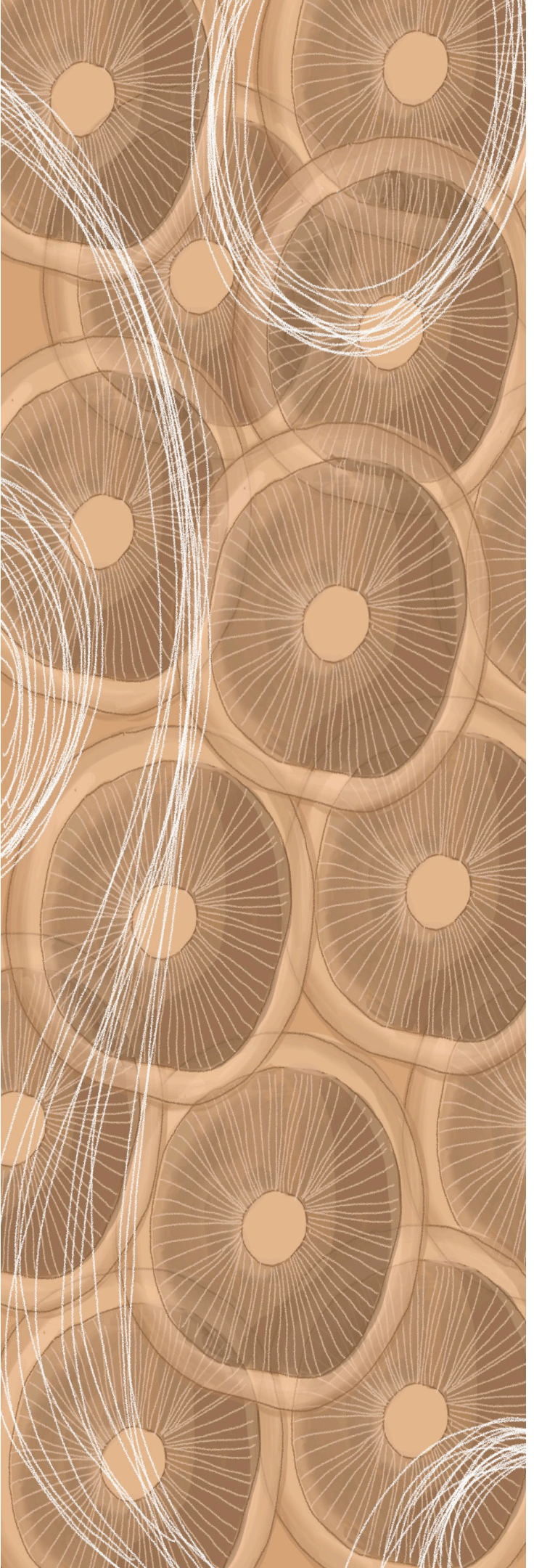

Words of a Fungi, Fungi's Communicative Connections

By Lara Potgieter

A secret mode of communication is occurring below our very feet, facilitating interspecies communication unbeknownst to us for nearly a billion years. Despite their occasional alien appearance, this is not the work of otherworldly beings, but fungi. Not only do they consume decomposing flesh or lurk somewhere in the back of your fridge, but they spread and multiply throughout the entirety of Earth. By transmitting electrical signals through their vast biological networks, they connect a diverse group of organisms in the biosphere—including us and our brains.

Fungi Structure and Survivability:

While fungi are critical to the wellbeing of both our planet and us as human beings, their diversity in function and form can make them difficult to identify. Fungi are most often recognized by, and named after the Latin word for, their unique outcroppings: mushrooms[1]. While mushrooms are critical for certain species of fungi to release spores and reproduce, not all fungi produce mushrooms. Consequently, fungi are more accurately identified by the key facets of their organic structure which includes the composition of filamentous bodies surrounded by cell walls[2], being eukaryotic organisms, and being nonmobile[1]. In spite of their lack of mobility, fungi are present on all seven continents due to their ability to withstand even the harshest climates. For example, in Antarctica, many fungi have developed adaptive mechanisms to ensure their survival, such as sheltering deep within rock formations to limit their metabolic activation to the warmer days of the year—a phenomenon known as entering a cryptobiotic state[3]. Although many organisms are unable to enter the cryptobiotic state, species of fungi and other microorganisms can due to their unique protein and membrane structure. This is because when their cells freeze, the structure of their membranes and proteins are not altered, allowing cells to remain healthy after thawing and giving them the ability to live for thousands of years despite otherwise unsurvivable conditions. With such resilience and adaptations, fungi's survivability can extend even beyond our world.

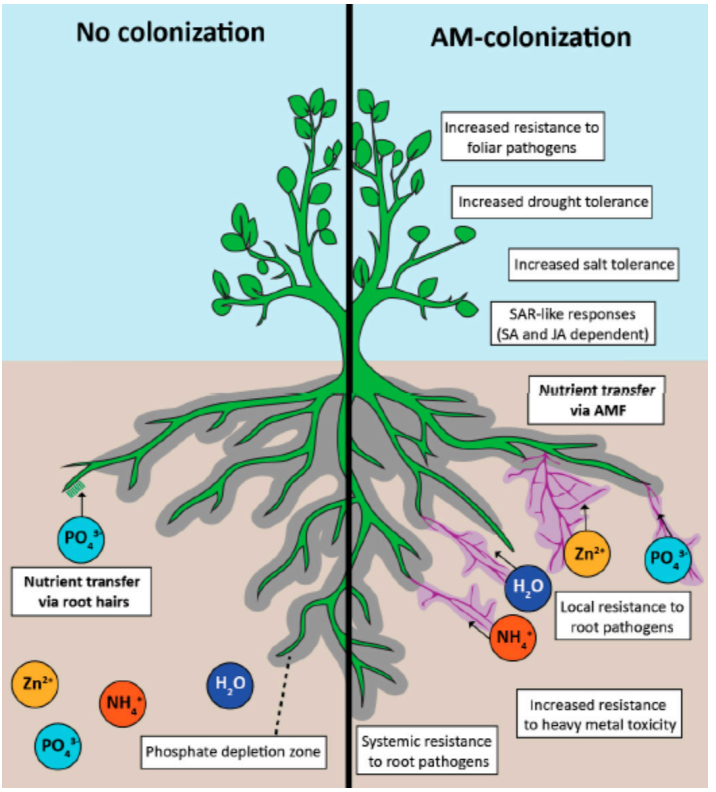

Figure 1.

In an experiment conducted aboard the International Space Station, scientists studied Antarctic black fungi and their ability to withstand simulated martian conditions for a period of one and a half years[4]. Scientists were able to simulate martian conditions for the fungi by placing them within pressurized containers with gas composition mimicking that of the martian atmosphere, shifting temperatures to reflect Mar's own, and exposing the fungi to simulated martian ultraviolet radiation. Following eighteen months of exposure, it was observed that certain species of the black fungi were able to remain with 10% of their original colonies still alive upon returning to Earth. The fact that strains of fungi were capable of withstanding the otherwise inhospitable simulated conditions of Mars is already astounding— and it was also found that their colony-forming abilities and high stability of DNA were maintained, demonstrating the viability of microbial organisms following long-term martian exposure[4]. Fungi's colony-forming ability remaining present in the surviving fungi is of great significance as this demonstrates surviving fungi were able to reproduce, and in turn survive both the hardships of Earth and beyond.

This mutualistic signaling between fungi and plants forms the mycorrhizal network[7]: an underground network of connected plants through fungal mycelium. This network functions as an underground "economy" where fungi allow plants to uptake nutrients such as phosphorus, nitrogen, and water, while the fungi in return receive sugar which has been produced through photosynthesis. This received sugar from plants is of great benefit to fungi for energy, due to fungi not being able to photosynthesize and produce their own sugars[7]. Plants in turn benefit from the nutrients fungi provide, which help to increase plants yields and chlorophyll production. In this manner, the survivability as well as the reproductive capacity of both fungi and plants are enhanced. Based on the amount of plants linked with fungi, it is estimated that without fungi, 80–90% of trees and grasses would not be able to survive1. Without mycorrhizal networks, our current planet— teeming with life—would be a very different world.

Interspecies Communication:

The mycelium, which connects fungi with plants, remarkably also serves as a system of communication which can be used between plants, and even between different species! Chemical signals which communicate information to other plants connected in the fungal system pass from plant to plant in this way. In a study conducted on arbuscular mycorrhizal fungi(AM fungi), a type of fungi which are able to form mutualistic relationships with most terrestrial plants through entering the root system of plants, found that signals were able to be sent between plants through the network[8]. This shared mycelium connection becomes a common mycelium network for the plants, in which the network can be used as a conduit for signals warning connected plants of attacking pests so that the plants have time to use chemical signals to attract the predators of these pests. In the study it was found that plants connected in a common mycelium network, when under attack by aphids, suffered less damage than plants not connected in such a network. This system of communication is often referred to as the Wood Wide Web[7], a term popularized by Dr.Suzanne Simard, in reference to the network's ability to allow distant plants to relay information in the "internet" of plants. Such "talking" between plants would not be possible without fungi and, based on the structure of the communication network, can be seen as one of Earth's first languages.

Fungi and the Brain

Language comprehension and communication are cornerstones of humanity, and it is through visual, auditory, and sensory mechanical input that we are able to comprehend language. This mechanical input is then transferred to the Broca region of the brain, where through electrical impulses, we are able to understand language. Fungi lack a central nervous system to make such communication possible, and yet recent studies indicate the possibility that fungi are capable of exhibiting cognitive abilities and communicating a language through electrical impulses, much like humans. In a study conducted by Andrew Adamatzky at the University of West England[9], he created a form of computing device using 4 different species of fungi. When he inputted electrodes into the fungal system, he was able to receive an output of 50 unique electrical spikes—spikes which he found to be comparable to spikes transmitted by neurons within the brain. The 50 electrical spikes can be equated to 50 words within a human language, being of similar electrical spike length to words processed within the brain. Currently, it is unknown what these fungal electrical spikes mean, from communicating one another's presences to warning each other of repellents to, in the words of Adamatzky, "another option—they are saying nothing." With the intricacies and meaning of the fungal "language" still unknown and

research regarding fungal communication being in its infancy, there is more research needed to decipher their communication and to understand fungi's potential connection to the human brain. A connection which could help us better understand the neural activity in the brain, and tap into fungi networks to improve survival of plants in agriculture and in our diminishing forests.

Connections

From the nutrient exchange between fungi and plant life, to the facilitated interspecies communication of plants possible due to fungi, it is undoubtable that the Earth would be a very different place without the mycelium of the fungal kingdom. Even within our own minds and language, we can be reminded of fungi's signaling communication. From plants to fungi to animals, we are all connected by the life of this Earth, and perhaps through understanding the crucial role fungi play in our ecosystem we can take steps to better preserve the life on this planet which depends on fungi. So maybe next time you see a mushroom, you'll think of the world of secret exchanges it hides below our very feet, and how fungi have helped shape the planet.

Figure 2: Image above is the* Cordyceps militaris *fungi, one of the species studied by Adamatzky in regards to fungal language communication.

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