A Tale of Nature's Collaboration - Mycorrhizal Connections and Evolution.

Plants, mosses, liverworts, like animals, have various means of getting water, nitrates, carbohydrate energy, nutrients, pathogen warnings, and extra defenses. While humans have water bottles, gardens, farmer's markets, parents, phones, and pharmacies, plants have stomata, roots of various thicknesses, lengths, and capabilities, and soil. Most plants, though, rely on far more than that. Most plants connect with fungi and many cannot live without specific fungi. [1]

Dr. Suzanne Simard (UBC): "It was more efficient for the plant to invest in cultivating the fungi than growing more roots because the fungal walls were thin, lacked cellulose and lignin, and required far less energy to make." With fungi, plants were able to seek farther and harder to reach water, nitrogen, and nutrients, even in ancient, or more acidic, poorer, and drier soils. Each of Earth's million fungi has distinctive niches and has co-evolved with particular flora.

Fungi can be generalists. Others have specific duties. Some share carbohydrates or amino acids, and others do not. Certain fungi forage for specific nutrients, in different places and times, or only for certain plants. Fungi are not the same.[2]

[500 MYA] ARBUSCULAR FUNGI began to associate with liverworts, recycle and form Earth's earliest soil. [3]

[466 MYA] MOSSES appeared on Earth's surface processing nutrients out of Earth's rock mantle. The ancient mosses had the ability to hibernate when there was drought and, as Dr. Tim Lenton (U. of Exeter) found, to weather calcium and magnesium from andesite rock and iron and phosphorus from granite. These mosses made more soil and brought Earth's atmospheric CO_2 down from between 5460 and 8580 parts per million to levels that caused an ice age. [4]

[445 MYA] ARBUSCULAR FUNGI (AMF) continued its interaction and evolution when the first vascular plants emerged on the surface of the earth. This collaboration formed soil and lowered levels of atmospheric CO_2. This cooling would cause a more significant ice age. Those vascular plants would be followed by club moss, ferns and then horsetail.

[385 MYA] SAPROPHYTE FUNGI. A significant change to Earth's flora was the advent of the earliest tree, *Wattieza*, and, with it, saprophyte fungi, allowing nature to break down that former tree's hard won wood nutrients and carbon.[5] Potential emissions were covered by moss, lichen, or topsoil. **Deeper soils need nature-processed deadwood!**

[Around 156 MYA] ECTOMYCORRHIZAS FUNGI (EMF) emerged. "Ectomycorrhizas fungi, are intermediate in their ability to take up nutrients, being more efficient than arbuscular mycorrhizas and less so than ericoid mycorrhizas, making them useful in an intermediate nutrient situation." Ectomycorrhizas fungi allowed conifers to grow and connect to some deciduous trees and plants for carbohydrates, nitrates, and special defensive capabilities. [6] Better AMF and EMF collaboration to new plants, flowering plants started to flourish. More atmospheric CO_2 was lowered after around 84 mya.

[Around 140 MYA] ERICOID MYCORRHIZAL FUNGI developed. Ericoid fungi could handle nutrient poor soils, dry soils, and especially acidic soils. This would allow future members of the Heath family (such as blueberries, huckleberries, cranberries, Labrador tea, rhodora, mountain laurel, azalea, and rhododendron) to live in such places. [7]

[84-66 MYA] ORCHIDACEAE FUNGI. Orchids, including lady slippers and ladies' tresses have a special fungus. Dr. Santiago R. Ramırez (UC Davis): "Our results indicate that the most recent common ancestor of extant orchids lived in the Late Cretaceous and also suggest that the dramatic radiation of orchids began shortly after the mass extinctions at the K/T boundary. These results further support the hypothesis of an ancient origin for *Orchidaceae*." [8]

[35-24 MYA] C4 PHOTOSYNTHESIS started in grasses. 46% of grasses now have C4 photosynthesis. The C4 characteristic allows plants to photosynthesize with less water. C4 photosynthesis has since developed for other plants even as recently as 5 MYA.[9] This author's favorite C4 plant is purslane, whose flower surprises him in sidewalk cracks.

Thankfully, though taking 100s of millions of years, fungi, like other life, adapted to the eco-situations in which they found themselves. With each new photosynthesizing ability, plant biochemical creation, root adaptation, and fungal adaptation, Earth's flora capabilities have grown for atmospheric CO_2 absorption and oxygen and carbohydrate creation.

Plants and fungi adaptions and collaborations, are a lesson for humans.

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[1] Prof. Tom Wessels (Antioch U.) July 3, 2019 "The Ecology of Coevolved Species" Youtube 35:10 New England Forests. At [12:28]

[2] Dr. Suzanne Simard (U. of British Columbia). Finding the Mother Tree. Canada: Allen Lane 2021. pp. 60, 167-170.

[3] MYA = million years ago. / William R. Remington (Imperial College London) et al. (+ 5 others) 10 Oct. 2018 "Ancient plants with ancient fungi: liverworts associate with early-diverging arbuscular mycorrhizal fungi." *Proceedings of the Royal Society B Biological Sciences* 285(1888):20181600 https://royalsocietypublishing.org/doi/10.1098/rspb.2018.1600 See also *Science* 19 Feb. 2018

[4] Sid Perkins 2012 Did Plants Freeze the Planet? *Science* https://www.sciencemag.org/news/2012/02/did-plants-freeze-planet See also.

[5] Wikipedia Wattieza & Wikipedia Paleomycology

[6] Wikipedia Ectomycorrhiza Evol. Photosynth. Briggs 2018 How Flowering Plants Conquered the World *BBC News* EMF also birch, beech, hazelnut, hornbeam, linden, oak. Both AMF & EMF: Alder (nitrogen-fixer); aspen, poplar, willow (salicin ASA). See & See.

[7] Wikipedia Ericoid.

[8] Dr. Santiago R. Ramırez (UC Davis) et al. (+4 others) "Dating the origin of the Orchidaceae from a fossil orchid with its pollinator." Sept. 2007 *Nature* 448 (7157) 1042-1045. https://www.nature.com/articles/nature06039

[9] Wikipedia C4 carbon fixation & Dr. Rowan F. Sage (U. of Toronto) 23 Dec.2003 "The evolution of C_4 photosynthesis." *New Phytologist* Vol. 161 Issue 2 Feb. 2004 pp. 341-370 https://nph.onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.2004.00974.x