule [AM]




Endomycorrhizae [AM] enter a root cell of the host plant and build a tree-like Arbuscule ***inside cortical cells*** where nutrients, carbohydrates, and water are exchanged.

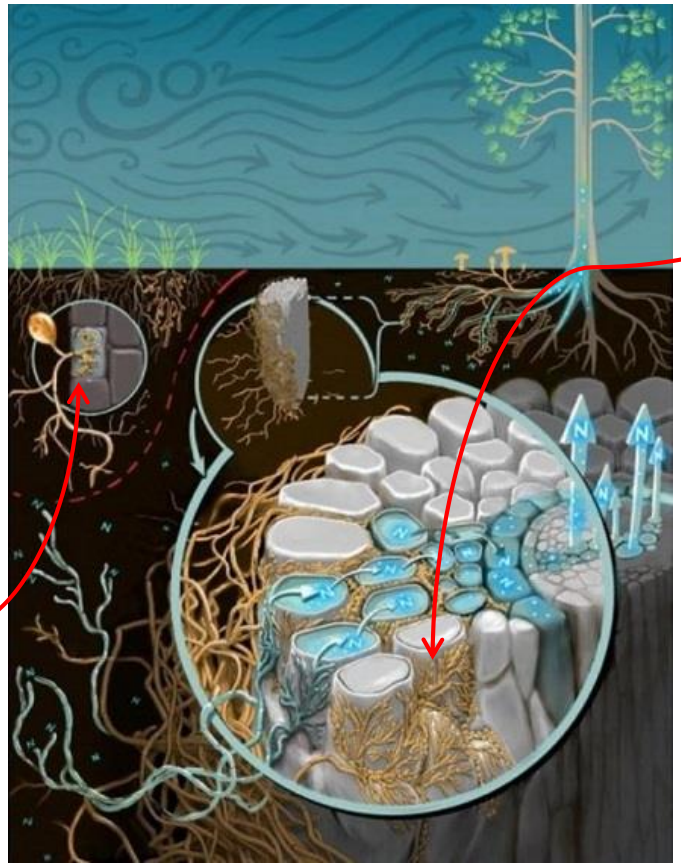
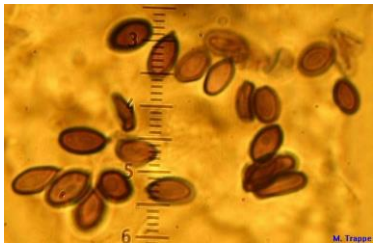


Image by: Victor O. Leshyk

Ectomycorrhizae [ECM] build a dense fibrous latticework of Hyphae called a 'Hartig Net' ***between and on the outside*** of the host plant's root cells where assets are exchanged through the cell wall membrane

ECM Spores



# Landscape Plants choose between these Mycorrhizal Types

**ENDO**

- Herbaceous Perennials
- Ferns, Grasses,
- Woody Shrubs (Incl. Juniper, Cedar, Yew)
- Softwood Trees (Maple, Prunus, Malus, Pyrus…)
- Vegetables, Grains

**ECTO**

- Conifers (Spruce, Pine, Fir, Hemlock, Larch…)
- Hardwood Trees (Birch, Beech, Oak, Ostrya, Poplar…)
- Nut Trees (Hickory, Hazel...)

# The Oldest Trees East of the Mississippi rely on mycorrhizae for both water and nutrients

- "The Snake" (Thuja occidentalis) Date of Birth: 795 AD

This ancient Eastern White Cedar is growing in a 5mm crack in the face of the Niagara Escarpment near Lion's Head Ontario.

**As of 2019, The Snake is 1,225 years old**

Image by: Peter E. Kelly | from "The Last Stand" P.E. Kelly & Douglas Larson | Natural Heritage Books 2007

# Essential to Soil Health: 3. A Consumer Culture

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2. Mycorrhizal Fungi (Symbiotic Root Partnerships)
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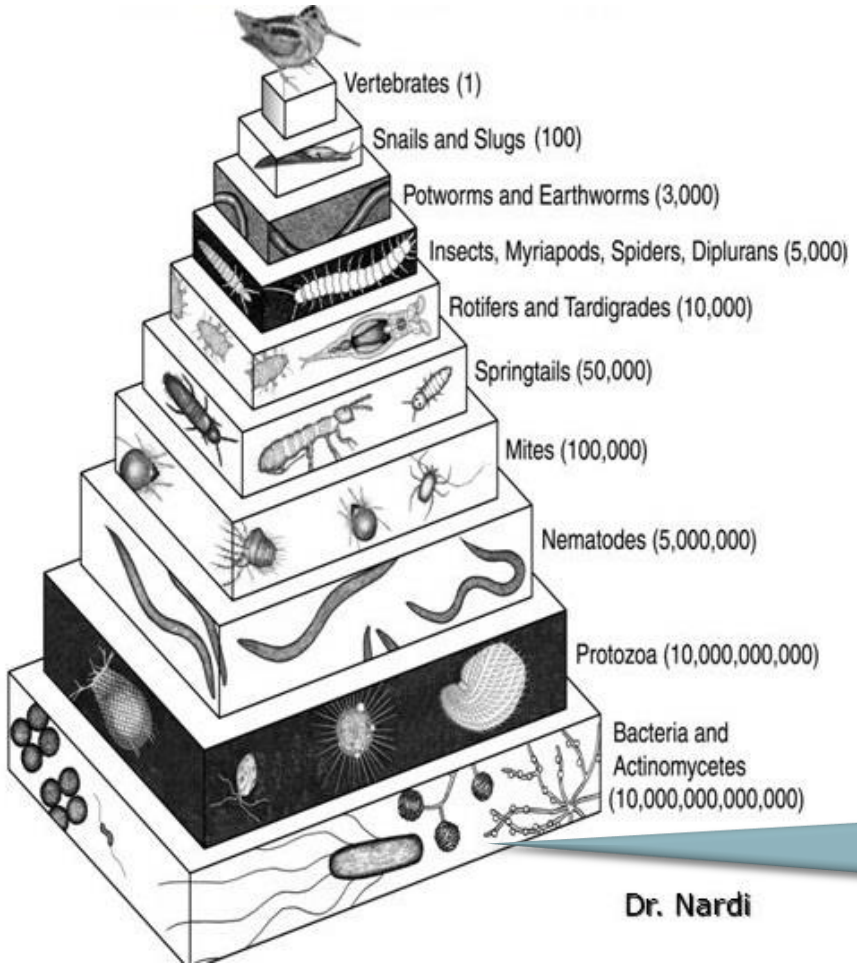
# Soil Microbes and Progressively Larger Foragers

- Healthy soil is teaming with a mixed community of countless billions of individual organisms – both single-celled and complex

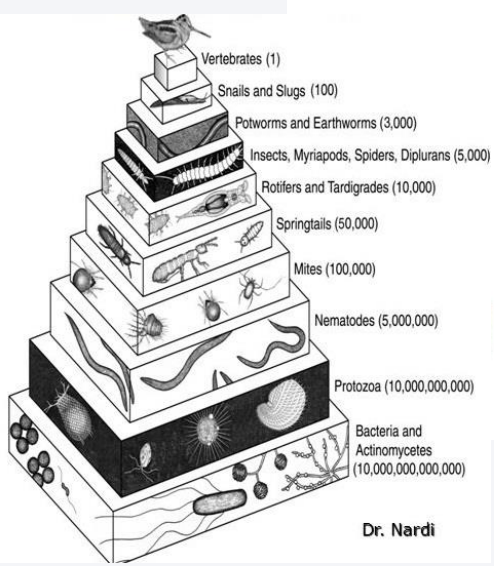


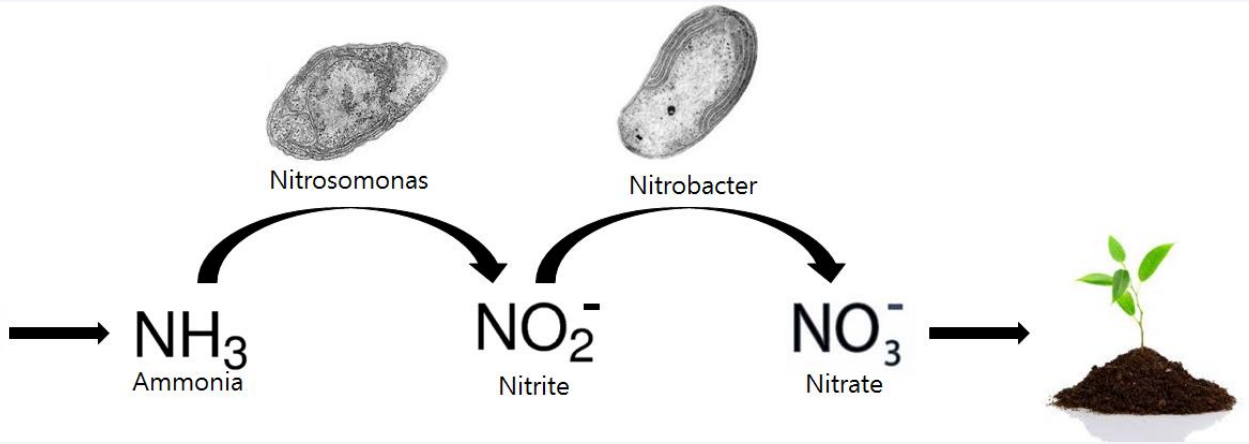

The 9 Trophic Levels of Life in Healthy, Undisturbed Soils

The bottom of the pyramid supports all soil life

# Nothing in a Healthy Soil Environment is ever wasted – <u>Especially Waste</u>

The zillions of creatures foraging (and perishing) in in healthy soils produce copious amounts of Ammonia ($NH_3$)

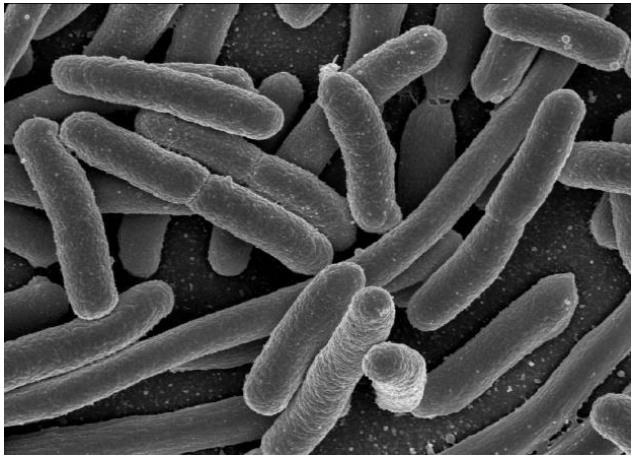



Bacteria convert this abundant Nitrogen resource into Nitrate ($NO_3$)

# Bacterial Colonies Exploit any source of Carbon

In the presence of scant water (just a Biofilm), within the right temperature range, bacterial colonies with rapidly multiply



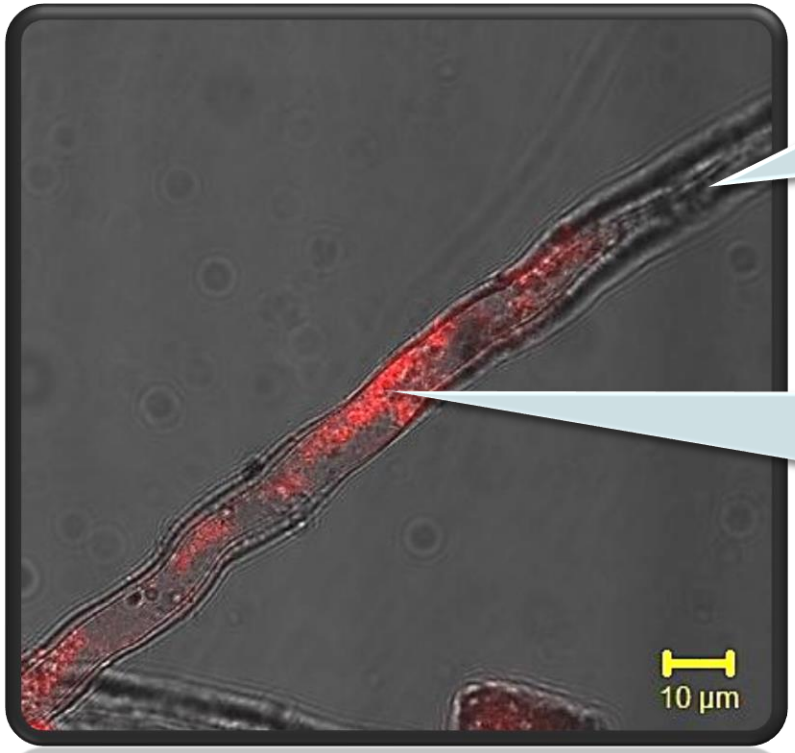
| Guaranteed Microorganisms | Minimum Count |
|---|---|
| *Bacillus subtilis* | $2.48 \times 10^8$ cfu/g |
| *Bacillus amyloliquefaciens* | $5.00 \times 10^6$ cfu/g |
| *Pseudomonas monteilii* | $1.00 \times 10^6$ cfu/g |

**CFU = Colony Forming Unit**

# Mycorrhizae move Water and Organic Nutrients to the roots of the host plant

- Macro and Micro Nutrients are transported to the roots in exchange for carbohydrates provided by the plant host

An $N_{15}$ Isotope in Soil Organic Matter fluoresces red on the way to the root




A hyphal (carbon) tube in the nutrient pipeline

Nitrogen is directly captured from bacterial colonies digesting SOM

Image from the publication: Nature

# Soil Microbes and Progressively Larger Foragers

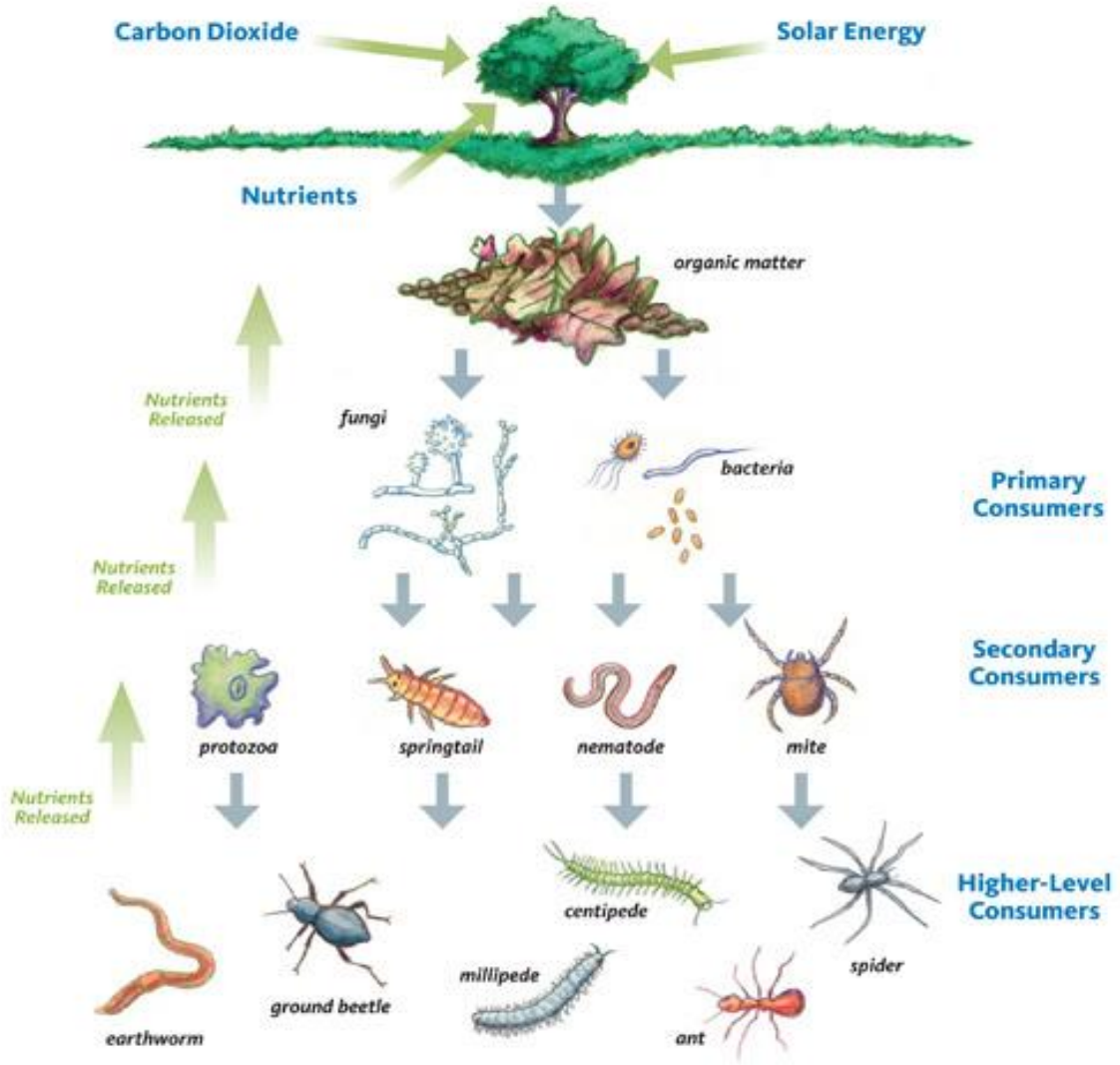



Image courtesy of: Landscapes For Life

It's all about
Who Eats What
(or whom)
and the Nutrient
Residues of all
that Activity

# The Soil Food Web & its Pipeline

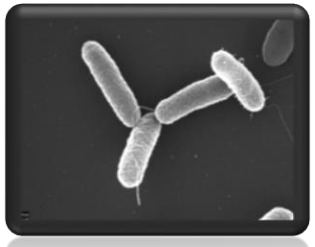
- Plant Roots exude surplus carbohydrates - Mycorrhizal networks are built
- Nitrogen digested by foragers is then converted into Plant Available Nitrate by bacterial colonies. Nitrate is also captured from Free Nitrogen Fixing bacteria – all flow to the roots through mycorrhizal hyphae (the living nutrient delivery pipeline)

**The Mycorrhizal Mycelial Network**

**Aerobic Foraging Bacteria (abundant in healthy soils)**

**Free Nitrogen Fixing Bacteria**

**Protozoa**
(Exude Ammonia)



**Nitrifying Bacteria**

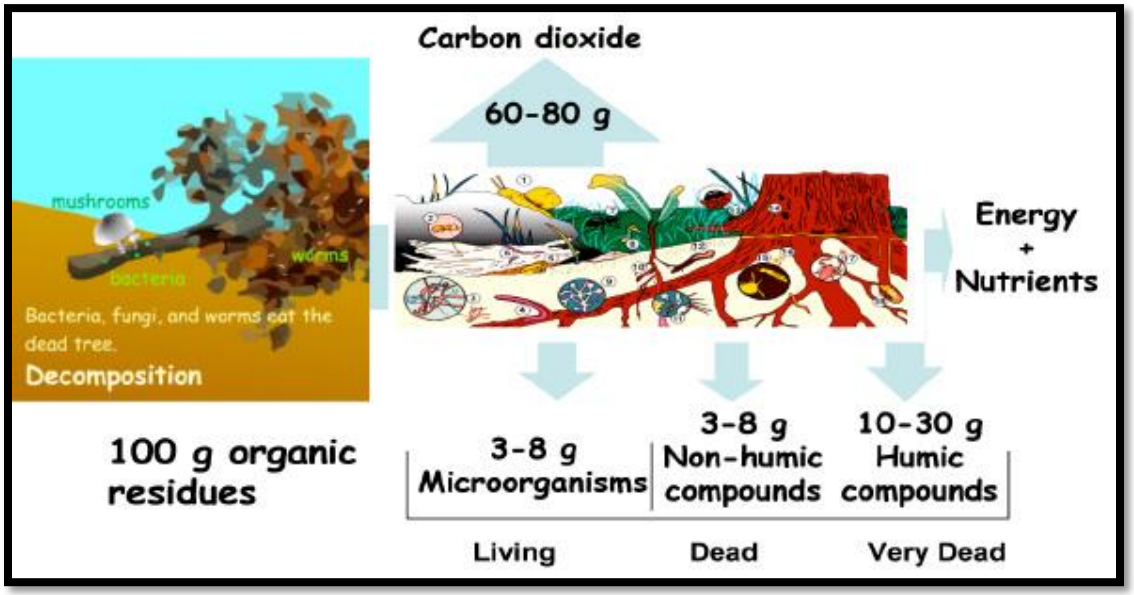
**PA Nitrate flows to the roots through the Mycelia**

# Essential to Soil Health: 4. Soil Organic Matter

1. Photosynthetic Plants (a Green Plant Community)
2. Mycorrhizal Fungi (Symbiotic Root Partnerships)
3. A Mix of Soil Biota (Bacteria, Protozoa, Beneficial Foragers)
4. Plant and Other Organic Residues (for Nutrient Cycling)
5. Soil Parent Material (a Mineral Nutrient Supply Reservoir)

# Soil Organic Matter [SOM]

- SOM includes: living microorganisms, fresh (recently dead) organic residues, plant roots, microbes, insects and animals, and very tough (long dead) organic compounds that resist microbial decomposition (humic compounds). These are the CEC 'Batteries' in soil that hold Nutrient Cations until needed by plants
- In healthy soils, billions of microbes digest and dismantle SOM, then root tips and mycorrhizal fungi transport the converted nutrients into plant roots

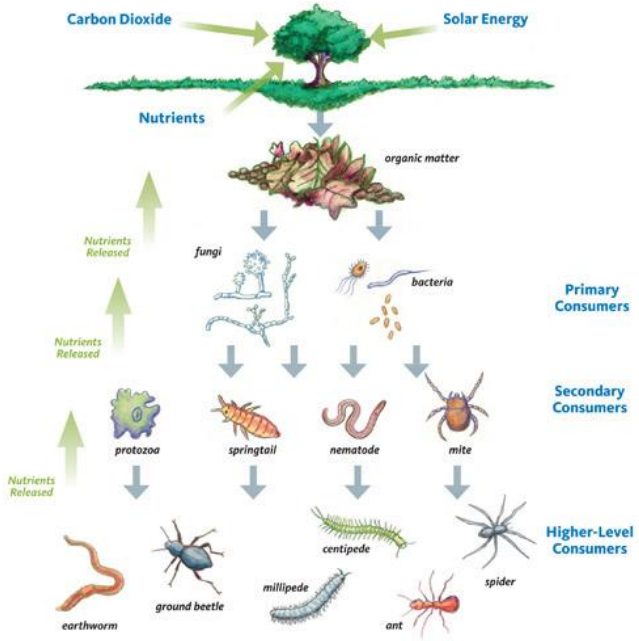



**CEC = Cation Exchange Capacity**

Diagram courtesy of OSU Fact Sheet SAG-16

# SOM and the C:N Ratio

- The Carbon/Nitrogen [C:N] ratio of organic residues (and particle size) will determine how quickly SOM can be cycled by soil microorganisms.
- In organically maintained landscape soils, Primary and Secondary Consumers, and Mycorrhizal activity can be maintained at a highly-productive pace. Resulting in <u>stable nutrient availability for plants</u>



# Essential to Soil Health: 4. Mineral Reserves

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4. Plant and Other Organic Residues (for Nutrient Cycling)
5. Soil Parent Material (a Mineral Nutrient Supply Reservoir)

# How do these ancient Red Pines get the nutrients that they need from the unyielding Granite of the Canadian Shield?

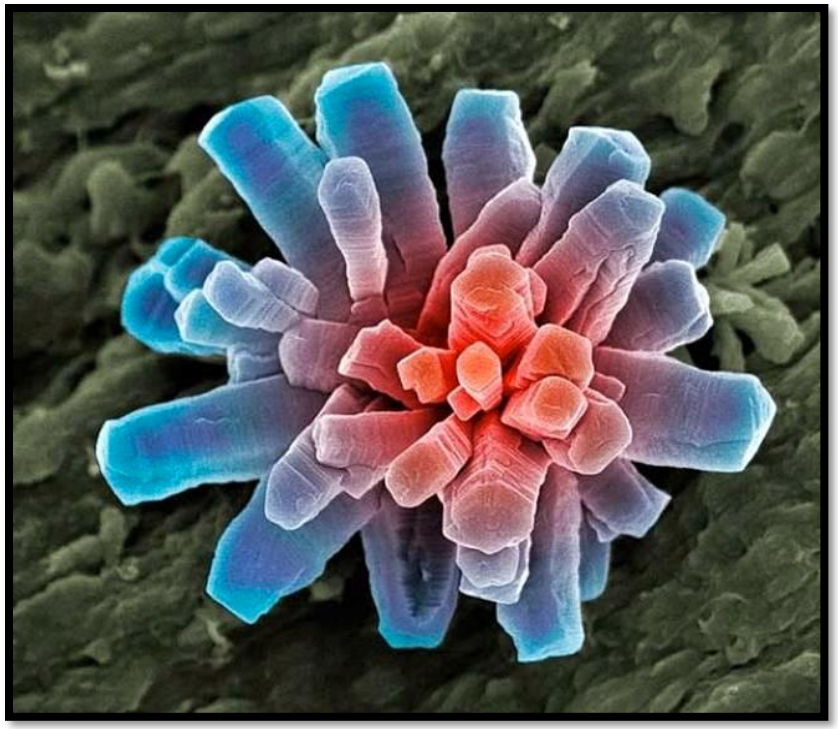
Image of Wolf Lake (Temagami ON) by Rob Nelson | http://www.savewolflake.org/ | http://www.robnelson.ca/

- Nutrients from mineral sources are obtained by plant roots through close associations with soil microbes and mycorrhizal fungi – these essential organisms solubilize minerals.

# A Very Close Look at Phosphate

- Mycorrhizae use enzymes (acids) to release tightly-bound nutrient anions

A calcium phosphate crystal 'bound' to a typical clay matrix

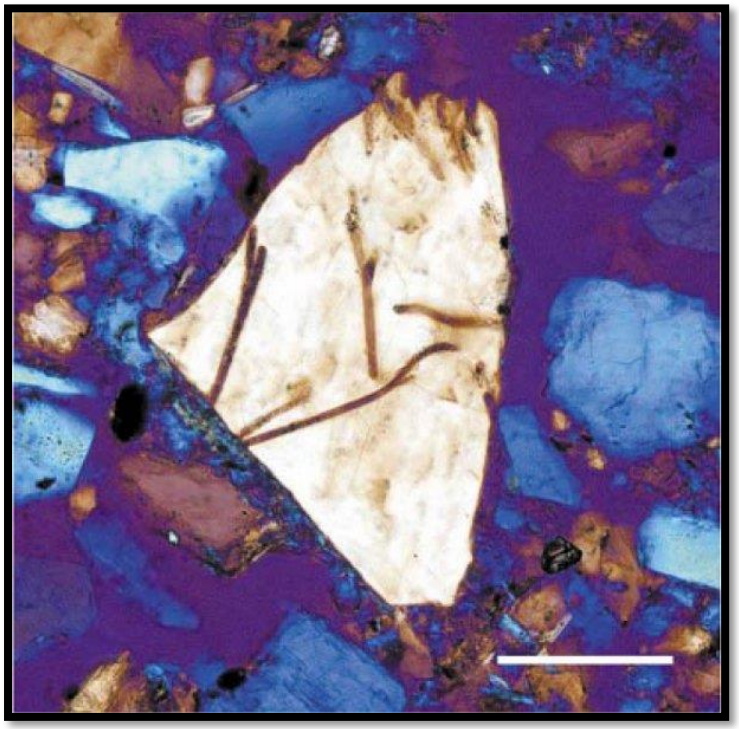


- Mycorrhizal hyphae inundate the parent material of soil and release bound nutrients
- Phosphatase enzymes exuded by mycorrhizal hyphae convert mineral phosphate to a Reactive (Plant Available) form and deliver it to the roots

# Mineral Mining in Action

- Mycorrhizal hyphae mining for minerals

A flake of feldspar showing grooves where hyphae 'bored' holes



- Phosphorus, potassium, calcium, magnesium, boron, manganese, zinc, iron, molybdenum, copper…
- Enzymes and acids exuded by mycorrhizal hyphae release and capture mineral macro and micronutrients needed by their plant hosts

Image by: Landeveert 2001
from Scientific American - by Jennifer Fraser

# Part 1: Summary

In Natural (Undisturbed) Soils all 5 of these essential elements are kept in balance

1. Photosynthetic Plants (a Green Plant Community)
2. Mycorrhizal Fungi (Symbiotic Root Partnerships)
3. A Mix of Soil Biota (Bacteria, Protozoa, Beneficial Foragers)
4. Plant and Other Organic Residues (for Nutrient Cycling)
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# Part 2

# Breaking Nature's Balance: The Factors that Disturb Urban Soils

# 3 Major Factors Disrupt Natural Soil Life:

1. Industrial Contamination (Toxins)
2. Construction and Cultivation
3. “Lazy Root Syndrome”

# Heavy Duty Damage

The fact that this kind of human activity harms the ecosystem is not hard to imagine. But, it doesn't take industrial-scale damage to harm soil ecology.

# What Gets Broken when we build?

## Topsoil is Stripped, Piled and Compressed

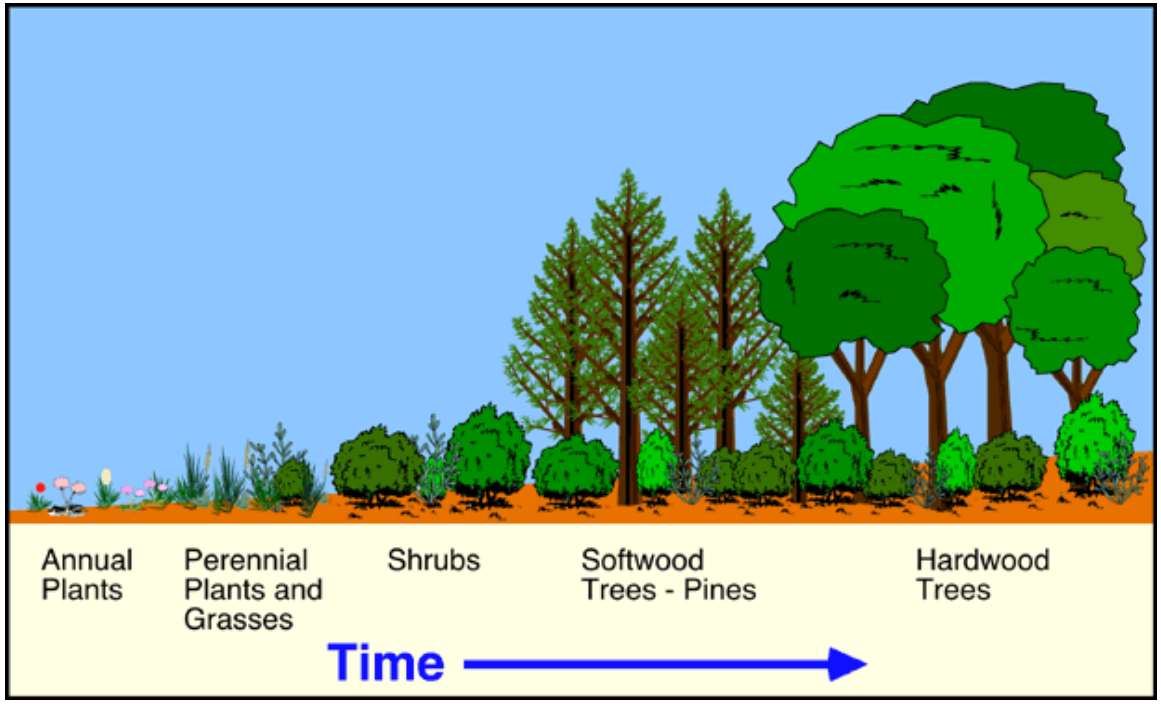
- Subsoil is raised by construction
- Heavy equipment compacts it all
- Desiccated organics drift in the wind

## Dust rises and the new streets look like a Western Ghost Town

- Eventually a thin layer of the crushed topsoil is spread over the compacted land
- Sod is rolled out and people move in

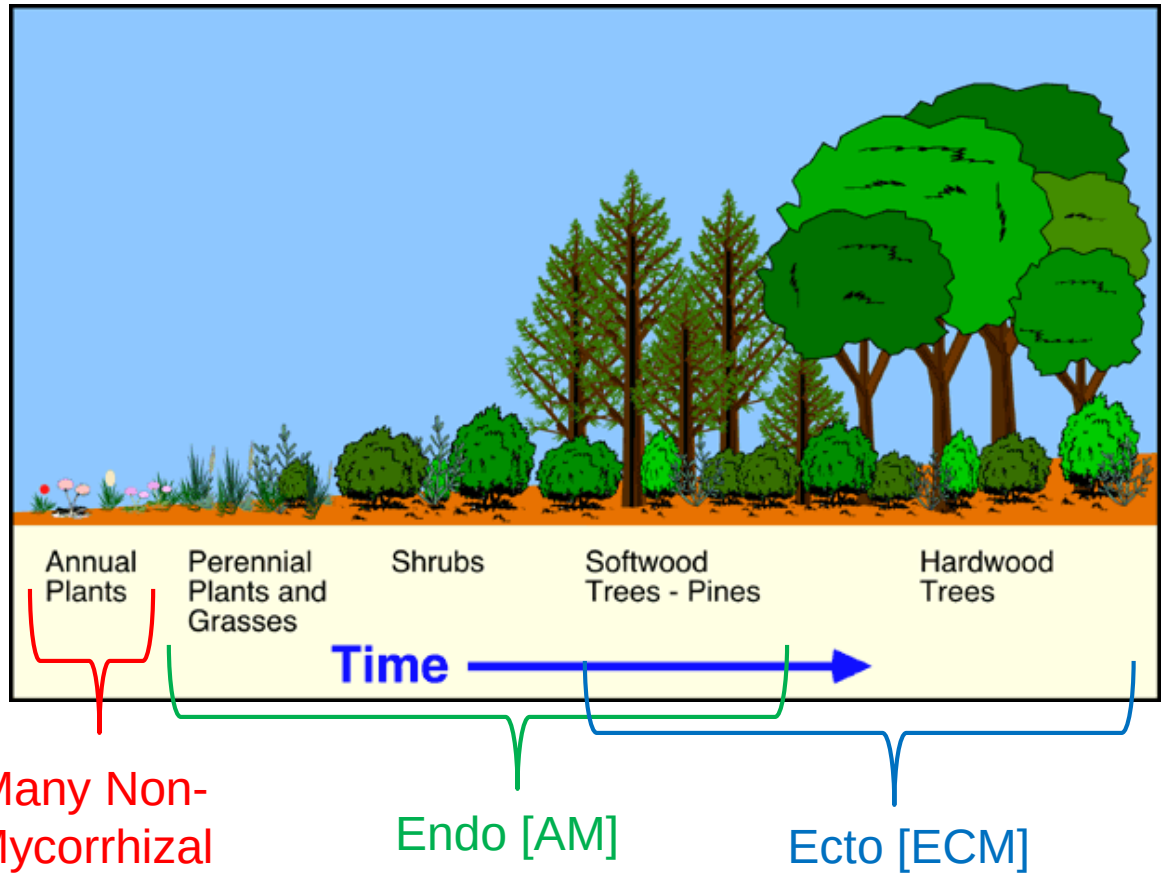
# Disturbed Soils are what Landscapers work with

- The soil on new construction sites are either sterile or bacterial, triggering aggressive infiltration of early-succession plants (weeds)
- But - we plant mid and climax-succession plants into these highly disturbed urban soils – no wonder they struggle to establish roots



# Mid & Climax Succession Plants struggle in Disturbed Soils

- Plants installed into the disturbed soils on landscape sites need mycorrhizal partnerships and nutrient producing microbial communities to function optimally
- **Assist Plant Adaption in disturbed soils.** Apply: Mycorrhizae matched to the plant host (Endo/Ecto) + Bacterial Colonies proven to provide nutrients



# Synthetics Switch-Off Natural Soil Life

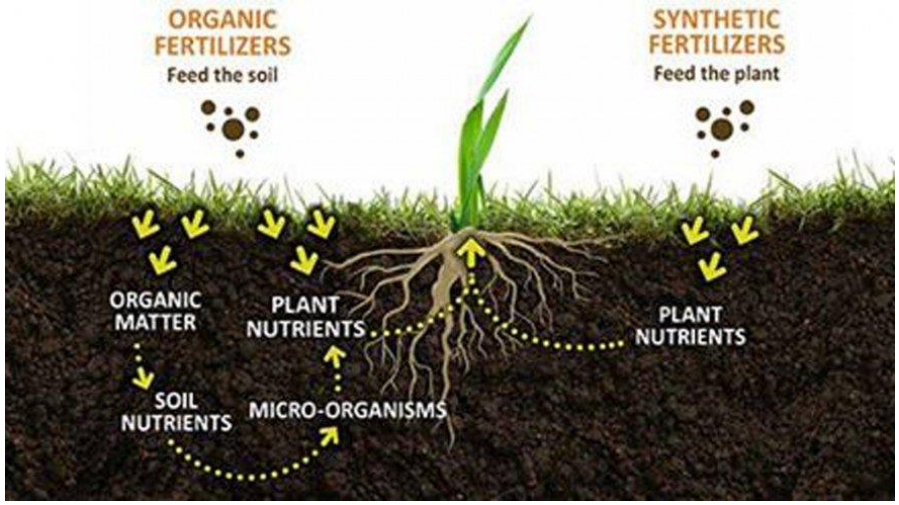
- Plant roots do not metabolize synthetic nutrients efficiently
- Leachates are a major environmental problem
- And - Plants abandon (stop feeding) their mycorrhizal/microbial partnerships. This is called "Lazy Root Syndrome".
- Soils become lifeless, shallow, compacted and unstable

# Synthetic Fertilizers Work – But…

- Synthetic Fertilizers Feed the Plant (via salt-based chemistry)
- Whereas, Organic Fertilizers & Bio-Fertilizers Feed the Soil

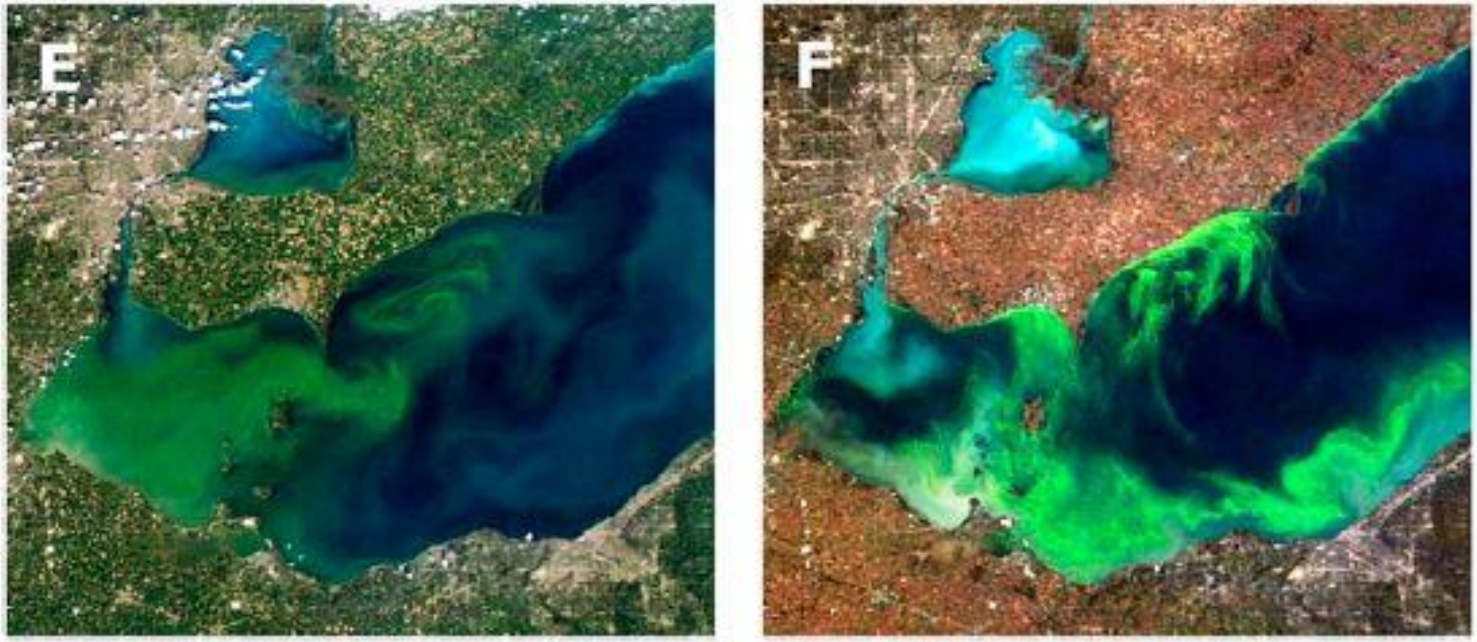
So, when we use Synthetic Fertilizers:

1. The microbial life in soil is starved-out (and their benefits are lost)
2. Plants have not evolved to directly access nutrients – they are only about 20-25% efficient at this task. As a result, 75-80 % of applied synthetic fertilizers escape as highly-reactive leachates



# Where do synthetic phosphates end up after leaching from fields and landscape soils?

- The Lake Erie toxic algae bloom as seen from space in Fall 2011
- According to the IJC, this annual algal bloom is created by a sustained runoff of Dissolved Reactive Phosphorus [DRP] from the watershed




Images from: International Joint Commission (2014). Report: A Balanced Diet for Lake Erie…

# Plants Roots do not Metabolize Dissolved Reactive Phosphate Efficiently

- Only 20% of applied synthetic phosphate is absorbed by plant roots – **80%** escapes into the environment – the consequences are far reaching
- Plant roots 'bathed' in synthetic nutrients develop "Lazy Root Syndrome"
- Plants stop supporting mycorrhizal fungi and the soil biome – and become dependent on continued synthetic fertilizer applications.

Image from: International Joint Commission (2014) Report: A Balanced Diet for Lake Erie

# We Can Restore the Benefits of Soil Microbial Life on Landscape Sites

- **An organically maintained landscape site.** Mycorrhizal Networks and Microorganisms below grade supporting a diverse plant (and soil life) community
- No leaching of valuable plant nutrients into groundwater and streams
- Survival rate on this Zone 5a site in Caledon (2015-2016): **100%**

Image courtesy of Reevisions Designs and Doug McClure Land Services (2015)

# Part 3: Re-establishing Natural Soil Ecology on Urban Landscape Sites

Image of Wolf Lake (Temagami ON) by Rob Nelson | http://www.savewolflake.org/ | http://www.robnelson.ca/

- We can learn from the way natural soils function
- We can re-establish/restore natural soil structures and biology on urban landscape sites
- The environmental and economic benefits are real

# Does Restoring the Mycorrhizal Population Help When Planting?

**How do we know that Inoculation with Compatible Mycorrhizal Fungi works?**

- 4 years of testing by the University of Guelph
- The latest technology was used


# Replicate – then – do it again!

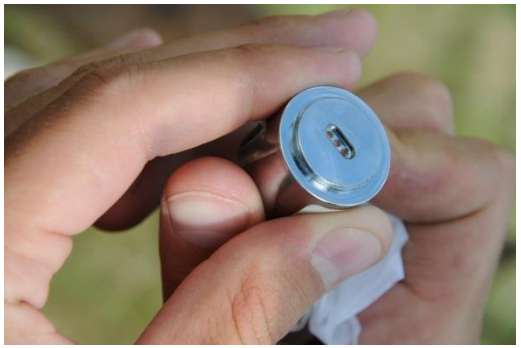
- Stem Psychrometers simultaneously reporting the stress levels of 32 trees
- Half were drenched with Root Rescue Transplanter – half were just watered
- Stress level data was collected every 30 minutes, 7 days a week


# Research Supports Biological Plant Care

UNIVERSITY of GUELPH

- Stem Psychrometers are attached to the trunk of a tree by scraping away a small amount of bark – exposing the Xylem layer – the pipeline from the roots.

Expose the Sapwood



Check the Sensor

Attach the Sensor

Seal the Connection

Attach the Datalogger

Insulate the Sensor

# Graphing Water Status (Stress) - 24/7

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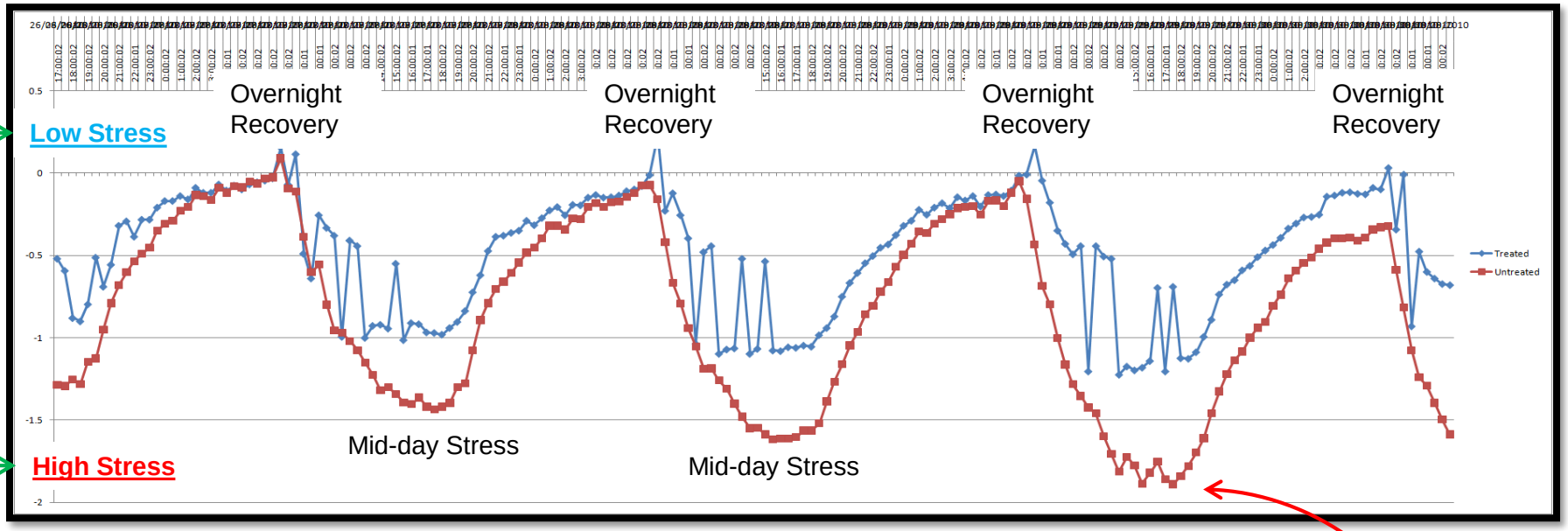
The data sample in this graph presents the average water status of 6 treated vs 6 non-treated Dawn Redwood

## Four Days Without Rain – a Pattern Emerges




- The Daily Rhythm of Stress and Recovery
- Blue trees were Transplanter inoculated
- Red trees are fending for themselves
- The Dangerous Dip

# When the Going Gets Tough the Mycorrhizal Advantage Kicks In

- Chanticleer Pear
- Stress takes its toll

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- U of G Research published in ‘Acta Horticulturae’ in 2015
- Publication available for download at: http://www.rootrescue.com/site/university-of-guelph-data

# Use the New Tools

## Inputs that Promote Healthy Soil Life

- Inoculate Plant Roots with Compatible Mycorrhizae
- Use Organic Sourced Nutrients: Granular or Liquid Organic Fertilizers, Insect Frass, Worm Castings, Kelp & Chitin
- Organic Mineral Supplements for boosting soil nutrient reserves and supporting beneficial microbial life: Basalt Rock Dust, Rock Phosphate, Carbonatite, Zeolite, Azomite
- Boost healthy soil microbial communities with Beneficial Bacteria Inoculates, and high-quality Compost
- Supply a quick nutrient boost and increase bacteria-consuming protozoa (boosting available N) with Compost Tea

# Develop New Habits

DO:

- Inoculate all new plantings with a Compatible Mycorrhizae
- Use Mulching Mowers. Grass clippings have a high C:N ratio
- Convince your clients that a lawn with 25% clover in it is "A Beautiful Thing"
- Boost healthy soil microbial soil communities with Compost Tea, Beneficial Bacteria Inoculates, and high-quality Compost
- Get a Leaf Shredder. The finer that leaves and twigs are broken down, the quicker they can be composted

DONT:

- Use synthetic fertilizers with a $P_2O_5$ percentage higher than 8% (if you must use synthetic fertilizer, only use slow-release forms - better still - use Organic Fertilizers)

# Become Your Own Supply House

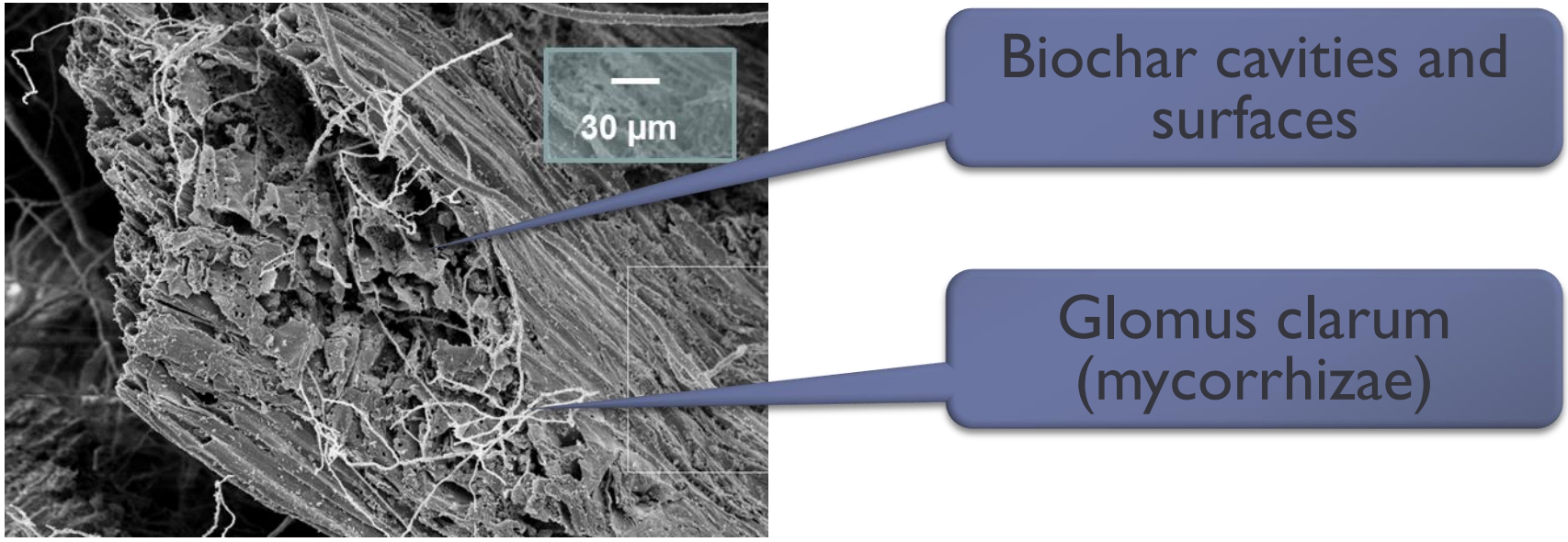
## Use space at your home base to make your own business more self-sufficient

- Become proficient at composting
- Use your own highest quality composts to brew your own Compost Tea
- Keep Grass Clippings for composting (an excellent compost accelerator with a high C:N ratio)
- Consider growing your own Green Manure crops for composting (an excellent way to improve the C:N ratio in compost)
- Use Wood Ash in compost and as top-dressing (vs. Lime)
- Consider buying (or building) your own Bio-Char Unit

# New Sustainable Technologies

## So, What is Biochar?

- Biochar is created by converting an organic feedstock (wood, biofuels etc.) into a stable form of essentially pure carbon. The process involves 'burning' the feedstock in an atmosphere of reduced oxygen at a controlled low temperature – Pyrolysis
- The internal structure of the Biochar provides a vast surface area where nutrient ions can be held until they are needed by plants. Soil CEC is dramatically (and virtually permanently) improved once the Biochar is activated by soil microbes.



# Part 4: The ROI

## How Caring for Soil Life Improves Your Bottom Line


- Natures has developed an incredibly efficient microbial community that supports landscape plants
- Engaging this natural network is like switching on an unpaid, self-sustaining workforce
- Once the microbial workforce has 'Punched-In for the Day", nutrient inputs can be reduced
- Plants establish deep root systems - soils retain more storm water - reducing irrigation requirements and storm runoff
- Healthy soil/plant communities also reduce the occurrence and severity of plant disease and insect attack

# Apply: Watering Can/Pail - On Planting Day

## The Wettable Powder Mixes Quickly and Easily in Water:

- 1 TSP per Watering Can
- 1 TBSP per 5G (18.5L) Pail

Images courtesy of: Cedar Springs Landscape Group

# Apply: Hose-End Applicator – Drench Plants without Heavy Pails

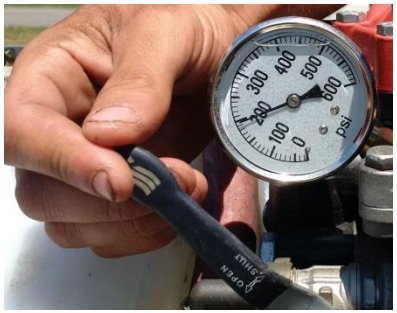
## The Wettable Powder Mixes Quickly and Easily in Water:

Download easy mixing instructions from:
www.rootrescue.com

Images courtesy of: Cedar Springs Landscape Group
www.earthalivect.com

# Apply: Motorized Tank Applicator - Drench or Inject into the Roots

## The Wettable Powder Mixes Quickly and Easily in Water:




# The ROI

## The Early Payback comes from Reduced Plant Failure Rates on Landscape Sites

- Replacing failed plant materials on landscape installations or at the Garden Centre kills profits - and makes no friends.
- Organic Inputs may cost more – but are used less frequently, have a sustained effect, and a perceived higher market value
- All sectors of the economy linked to 'Organics' are growing in market share.
- Today's homeowner is highly motivated to choose products and services based on concerns for the health and safety of their family and the environment.
- Your company's 'Organic Profile' will win you market share

# Unlock the Power in Microbial Soil Life

Are we not “The Green Industry”?


We need to become Stewards of The Soil – Nature can, and will, take care of plants.

## Key Points:

- Respect the dynamics of soil life.
- Move toward Sustainability – and beyond - to Restoration
- We have new tools in the toolbox
- Synthetics-based plant care ignores or disrupts the sustained power that a healthy soil microbiome provides to plant communities – and to all of us
- Support plants with Biology not Chemistry - inputs and failures decline as self-sufficiency increases
- Synthetics damage the wider ecosystem – we have alternatives
- Nature has perfected a self-correcting, sustainable engine for growing plants. Ignore it, or employ it – it’s your choice

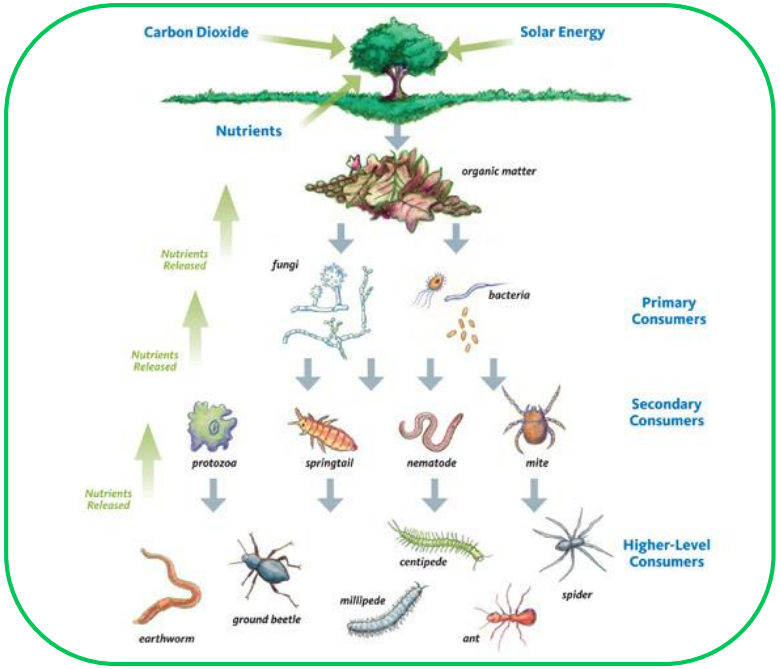
# The 2 Options we have:

## A Nitrogen Fixing 'Plant'

Powered by:

- Burning and converting billions of cubic meters of non-renewable natural gas to make Urea
- A massive hydrocarbon-fueled infrastructure

## A Nitrogen Fixing 'Plant'




Powered by:

- Re-purposed local waste products
- A dynamic living soil community
- And – The Sun
- Note: Also fixes Phosphorus, Potassium, Carbon, Zinc, Boron….

Tulip Tree
Field Trial – Summer 2009
(Photo taken Oct. 2015)

# Thank You!

**To get your PDF version of this presentation, email your request to breeves@earthalivect.com**

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## Visit our site today!

www.earthalivect.com

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More Info? Contact Bob Reeves:
breeves@earthalivect.com