Relational World Building

On Fungi and Their Role in Creating Ecosystems

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Abstract

Nonhuman actors are often overlooked as backdrop to human life, however they are actively engaging with their surroundings and each other, to create ecosystems. This research aims to decentralise human voices and understand nonhuman actors as having agency. This thesis explores the way nonhuman relationality creates ecosystems from the perspective of the fungus. Three different cases of fungal relationality are mapped: lichen, mycorrhizal fungi, and *African Macrotermes* termite and *Termitomyces* fungi, to inquire how they create ecosystems with their nonhuman partners. To articulate relationality, Gilles Deleuze and Felix Guattari's (1987) rhizomatic theory, Rosi Braidotti's (2013) concept of co-creation, and Anna Tsing's (2017) concept of contamination, are used. These theories make for a dynamic, flexible, and active analysis on how fungi create ecosystems with their nonhuman partners. In understanding the way that fungi connect through these theories it is possible to understand the scope of fungal relationality as further than the fungi's physical end. This research is located in the posthuman school of thought with the aim to decentre the human and instead understand nonhuman actors with agency, capable in shaping their habitat with their partners. In doing a synthetic reading of the three cases of fungal relationality, various ways of performing relationality that are dependent on the partners of the fungi appear. These partners can be water, rock, insects, and plants. Fungi create ecosystems with their nonhuman partners in a relational way that is located in a place and time. Specifically in creating soil with their partners, fungi are actively engaging and building the ecosystems they inhabit together with their nonhuman partners. This research project investigates the way that fungi as nonhuman actors actively engage with their surroundings and demonstrate that through interaction the reach of nonhuman relationality is vast.

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Table of Content

Introduction

When I forage I listen to the rustling of the pine trees, feel the lichen clinging to my fingers as I touch the bark of the tree closest to me, and smell the mushroom that I am looking for as I scan the forest floor. Interacting with fungi allows me to explore environments by investigating fungal relationships by looking for the combination of leafy tree and pine that the boletes like to connect with. The fungi lead the way in my exploration as I continue my search for mushrooms, searching in a forest that fungi weave a web of connections. The fact that fungi are older than trees (Sheldrake 2020, 73 & 90) and are one of the reasons that life can exist as it does today (Sheldrake 2020, 90) is cause for wonder and amazement.

In this research project I will explore how ecosystems are created relationally by nonhuman actors, from a fungal perspective, by examining three distinct ways that fungi form connections and how these connections inform contemporary ecosystems. Fungi are continually entering into new relationships while maintaining old ones, (re)acting based on these relationships with nonhuman actors, and moving through space and time situationally (Sheldrake 2020). Mapping how fungi and their networks expand, persevere, and change will guide my exploration to explore the pathways of nonhuman relationality. Fungi have existed for billions of years, sustaining other plant life by entering into relationships with them. Fungi share food and information with neighbouring organisms, rearticulating these relationships, and through this fungi shape their surroundings. Fungi move in a nonlinear and asymmetrical fashion; there is no centre, but a multiple/single organism that moves in the margins towards a situational need. Hasmik Djoulakian and Patricia Kaishina write that the very nature of fungi rejects normative thinking and enacts what can appear to be chaos (Djoulakian & Kaishian 2020, 7-8). Thinking past normative understanding of relationality and nonhuman actors I aim to trace how nonhuman actors engage with agency in creating their habitat.

The myriad ways that fungi connect to their surroundings, intrinsic to their survival, make them a prime case to map how nonhuman actors perform relationality. I use the word actors here to designate a wide range of organisms, plants, and environmental features. By using this word, I aim to explore nonhuman actors' relationality without falling into the dualistic language of life and nonlife that is present in Western knowledge production and rhetoric.

Looking at fungi and how they impact ecosystems with a relational lens is important because it showcases how nonhuman actors shape our environment and how they do so together (Djoulakian & Kaishian 2020, 3). By looking with the fungus it is possible to examine how our surroundings are shaped, and are being shaped, through a lens of nonhuman activity. Tracing relationality through this nonhuman perspective shows ways of relating that are collaborative, adaptive, and flexible, in which many actors are involved, as opposed to the dualism of exploring an environment as 'naturally' occurring and only influenced by humans. By shifting the emphasis to a relationality that focuses on nonhuman actors, ecosystems can be underwood in terms that do not centralise human activity, instead nonhuman actors are considered with agency within ecosystems.

This thesis takes the posthuman school of thought within feminist discourse as its context. This school of thought aims to challenge anthropocentrism and explore how actors are not independent but entangled with environments. Braidotti writes: "… posthuman theory is a generative tool to help us re-think the basic unit of reference for the human in the bio-genetic age known as 'anthropocene', the historical moment when the Human has become a geological force capable of affecting all life on this planet. By extension, it can also help us re-think the basic tenets of our interaction with both human and non-human agents on a planetary scale" (Braidotti 2013b, 5-6). By placing my research in the posthuman context I can de-centre the human, instead understanding nonhuman as active agents instead of passive. Stacy Alaimo writes: "Nonhuman subjects as not in the background but acting on equal footing to 'affect and transform'" (Alaimo 2008, 246-247). Thus here, as with Braidotti, the human is decentered, and the nonhuman subject has agency. Agency of the nonhuman subject is posited– an integral element for my research. Alaimo argues that nonhuman agency must be understood differently from the humanistic understanding. Biological agency is the "'doing'/'being' in its intra-activity" (Alaimo 2008, 248). Thus activity defines nonhuman agency, specifically in this activity's interactions with the nonhuman actors' surroundings. I understand fungi to be moving and actively transforming with their surroundings, thus enacting Alaimo's nonhuman agency of "intra-activity." Questions of agency and activity de-neutralise dualistic thinking. Fungi, with their ability to decompose and transform matter across space-time, enabling reconstitution of bodies into new materialities, are crucial agents of non- capitalist, anti-dualistic interchange" (Djoulakian & Kaishian 2020, 14). Studying fungi allows us to move past a hierarchy, of human versus nonhuman, and understand the nonhuman as having agency. Thus, a posthuman perspective allows for an analysis that treats fungi and their partners as substantive and with agency, transgressing the limitations of nonhuman subjects assumed to be static. Therefore, as Braidotti writes, "The posthuman condition urges us to think critically and creatively about who and what we are actually in the process of becoming" (Braidotti 2013, 12). In thinking with a posthuman lens, which allows the emergence of the nonhuman subject as active and substantive, it is possible to understand how modes of becoming are enacted through nonhuman relationality and the implications it can have when studying them.

To understand and highlight how ecosystems are formed by nonhuman relationality, specifically fungal relationality, I will analyse three different examples of fungi and their partnerships and conclude with a synthetic reading of my case studies. Mapping of how fungi interact with partnered nonhuman agencies makes visible some of the relationships that inform ecosystems. I will perform a synthetic reading on my three chosen cases: lichen, mycorrhizal fungi, and fungi and termite partnership. For my understanding of relationality, I turn to Gilles Deleuze and Felix Guattari's (1987) rhizomatic theory, Rosi Braidotti's (2013) concept of co-creation, and Anna Tsing's (2017) concept of contamination. By applying their articulations of relationality in my analysis of the three fungal ways of relationality, I aim to illustrate how fungi, as nonhuman actors, transform ecosystems.

Theoretical Framework

In order to explore how fungi relate to their partners and surroundings I turn to Gilles Deleuze and Felix Guattari's rhizomatic theory in *A Thousand Plateaus* (1987), Rosi Braidotti's concept of co-creation in "Nomadic Subject" (2013), and Anne Tsing's concept of contamination in *The Mushroom At the End of the World, On the Possibility of Life in Capitalist Ruins* (2017). I have chosen these theoretical frameworks because they develop an understanding of relationality that corresponds to what I have been observing in fungi. Guided by the concepts of rhizomatic theory, co-creating, contamination, and multiplicity, I am able to explore the ways of relating by which fungi create ecosystems together.

Deleuze and Guattarian rhizomatic theory (1987) articulates a collectivising model of entanglements; it's a means of delineating entanglements that exist, instead of confining actors to a false binary logic. To oppose the hierarchical structure of signifying systems, in which the sign organises the contents of the signified, Deleuze and Guattari articulate relationships that are mutually defining in a process of reciprocal becoming that is not signifying or representative, but active. This means that actors in connecting to each other influence one another, transforming instead of imitating each other. Deleuze and Guattari's rhizomatic theory is meant to describe reality and its non-hierarchical entanglements. Their theory is based on a set of principles for complex relating that allow for an analysis that is active, as well as situated to understand fungal relationality. In this thesis I will focus on the principles of "connection and heterogeneity" (Deleuze & Guattari 1987, 7) and "asignifying rupture" (Deleuze & Guattari 1987, 8) as they allow me to think through connecting through differences, as well as adapting to changing circumstances by re-relating oneself to the other. In depicting their proposed rhizomatic structure, Deleuze and Guattari write: "The rhizome itself assumes very diverse forms, from ramified surface extension in all directions to concretion into bulbs and tubers" (Deleuze & Guattari 1987, 7). Rhizomatic theory is thus adaptable, capable of taking on many forms and expressions. The theory's flexibility allows it to articulate the way that actors connect to one another in reality without limiting them to binary systems of organisation that Deleuze and Guattari are critiquing in western thought. As fungi exist in many forms with different needs and relative to disparate environments, they typify a style of relationality that adapts to different life forms and situations and thus necessitates a theoretical engagement that is capable of elaborating on mutability and complex relating. Deleuze and Guattari write: "Principles of connection and heterogeneity: any point of a rhizome can be connected to anything other, and must be" (Deleuze & Guattari 1987, 7). In this form of relationality all parts are necessarily connected to each other, simultaneously defining one another, and these connections happen across difference. Instead of presupposing homogenous subjects and objects that communicate representationally but remain discrete and separate entities, rhizomatic relationality articulates how different actors connect to each other, by reaching across difference, and thus become themselves/each other through their reciprocity. Actors move together through their entanglement. This reaching for each other, or becoming with (Deleuze & Guattari 1987, 10), is also represented in Braidotti's (2013) work. However, in her work the focus is on creation and possibilities through connection, while rhizomatic theory articulates relationality that reaches transformatively across difference and through connection to describe existing structures. Their focus is on creating language to articulate a system of entanglement that is non-hierarchical instead of a representational system that is based on signifying hierarchies. Rhizomatic theory composes a language of relationality where actors inform one another through connection that reaches across difference. In the principle of asignifying rupture, even if a line of connection in the rhizome moves, changes, or is broken the rhizome will reorganise itself to reconnect and re-relate itself to fit the need or conditions of a situation (Deleuze & Guattari 1987, 8). Deleuze and Guattari write: "A plateau is always in the middle, not at the beginning or the end. A rhizome is made of plateaus" (Deleuze & Guattari 1987, 21). The rhizome exists as interconnected plateaus, which shift with each other to absorb change and incorporate difference. There is no end to the rhizome; even if a rhizome breaks it will re-relate itself to continue existing. Deleuze and Guattari write: "In contrast to centred (even polycentric) systems with hierarchical modes of communication and preestablished paths, the rhizome is an acentered, non-hierarchical, nonsignifying system without a General and without an organizing memory or central automaton, defined solely by a circulation of states" (Deleuze& Guattari 1987, 21). In this form of relationality there is no central command post or head that controls the rest of the rhizome, as it exists entirely as a middle. The rhizome adapts to the multiplicities it is connected to in a horizontal way. They further assert that the rhizome will change and adapt to negate hierarchies or systems of centralisation (Deleuze& Guattari 1987, 12-13). Thinking with rhizomatic relationality is to resist structures of organisation that call for a top-down order, like signifier-signified relationality, or a system of centralisation. The rhizome will escape and transform when such structure is imposed upon it. Rhizomes relate back to themselves to incorporate new actors and maintain old ones (Deleuze & Guattari 1987, 7). Actors change and move with one another through their connections across difference, enacting mutual becoming in that it's reciprocally informed between them. Rhizomatic theory allows for an elaboration of fungal connections with their partner actors across a multitude of different organisms and within a mirage of unpredictable and changing environments. It allows for an exploration of the ways that fungi connect to other actors outside of binary borders, instead focusing on mutually becoming with each other that is non-hierarchical in their rhizomatic nature.

In addition to rhizomatic theory I turn to Braidotti's (2013) interpretation of co-creation to analyse the ways that fungi connect with other actors. In her work outlining the nomadic subject she introduces the concept of co-creation as a way to bring about change in interaction through collective effort and affirmative action which includes human and nonhuman actors

(Braidotti 2013, 342). She builds on Deleuzian ethics to express a relationality that "prioritises relation, praxis and complexity as its key components" (Braidotti 2013, 343). Braidotti writes that when actors come together there is creation. As in rhizomatic theory, when actors connect, they influence each other instead of representationally mimicking one another. Braidotti emphasises the process of coming together as a form of transformation. She writes: "This makes reciprocity into a gesture of creation, not as the struggle for the recognition of Sameness. An ethically empowering relation to others aims at increasing one's *potentia* or empowering force and creates joyful energy in the process" (Braidotti 2013, 343). Here Braidotti explains that through connection all parties involved transform together into something new, instead of multiplying in "Sameness." This process is asymmetrical and thus there must be attention to the difference of all actors in the relational whole (Braidotti 2013, 345). By working with co-creation and looking with '*potentia'* (Braidotti 2013, 343) transformative coming together is active, instead of static. She writes:

> "Becoming-woman/animal/insect is an affect that flows, like writing; it is a composition, a location that needs to be constructed together with, that is to say, in the encounter with others. Becomings push the subject to his or her limits, in a constant encounter with external, different others. The nomadic subject as a non-unitary entity is simultaneously self-propelling and hetero-defined, that is to say, outward-bound" (Braidotti 2013, 348).

Connection is no single action, instead it is a process. Through connecting with various actors, they transform in a process that is defined by their difference. Actors are constructed through their contact with each other. Braidotti calls this method of relationality 'ontology of process' (Braidotti 2013, 343), this approach calls for looking at the potential of connection (Braidotti 2013, 343 & 353). Thinking with co-creation allows for an analysis of fungi that focuses on the point of contact between actors as the concept of co-creation provides language for understanding fungal partnerships as transformative through contact. Braidotti's outline of the concept of co-creation, or becoming-with, is particularly relevant to my thesis because it explicitly includes nonhuman actors (Braidotti 2013, 348). Ontology of process' nonhuman inclusions and creative transformative nature allow for language to discuss building ecosystems through relationality.

The concept of the productive agency of contamination provides one of the most enigmatic forms of environmental relating. As described by Tsing (2017), nothing is pure as everything carries the traces of its relational connections. Tsing writes: "We are contaminated by our encounters; they change who we are as we make way for others. As contamination changes world-making projects, mutual worlds—and new directions—may emerge" (Tsing 2017, 42). Through 'encountering' each other, actors influence and transform one another. The contamination concept of actors carrying histories of transformative contact grants vocabulary for exploring how ecosystems can be created through contact between nonhuman actors, and how fungi contribute to this. Additionally, they make apparent different relationships of causation that are more communal rather than hierarchical. When looking with a lens of contamination, encounters are located in histories and relationships that occur across time. Like Braidotti, Tsing writes that through contact there is creation that is not based on sameness because nobody can exist in a pure form, thus an exact copy is not possible. Tsing urges to look at location or situations as assemblages to properly understand the interplay of many actors (Tsing 2017, 158). In Tsing's work, the concept of contamination deliberately locates encounters in time and space. While contamination works well with rhizomatic theory as it similarly emphasises how actors influence each other, Tsing's focus uniquely lies in how encounters leave traces, engaging specific histories. Rhizomatic theory, unlike concepts of contamination, lacks historical focus. In her study mapping pine and matsutake's partnership as it undergoes the effects of capitalism, Tsing describes how various encounters influence and transform the primary partners. Tsing's approach to outlining how fungi are part of creating ecosystems through the concept of contamination is relevant to my argument that nonhumans create ecosystems through relationality that connects through time. I use contamination as a concept to examine the various ways that fungi impact their surroundings and the consequences of them doing so.

In this thesis I use relational individuality to explore interactions between actors. By doing so I aim to examine the ways that fungi interact with both concepts of individuality and multiplicity. These three concepts that I turn to analyse fungal relational work in the form of a multiplicity. Rhizomatic theory is founded in the "Principle of multiplicity: it is only when the multiple is effectively treated as a substantive 'multiplicity,' that it ceases to have any relation to the One as subject or object, natural or spiritual reality, image and world." (Deleuze & Guattari 1987, 7). Rhizomatic theory makes multiplicities substantive. To be part of the rhizome one cannot be seen as separate from others in the rhizome or the rhizomes connected to it. What is most relevant for my analysis in this theory is that change happens through connection: "Multiplicities are defined by the outside: by the abstract line, the line of flight or deterritorialization according to which they change in nature and connect with other multiplicities" (Deleuze & Guattari 1987, 9). The actors involved in the rhizome change with each other, spurred on by action coming from outside of the rhizome. A change or movement will be accompanied by a change in all the actors involved. Through this understanding of multiplicity a change in environment and actor cannot be seen as singular–instead when change happens the relational whole must be considered. Using this concept in my analysis it is possible to interpret the actions of fungi as reaching further and with larger influences. Understanding the full relational reach is significant when exploring how ecosystems are formed through the perspective of the fungus.

Both Braidotti's concept of co-creation and Tsing's concept of contamination work with multiplicity. Focusing on the point of connection when looking at co-creation with Braidotti's ontology of process usefully illustrates how actors become together. Through contact something new is created that is unpredictable and different from when the actors were separate (Braidotti 2013, 343). Within Braidotti's theoretical framework, an actor comes into existence through its relation to the other–they cannot be seen as separate. Thus, they are multiple in their individuality, or as in this thesis, relationally individual. Tsing's concept of contamination similarly stresses that actors are not neutral as they carry traces of their partners. However, Tsing writes: "No 'one' fungal body lives self-contained, removed from indeterminate encounters. The fungal body emerges in historical mergings" (Tsing 2017, 238). Tsing argues that the fungus carries with it traces of past encounters and is shaped by them. Since one is influenced by many different connections, the actor cannot be separated from its context, as the context makes the actor. While Braidotti argues that actors create each other through contact, Tsing focuses on the histories that are carried by actors which emerge through contacts that are thusly passed on as they continue to shape the actors. Understanding fungi as integrally defined by being part of their partners and their environment allows for a nuanced tracing of the different ways that fungi are part of, and change, with ecosystems. I aim to understand fungi as extending into their partners and vice versa, thus relational individuality in various expressions allows for language that goes beyond a binary vision of individual versus multiple.

In the examples to follow I will use rhizomatic theory, and concepts of contamination, co-creation, and multiplicity, to explore three cases of fungi relationality: lichen, mycorrhizal fungi, and between termites and fungi. These concepts provide the necessary lenses and vocabulary to examine fungi in their relational actions, and how they interact with ecosystems.

Methodology

To understand fungi, I have referenced experts and amateur writers on the subject and consulted with a forager. Much of our knowledge about fungi comes from amateur researchers, as mycology is not a popular, or vastly explored field within sciences (Djoulakian & Kaishian 2020). Primarily I turn to Merlin Sheldrake's book *Entangled Life: How Fungi Make Our Worlds, Change Our Minds & Shape Our Futures* (2020) for information on fungi, as I am not trained as a mycologist. To understand the interwoven habits of fungi and how they interact with ecosystems, I use philosophical theory to analyse the way that fungi enact relationality. In this thesis I am doing interdisciplinary research, specifically a synthetic reading of the three chosen cases to draw conclusions about the ways that fungi create ecosystems through relationality to obtain a concrete understanding of the whole.

In this thesis I define ecosystems as, "the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space" (Britannica, T. Editors of Encyclopaedia). I turn to this definition as it defines ecosystems as a series of interactions between organisms, their environment, and their relationships in a location. In my exploration of how nonhuman actors form ecosystems, using the fungus as a case study, I examine three different ways in which fungi are relationally part of creating ecosystems

In piecing together the different ways that fungi interact and create ecosystems, I intend to both draw parallels and touch upon the key differences amongst the three examples of fungal relationality in connection to ecosystems (Taura, T. & Nagai, Y 2013). Djoulakian and Kaishian write that "Biological discourse has limited our framework of possibility for fungal biology because this discourse was formed in the context of mycophobia. Mycology is on the margins, where biological discourse has been abruptly cut by the cookie cutter; on the boundaries of discourse that prioritises and enforces normalcy of other organisms" (Djoulakian & Kaishian 2020, 17). Dominant cultural lenses, such as binaries and racism, have shaped scientific understandings of science and mycology (Djoulakian & Kaishian 2020, 2). As a result, fungi have been understood through dichotomies that reject the chaotic and creative aspects of fungi. In applying philosophical theory, such as rhizomatic theory and Braidotti's concept of co-creation, I wish to elaborate an understanding of fungi that allows for unpredictability. I aim to shift the narrative to focus on a nonhuman actor, philosophical concepts and language that incorporate nonhuman agency, such as rhizomatic theory and Braidotti and Tsing's work, are productive in my analysis. Deleuze and Guattari write; "Plants with roots or radicles may be rhizomorphic in other respects altogether: the question is whether plant life in its specificity is not entirely rhizomatic" (Deleuze & Guattari 1987, 4). Here they write that plant life, the nonhuman, is at least partially if not entirely rhizomatic. In my analysis I am applying rhizomatic theory because fungal interactions are rhizomatic in character. Through a synthetic reading of fungi in three different settings I aim to explore the role of fungi in ecosystems.

My own relationship with mushrooms has only recently extended to a more scientific and analytical sphere, before it was a way for me to spend time with my family and be in nature. Growing up, from September until November, my house would smell like mushrooms with endless strings of drying boletes in the kitchen that my family and I foraged. Fungi are a way for me to connect to other people and nature, and maybe that is why thinking with fungi to explore relationality is the next logical step for me.

In writing about relationality from a nonhuman perspective I do not intend to anthropomorphise fungi, however it must be noted that by speaking, thinking, and writing about fungi I am subjecting them to a human understanding of the nonhuman. In writing about them without a way to communicate with them in a language that we share in common, I am subjecting them to a hierarchical relationship between the researcher and object of study. Thus, anthropomorphising is not completely avoidable or an unbiased account of fungal activity.

As I am based in Northern Europe, I want to locate my argument from a Western perspective. There are many ways of understanding fungi that are tied to indigenous knowledges in different places (Djoulakian & Kaishian 2020, 3), for instance in some regions in Mexico certain species of fungi are considered divine by the Wixaritari (Haro-Luna, et al. 2019, 9). However, I am not situated in this socio-historical milieu thus I am choosing to examine fungi with the lens of rhizomatic relationality, concepts of co-creation and contamination. From my position as a person that is located in the Netherlands, I want to touch upon the exploitative history of fungi, specifically psychedelic fungi. The increased use of psychedelic drugs in the 60s led to mass farming of psychedelic fungi in the United States and in Europe. These substances were taken out of their original context and used for pleasure, monopolised upon by non-indigenous people, and criminalised in many places. Now psychedelic properties in fungi are being studied for their medicinal potential in treating a multitude of mental health issues. The medical study of psychedelic fungi is growing fast in Western settings (Conference Fantastic Fungi 2022). It can be argued that the West is colonising the sphere of fungi, however, this is not what I will discuss in this thesis, and I aim to distance myself from this kind of exploitation of knowledge and resources.

Thesis Structure

To explore the question: *How do nonhuman actors relate to each other to create ecosystems with a fungal perspective?* I will discuss three different cases of fungal relationality. First, I will analyse how fungi enact relationality within the lichen. This is a tight knit relationality where different organisms that create the lichen can't be observed by the naked eye, yet is incredibly resistant to extreme environments and environmental changes. This resistance is made possible through their partnerships with the organisms around them, and each other (Sheldrake 2020, 99-103). Second, I will explore mycorrhizal fungal relationality. Up to 90% of plant life relies on these fungi to get the nutrients they need to survive (Sheldrake 2020, 138). Through forming bonds with their surrounding mycorrhizal fungi shape their environment and come into existence with their plant partners. Lastly, I will analyse *Termitomyces*, or white rot fungi, and their relationship with termites, more specifically *African Macrotermes.* Through their connection these two actors are able to build termite mounds that are architectural wonders that not only sustain the termite and fungus, but also the organisms around them (Sheldrake 2020, 211). I will conclude with a synthetic reading of the three cases. In mapping out the differences, parallels, and patterns of how these three examples of fungal relationality are enacted I aim to examine the different ways that fungi create with their partners, and the influence of it on ecosystems. Analysing fungi must be done with careful consideration of their environment and connections as “fungi defy objectivity and standardization” (Djoulakian & Kaishian 2020, 3). Instead, they must be situated within their environment, to be grounded in their histories, and connections (Haraway 1988, 583). Through a synthetic reading of the cases, it is possible to start seeing parallels, patterns, and differences, while leaving space for the unknown and the nuanced for each fungus. By doing a synthetic reading of how lichen, mycorrhizal fungi, and white rot fungi perform relationality I aim to show the different ways that connections are formed, and how through relationships ecosystems are shaped.

Chapter 1: Entangling into Existence*, On How Lichens Enact Non-Human Relationality*

This chapter introduces symbiotic relationships in which fungi are an actor. Lichen are two or more organisms, fungi, algae, and often yeast, and other bacteria, that form symbiotic relationships to survive and thrive. To understand how lichen enact a relationality that creates ecosystems I will use Deleuze and Guattarian (1978) rhizomatic theory, as co-creation as described by Braidotti (2013) to define relationality. To explore how fungi perform relationality within lichen I will first start by interrogating what a lichen is, then explore the way that they enact relationality based on the aforementioned theories. To conclude I will discuss how their relationality creates ecologies. Trevor Goward writes that lichens are like ecologies because they are systems that work together to be a lichen (Goward 2008b. 1-4). Through interacting with lichen Goward has glimpsed the intricate relational web that lichens entangle and connect to. In this chapter I ask the question: How do fungi enact relationality in lichen, and what role does this relationality play in ecosystems? I will explore this relationship to examine the nonhuman relationalities that generate ecosystems.

Technicalities of What Lichen Are

Algae, yeast, bacteria, and fungi start a partnership to become lichen when it is mutually beneficial and when they cannot exist in an environment without coming together. The lichens are conductive to partnership as it is very adaptable and organises itself in varying ways depending on need and partners involved (Christensen 1969, 45-6; Spribille et al. 2022). Lichens enter into, build, and maintain relationships to survive in response to their circumstances. Lichen can vary according to their type and number of partners, interacting with differing yeast and bacteria (Sheldrake 2020, 100). It is speculated that some bacteria help in defending the lichen, while others produce hormones and vitamins (Spribille et al. 2022). Toby Spribille (2016) hypothesises that some bacteria might even be crucial in tying all the partners together and forming a shape. However, since these relationships remain to be established, I have focused instead on the algae that is consistently present next to the fungus. Spribille (2016) writes that the interaction between fungi, algae, and other partners that become lichen are more like systems than components that are put together (Sheldrake 2020, 100-1). The organisms in lichens fuse together in a structure where it looks like it is one organism (Sheldrake 2020, 4-5), as illustrated in Image 1. Here one can see round textured structures that look like one growth: the lichen.

At the time when earth's surface was still barren rock, and most life forms that existed did so in water, fungi and algae formed a relationship that made it possible for a few organisms to exist on land as the fungus could burry into and gain nutrients from the rock, while algae photosynthesise to gain sugars (Sheldrake 2020, 138, 4-5). Sheldrake writes that, if fungi and algae are in an environment where they cannot exist alone, they will partner with each other. "[…] they will coalesce into entirely new symbiotic relationships" (Sheldrake 2020, 139). In the process of 'weathering' lichen can gain nutrients from rocks and other hard surfaces. First, they break up the surface that they grow on through the force of their growth, and then with a combination of acids and mineral binding compounds they digest the rock (Sheldrake 2020, 85). Lichen not only break down, but also become soil: when lichen die and decompose, they "give rise to the soil in new ecosystems" (Sheldrake 2020, 85). Lichen is a link between life and non-life, as the metal that the lichen in Image 1 grows on will slowly weather and be broken down into soil. Because lichen generate soil through weathering, they make life possible for plants, and subsequently animals. Lichen can be found growing on rocks near the ocean, on roof tiles, and statues and other places that are harsh to inhabit, but they are also found on trees and in abundant tropical environments. The fungus will look for connections to gather carbon and sugar, which the fungus cannot get itself, but depends upon as a food source. Algae can photosynthesise to contribute sugars, while the fungi can reach nutrients from beneath the surface of where the lichen is growing (Griffiths 2019, 39; Sheldrake 2020, 138). Thus, fungi and algae through their relationships can inhabit spaces that were before inaccessible to them, and through partnership are able to become the lichen.

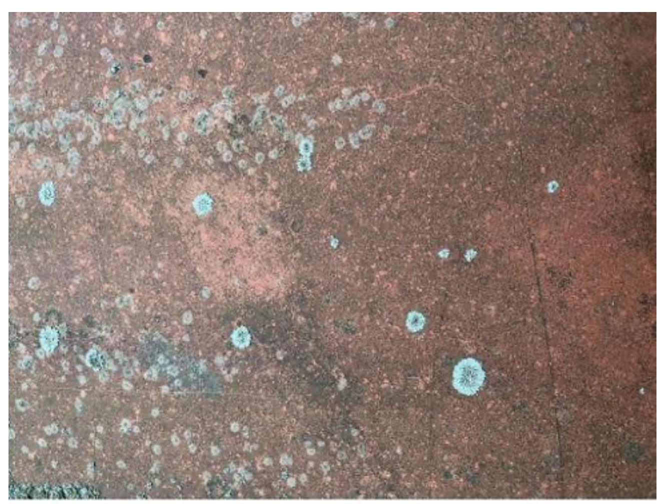

Image 1. Lichen growing on metal garbage container. Amsterdam.

Lichen as Relational Creators

In order to become lichen, different organisms must be in a dance of reciprocal giving that is active. In mapping the relationships that lichen activate, in the way that Deleuze and Guattari describe, it is possible to glimpse a form of nonhuman relationality that is based on the needs of all organisms involved. In this section I will first outline how lichen build and maintain relationships using rhizomatic theory (1978) and Braidotti's (2013) articulation of relationality.

Through the relationality with each other that forms the lichen, and the relationship with their environment, the lichen is a 'becoming-with,' as all the partners collectively connect into a lichen. Braidotti (2013) emphasises that through partnership one does not only complement one another but become something new through cooperation. Braidotti (2013) writes that one must not only look at how entities relate to each other, but also how they become with one another. Haraway, similarly, writes that through relational corporeality all "players render each other capable; they 'became-with' each other in speculative fabulation" (Haraway 2016, 22). Through togetherness and connection there can be creation into something that could not exist without coalescing. The partners involved in the lichen do this by entering a relationship and through that entanglement become lichen, where each partner is indistinguishable from the other; how the lichen is organised (shape, relation within the partnership) is based on the partners involved and their environment. Braidotti and Haraway suggest that through togetherness creation is possible. This connection does not equate largeness, but that something new is precipitated into being. The lichen embodies this notion as the entanglement is so embedded that one cannot distinguish one organism from the other, such that a new figure emerges. Instead of reading different capabilities of organisms as more important than the prior it should be understood how different skills, like photosynthesis and weathering, can complement each other. One must understand the process of becoming together not as a process that has a clear beginning and end, but as one of continually growing and changing based on connection (Braidotti 2013, 344-5). Like with the lichens in Image 1, that I came across while peering into the container for some thrown away furniture, the algae will be more present within the partnership if the container is in a sunny spot, however if the container had been moved to a shadier spot or if the metal had corroded and the fungus could reach the trash in the container the fungi, or other bacteria, could become more present within the partnership. This is possible as algae can thrive on sunlight; while fungi cannot gain energy from sunlight, fungi can indirectly do so by consuming the matter that they grow on. Lichens are nonlinear adaptable systems so their behaviour cannot be predicted by the components characteristics that make up the lichen or their environment, as through entering the entanglement together they are in a continuous state of becoming together that is always active and unpredictable (Goward 2009b, 2). Looking with co-creation allows an exploration of fungi, as part of the lichen, that understands relationality as a place of creation and a point of activity.

Deleuze and Guattari's rhizomatic theory (1978) is a productive way to look at relationality as it describes a relationality that is continuous, moving, non-linear, and non-hierarchical. Every 'strand' in the rhizome can be connected to any other, thus the rhizome has multiple points of connection, which are flexible and can be reshuffled. Deleuze and Guattari write that a rhizome can be broken at any point but must be able to reshape itself to start again based on new lines or old ones in the rhizomatic chain (Deleuze & Guattari 1978, 7-8). This is relevant to my analysis as it gives us tools to look through change that is productive and continuous, instead of seeing it as negative and static.

Rhizomes are multiple and must be treated as substantive multiplicity. These multiplicities can be reshaped, and morph based on different points of connection within the rhizome and its connections to other rhizomes (Deleuze & Guattari 1978, 5). However, if a multiplicity changes, multiplicities within and connected to the rhizome must also change, as a multiplicity has neither subject nor object, as it has "only determinations, magnitudes, and dimensions" (Deleuze & Guattari 1978, 8). Thus, meaning is made through plasticity and connection that happen within and with multiples, which allows for language that goes beyond individual versus multiple. Lichens exist outside this binary: the lichen enacts rhizomatic multiplicity while being connected to other multiples. Through lichen's performance of relationality lichen cannot be seen as an individual, however, it is not multiple autonomous organisms jumbled together either. Lichen exists in a liminal space where its shape is formed through creative cooperation and relationality. Not only is the lichen multiple, but it is also inextricably connected to its environment, blurring traditional understandings of autonomy, as the lichen is connected to its environment, in a way that it is dependent upon and inseparable from it. The lichen is not a static being, as it changes with its environment and is in motion through entanglement. Lichen materialises rhizomes relationality and co-creation, as it is a structure that is coalescing with partners to exist and thrive in places where it could not as a single organism. Here fungi, as part of the lichen, perform relationality in a tightly knit way with its multiple partners that is relationally individual and interacts with their surrounding actors.

In exploring the lichen with rhizomatic theory it is possible to delineate intersections of interest and change with more nuance. These rhizomes resist and disrupt any type of hierarchy and deep structure imposed upon them as there is no centre, head, beginning or end in the rhizome, it is a collection of plateaus that connect to each other (Deleuze & Guattari 1987, 21). If a structure is imposed upon a rhizome, it will reshape itself to resist this model (Deleuze & Guattari 1978, 12). A rhizome is an evolving map, instead of a tracing of lines. Deleuze and Guattari write:

> Per- haps one of the most important characteristics of the rhizome is that it always has multiple entryways; in this sense, the burrow is an animal rhizome, and sometimes maintains a clear distinction between the line of flight as passageway and storage or living strata (cf. the muskrat). A map has multiple entryways, as opposed to the tracing, which always comes back "to the same." The map has to do with performance, whereas the tracing always involves an alleged "competence" (Deleuze & Guattari 1978, 12-13).

As the rhizome has no centre, or 'head', the whole of the rhizome, and the connection to other rhizomes, forms reality. Instead of competence which is static, one must look at how different points of the rhizome have meaning in their activity with each other, instead of individually. Meaning is made through relationality to the subject; lichen wouldn't exist without the relationships of environment, fungus, alga, bacteria, etc. By looking at the different entry points of the rhizome and the multiple lines of connection, one maps the rhizome. Deleuze and Guattari hypothesise that plant life in its entirety is rhizomatic (Deleuze & Guattari 1978, 4). I agree with this hypothesis, as plant life and fungi interact with each other with a feedback loop where every connection moves with the other. This is how I want to contextualise the fungi, as a way to understand the lichen that incorporates non-hierarchical and active relationality. Lichen's rhizomatic nature is apparent here as the partnerships are defining rather than being dependent upon a leader organism. This process is continuous without end as the lichen is self-organising itself in an active way. By reading lichen as a rhizome and with Braidotti's concept of co-creation, whose theories allow for language that falls outside of hierarchical structures, while allowing for a view on relationality that is active and changing.

This active relationality, that is transgressive because of its flexibility, that lichen perform can be illustrated by being shot up to space. Lichen can survive a lot. Since 2002 lichen have been sent to space in various research projects. They are chosen to study life forms in space because if re-hydrated they can survive in harsh environments (Sheldrake 2020, 89). Scientists puzzle over this capacity, but I propose that due to the lichen's ability as a rhizome that is in motion through multiple forms of relationality (within the lichen and its environment) it can adjust to extreme changes to its habitat. Through rhizomatic relationality, lichens have the skill to survive even the most extreme changes and conditions. Goward claims that this is possible due to lichen being able to identify components that are familiar and "splinter them into new forms" (Sheldrake 2020, 88). In the lichen every organism can be considered as strands in the rhizome, as can every environmental element. The way lichen transform into, or as Goward writes: "splinter into new forms," can be read as the rhizome changing and mutating with its partners to be able to survive extreme environmental shifts. As rhizomatic multiples dictate, if one part of a multiplicity changes, the rest must change with it (Deleuze & Guattari 1978, 8). The organisms in the lichen that enact strands in the rhizome will identify what is familiar and what is not in this new space environment and shift itself into a new relational whole to be able to accommodate these changes. Thus, the lichen can withstand extreme temperatures in space through the responsive shifts in the relationality. When the lichen is rehydrated when it lands back on earth it can continue re-relating itself to adjust to the current climate and environment (Sheldrake 2020, 89; Spribille, et al. 2022, 4). The organisms will continue changing with each other until they find a balance where their combination which composes lichen can survive its environment. Here the lichen is performing 'principles of asignifying rupture.' Deleuze and Guattari write about the rhizome; it must be able to continue even if part of it is separated or untangled, 'principles of asignifying rupture' (Deleuze & Guattari 1987, 8). Even though the lichen is pulled out of its environment and thrown into another it continues re-relating itself to its context, or if it does die it changes into soil with its partners to continue connecting to the multiplicity that is the environment (Sheldrake 2020, 85). This principle allows a more complete account of the lichen which transforms itself to continue existing even after death. The lichen's adaptability is to its advantage as it lacks the ability to respond by moving locations and this adaptability is achieved through its connections with other organisms.

In my research, I read the relationships that form the lichen as a coalescence of two or more organisms that organise based on need and situation. Lichen form complex situational bonds that are remediated through environment and organism specific characteristics that are symbiotic which in combination explode into an unpredictable creation. The sense that the bond makes it possible for all organisms involved to exist in a place and environment where it could previously not do so, like algae living on a garbage container in the middle of Amsterdam.

Conclusion

By having a relationship with algae, and other bacteria and organisms, the fungus enters a multiplicity that exists outside of what normatively is considered singular and multiple, instead it enacts multiplicity in an individual shape. It enacts Braidotti, Deleuze and Guattari's multiplicity, within its structure, but also how it interacts with its environments. The organisms that create the lichen are not autonomous, however, this does not mean they do not have agency as only through changing together can all organisms that are lichen continue moving with their environment and keep existing. Together, in a togetherness that is so dense that they cannot be seen as either separate or a complete whole, lichen re-imagine the boundaries of individuality and illustrate active entanglements of mutual creation. This relationality is so tight that with the naked eye the multiplicity of lichens is not visible. Lichens' entangled partner strands interact in a dynamic way allowing the lichen to respond to multiple factors and systems of weather and earth composition, even when these conditions are harsh and fluctuating. The fungal actor in the lichen relationality assists with weathering away the inhabited surface, breaking it down as a food source, and slowly producing soil of which the lichen itself is a part of. Soil also consists of a combination of different actors that come together in a relationality, which I will further elaborate on later in the thesis.

Through relational entanglement the lichen is actively constructing environments by creating soil that other actors in the environment can inhabit, like flowers. A metal container, like the one in Image 1, if left long enough without cleaning would become soil through its interaction with the lichen. Because lichens are co-created and enact rhizomatic relationality they can exist in places that are almost uninhabitable and interact with them in such a way that facilitates life for others. This interaction adds to creation of ecosystems, through relationality between different actors in the environments and lichen.

Chapter 2: Shaking Hands with Mycelium, *On Relationality of Mycorrhizal Fungi and Plants Co-creating Ecosystems*

As I begin this chapter, I am listening to music by Tarun Nayar, using electrical synthesis he reads the electrical waves that travel through mycelium in his project Modern Biology to compose music (Modern Biology 2015). His work provides glimpses of the conversations that happen beneath the earth's surface. The electrical pulses that inform Nayar's compositions is how mycorrhizal fungi send information through the mycelial network. The pulses that Nayar reads are but a fraction of the activity that happens beneath the surface where fungi span kilometres and are in communication with scores of plant species. In this chapter I will explore how fungi connect with other plants and interact with their environment and through this interaction are part of creating ecosystems.

In this chapter I will be exploring how mycorrhizal fungi perform relationality to further explore how nonhuman relationality shapes ecosystems. I have extrapolated three levels of relationality from observing the patterns of connection between mycorrhizal fungi and other actors. To discuss this question and the patterns of connection I have observed, I will start by describing what a mycorrhizal fungus is, then I will discuss how mycorrhizal fungi stage relationality within themselves, and subsequently how mycorrhizal fungi connect to their plant partners. Finally, I will examine how a mycorrhizal relationality interacts with its environments. To make the argument that mycorrhizal fungi transform environments through their relational engagements with other nonhuman actors, I will be revisiting rhizomatic theory (Deleuze & Guattari 1987), Braidotti's concepts of 'becoming together' or co-creation (Braidotti 2013), and Tsing's (2017) concept of contamination. With these theories I intend to understand the impact of mycorrhizal relationality in the context of creating ecologies.

What are mycorrhizal fungi? A mycorrhizal fungus usually consists of three parts: hyphae strands (1), mycelium (2), which is made up of hyphae strands; and the fruiting body (3), which is the mushroom, consisting of a hyphae structure that is inflated with water and filled with spores. However, fungi can vary drastically in their structures as mycelial structures transform and adapt to their environment to cope with unpredictability. Correspondingly, no two mycelial networks are the same, with varying species having more pronounced diversity within their growth patterns. As fungi exist within their food source, if the material of the food source is strong, fungi develop hyphae that can break it down, some can even penetrate kevlar and crack solid rock (Sheldrake 2020, 58-59). Fungi, like *Termitomyces* (white rot fungi), are among the few organisms capable of breaking down wood, through a non-specific structure of enzymes (Sheldrake 2020, 211). Like the lichen discussed in the previous chapter, mycorrhizal fungi make connections with the organisms in their surroundings to survive. However, there are significant differences in ways of connecting, growth patterns, and interaction with environments.

I'm focusing on how these mycorrhizal networks, while less systematically entangled than lichens, have their own unique advantages through partnerships that preserve the differences of the partners. In exploring different ways of relationality that create ecosystems as a result of their partnerships broadens the understanding of the role nonhuman actors have in ecosystems. It is advantageous for lichen to be a system of non-distinguishable strands as their form of relationality makes it possible to exist in areas where almost no organism can survive, whereas mycorrhizal fungi have a different form of connecting which makes it possible to have more connections over a larger area. Unlike lichen where the partnership of fungi, algae, and other organisms form one structure; in mycorrhizal partnerships between plant and fungi, the plants “stay recognisable as plants, and mycorrhizal fungi stay recognisable as fungi” (Sheldrake 2020, 139) thus, there is a more apparent distinction between a fungus and its partner. However, it is hard to see them as separate; “Fungal hyphae fork and fuse and erupt within plant cells in a riot of branching filaments. Plant and fungus clasp one another. It’s difficult to imagine a more intimate set of poses” (Sheldrake 2020, 140). As Sheldrake writes, plant life is intimately tied to mycorrhizal fungi, not only because on a microscopic level fungus and plant interact, but also how they make each other, and their environment possible. Similar to lichen, mycorrhizal fungi and plants work together to sustain each other, however mycorrhizal fungi do so on a much larger scale, as some mycelium can span kilometres. In Oregon, United States of America, an Armillaria ostoyae (honey mushrooms) was found spanning 964,7706 hectares (Casselman 2007). Due to the partnership between fungi and plants, the plant can exist through the unpredictable conditions of its ecosystem, like droughts or wildfires. This is comparable to how lichen partnerships allow the lichen to adapt to extreme environments. However, in this case, the mycelium can reach resources deep underneath the earth's surface, as their mycelial system is a lot larger than that of lichen, and thus capable of reaching remote water sources. Like lichen, mycorrhizal fungi shape environments through their relationships, but in different ways (Tsing 2017, 171). There are similarities between relationalities of lichen and mycorrhizal fungi, however the differences show the nuances of nonhuman relationality. Exploring these nuances in relation to mapping mycorrhizal relationality shows the entangled and different ways that environments are shaped by various actors, thus creating a clearer picture of ways that ecosystems are created with nonhuman actors.

Relationality Shaping Mycorrhizal Fungi

Mycorrhizal fungi are shaped relationally between its hyphae strands and partners. To articulate the ways that mycorrhizal fungi connect to become the fungus, I will read them as acting in modes of multiplicity. To describe how these fungi are relational internally, I will first discuss how mycorrhizal fungi co-create themselves with hyphae strands, then I will discuss how they perform relationality as a rhizome.

Mycorrhizal fungi co-create with their hyphae strands to become a fungus. As discussed above, they consist of mycelium which are composed of hyphae strands, which form based on the needs of the fungus and its connections (Sheldrake 2020, 7). Hyphae strands create a network that links together and shares nutrients and information across this network. Mycorrhizal fungi can move and direct the flow of information and resources by thickening, pruning hyphae strands, or merging with another network (Sheldrake 2020, 178). Hyphae tips and their strands are in a constant process of growing, searching, and merging, while connecting with the whole mycelial structure, as well as outside the mycelial structure (Sheldrake 2020, 7). This structure of hyphae strands can be understood as reciprocity that manifests into creation. Braidotti writes: "This makes reciprocity into a gesture of creation, not as the struggle for the recognition of Sameness" (Braidotti 2013, 343). She argues that when actors come together something new is created instead of duplicated, thus, connections between actors result in new forms of life. In the case of mycorrhizal fungi when hyphae strands connect with each other they create mycelium. This creation through connection is ongoing as hyphae strands grow, retract, and merge. Thus the creation from connection must change with the actors that generate this creation, instead of resolving into a static final product. The mycorrhizal fungus becoming through its many strands co-operating in a continuous loop of activity and information. Mycorrhizal fungi shift together to keep becoming with each other, adapting to the needs of the hyphae strands, as the mycelium changes to incorporate those needs. Here I read the fungi's productive connections as a becoming with each other that becomes mycelium, which precipitates the becoming of the mycorrhizal fungus.

While applying the concept of co-creation to mycelium is useful for gaining a better sense of what mycorrhizal fungi are, Deleuze and Guattari's (1987) articulation of rhizomatic relationality allows for insight into how mycorrhizal fungi exist relationally. Hyphae strands are in an interconnected web that creates mycelium, and this mycelial structure can be understood as a rhizome as hyphae strands can be interpreted as rhizomatic strands that interconnect and move with each other. All strands of the mycelium are connected to each other through a complex and mutable system. True to the rhizome model "all individuals are interchangeable, defined only by their state at a given moment–such that the local operations are coordinated and the final, global result synchronized without a central agency" (Deleuze and Guattari 1987, 17). As in the rhizome which privileges interchangeable relations of connection, hyphae strands can connect to each other, fuse, and release depending on the movement and information communicated by other hyphae strands (Sheldrake 2020, 178). Mycologists still don't understand the mechanism behind this, but it is known that there is no central point in the fungus controlling the strands (Sheldrake 2020, 67 & 69). Thus, hyphae strands materially enact a-central communication and connection (Deleuze and Guattari 1987, 17). Through adapting and changing with each other, hyphae strands are enacting rhizomatic relationality by forming connections with multiple strands into a network that can interchange and shift depending on need, which leads to complicated and durable connectivity.

As hyphae strands move, change, and fuse together like rhizomes, rhizomatic theory determines them as multiple. Braidotti writes: "Multiplicity does not reproduce one single model … but rather creates and multiplies differences" (Braidotti 2013, 351). As previously discussed with the concept of co-creation, mycorrhizal fungi must be understood in modes of multiplicity. If the fungus is co-created through connectivity, it cannot be seen as strictly individual. And when two actors create together, they create new avenues of being. In the case of mycorrhizal fungi, a multitude of hyphae strands are growing with each other to create a mycelium structure that changes depending on different information, connections, and environmental activity, composings a unique mycelial structure that, as Braidotti writes, “creates and multiplies difference” (Braidotti 2013, 351). Deleuze and Guattari write that rhizomes are multiple, and the hyphal structure of mycorrhizal fungi enact the rhizome in its multiplicity, rejecting structural centrality, which might be hierarchical. Therefore, I argue if the fungus is co-created through connectivity and enacts rhizomatic relationality, the fungus must be discussed in modes of multiplicity. Hyphae strands are becoming with each other in creative movement and connection that forms mycorrhizal fungus.

Mycorrhizal fungi enact non-hierarchical modes of relating in the sense that it has no centre and in an interconnected fashion, unlike trees having a central commanding stem (Deleuze & Guattari 1987, 7). In conceptualising the fungus as a rhizome it will re-relate itself to slip out of any type of hierarchical imposed structure, and find a balance with its partners to interact outside of hierarchical structures.

Looking at the internal structure of mycorrhizal fungi with rhizomatic theory and the notion of co-creation allows for language and conceptualisation of the mycorrhizal fungus to address how it connects with plants and influences their environment. By looking with Braidotti’s (2013) co-creation and rhizomatic theory understanding the extent of relationality that fungi engage with that allows them to connect to others and thrive.

Relationality Between Plants and Mycorrhizal Fungi

Internally mycorrhizal fungi have a relational structure that enacts the concepts of co-creation and the rhizomatic, including in its modes of multiplicity. This structure adds and is extended to the relationality between fungus and plant partners. To exist mycorrhizal fungi make partnerships with plants to exchange resources. By doing so fungi have access to resources that they do not have underground, while plants gain access to minerals that are deep underground. Due to living in their food source and the productive ways to grow in even the hardiest environments, fungi are more successful than trees in reaching minerals and other resources beneath the surface, while trees can provide minerals like carbon. Thus, an entanglement between plant and fungus is beneficial, if not crucial, to both organisms (Sheldrake 2020 139 & 147; Tsing 2012, 143). How this entanglement is formed depends on environmental factors, as well as the partners involved. Here I will use a case study that focuses on the connection between mycorrhizal fungus and plant partners to more thoroughly illustrate the way the fungus relates to its plant partners.

Understanding how mycorrhizal fungi and plants interact with each other allows for a perspective on how nonhuman actors create together. Sheldrake writes about mycorrhizal connectivity: “A mycorrhizal fungus that can keep its various plants alive is at an advantage: a diverse portfolio of plant partners insures it against the death of one of them” (Sheldrake 2020, 179). By exchanging resources with multiple plants, even across species, fungi have more stability. Through facilitating and mediating entanglements with multiple partners, fungi increase the survival chance of themselves and their plant partners by being part of a larger network. However, each entanglement is mediated by the needs of all plant partners involved, as well as their environment. Some fungi and plants have very specific relationships catering to each other’s needs (Tsing 2017, 139). An example is matsutake and pine, their relationship does best in environments where there are not many other living organisms, thriving in mountains and logged forests. The hyphae strands of the matsutake can penetrate rock where the fungus forms a mat-like structure excluding non-partners from the environment (Tsing 2017, 171). The mycelium moves through the rock finding minerals and water, while pine absorbs carbon. Pine is only able to exist in rough, rocky terrain through this connection with the matsutake. The entanglements that form the network facilitated by mycelium create an interchange of resources and information that allows for relational survival. By connecting with a partner different from itself mycorrhizal fungi can access resources not available to it, and as a consequence of the added resources thrive in its current form through reciprocal action with plant partners. Braidotti writes that becoming with any entity is “in a constant encounter with external, different others” (Braidotti 2013, 348). Here she writes that connecting through difference creation happens, something new is created (Braidotti 2013, 348). Mycorrhizal fungi and plants create through connection, as they are two different actors that make each other possible through interaction and become inseparable through their reciprocity. I write creating as an active and an ongoing process. This creation is focussed on possibilities, movement, and how fungi and plants complexly create together. Deleuze and Guattari’s (1987) ‘principles of connection and heterogeneity’ (Deleuze & Guattari 1987, 7) articulate the formations of connections across differences while entailing that all actors in the rhizome are necessarily able to connect to one another (Deleuze & Guattari 1978, 5-12). This connectivity creates the rhizome. The hyphae strands connect with the plant and incorporate this connection into the mycelium. In this process they can interchange strands of connections, roots and hyphae strands, and move with each other to account for change. Thus, if the relationship between plant and fungus is understood as rhizomatic then even though the two organisms are different they can connect and become a rhizome. Fungus and plant partners extend into each other, dissolving the border between them. This is not to say they are one and the same, rather the partners are overlapping strands connected in a series of actions that overlap with other multiplicities, thus they must be understood as relationally individual. I will concentrate on fungi and plant partners, however this is only a glimpse of the various connections contributing to the mycelial network. These nonhuman actors–fungi and plants–create a network of connections across heterogeneity in order to facilitate their existence in a world where change is constant.

Both rhizomatic theory and co-creation help articulate how plant and fungus merge into an inseparable whole through inter-connections. In the entanglement of pine and matsutake the conceptual boundaries between plant and fungus are blurred as they productively flow into one another. One without connecting to the other would manifest themselves differently in their existence, by connecting they become with one another. Unlike with rhizomatic connection where strands in the rhizome influence each other through entanglement and thus are in a dance of rearranging themselves based on their relationality, co-creating specifically outlines the creative force of connecting with others. Through reciprocity and connection fungi and plants create each other.

The mycorrhizal fungal relationships, like matsutake and pine, interact as and with multiplicities. Deleuze and Guattari argue that multiplicities are defined by their interaction with other multiplicities (Deleuze & Guattari 1987, 9), through contact with other multiplicities and actors the rhizome changes. The actors that are part of the rhizome must re-relate with each other, as if one part of the rhizome changes, the rest must change with it (Deleuze & Guattari 1987, 8). This way of relationality is enacted in how pine and matsutake relate and connect with each other. If part of a pine forest is logged, the matsutake and the left-over pine would need to re-relate themselves to the new condition. Thus, even if plant partners are not multiplicities themselves, like a tree as Deleuze and Guattari argue (Deleuze & Guattari 1987, 7), they influence the multiplicity that is mycorrhizal fungi. Through relationality, communication facilitated by mycelium, and the rhizomatic nature of mycorrhizal fungi, plant partners and fungi react with one another. Here actors are in communication with each other without centralised control, but instead through a relational communication loop that is facilitated by the mycelium, where they continue re-relating with each other to find a balance for existing. How mycorrhizal fungi and plant partners move and change with each other is an important concept to understand how environments are created through nonhuman relationality.

My incorporating the tree into the discussion of rhizomes poses a potential problem, as Deleuze and Guattari write that the concept of the tree is not rhizomatic due to the rhizome being a structure that opposes the centralised, and thus hierarchical structure of a tree as having a centre or trunk which organises the overall organism (Deleuze & Guattari 1987, 7). However, research shows that due to the fluid nature and openness of the rhizome (Bÿrger 1985, 34) it can infiltrate structures such as the tree. Trees make connections with many fungi and vice versa, and thus becoming part of a vast network of actors, to increase chances of survival, as the more connections one has, if one fails this can be compensated through other connections of reciprocation of resources (Sheldrake 2020, 19). I will argue that trees in connection with fungi engage in rhizomatic relationality to some extent to collaborate with the fungus. The tree changes with the mycorrhizal fungus connected to it, accounting for changes in the environment. Even though it has a central body that branches stem from, the tree is connected to other trees through its connection to the fungus, by means of mycelium. If we look at the matsutake and pine, the matsutake fungus creates a mycelial network underground that connects with multiple pines to exchange resources in an inhospitable environment. Thus, the tree itself becomes part of a larger network that can modify according to environmental changes, a strand in the rhizome that is actively changing with its partners.

Mycorrhizal Fungi and their Environment

Throughout this chapter I have argued that when mycorrhizal fungi make connections they enact creation and change. Additionally, I have observed that the mycorrhizal fungus materially performs rhizomatic relationality within its own organisational structure. The mycorrhizal fungus expands its plant connection through moving with each other, while connecting, and changing those connections based on need. In this last section of my chapter, I argue that through relationality mycorrhizal fungi are in relation and co-create with their environment through the relationality that I have described on an internal fungal level as well as through their plant connections. To highlight this specific argumentative point I made earlier, I turn to Tsing (2017) to explore the concept of contamination in relation to fungi.

In embarking on how Tsing's (2017) concept of contamination is relevant in understanding mycorrhizal fungi influence on their surroundings, I make the assumption that environments are multiplicities. The fungi considered in the case studies change depending on their engagements with their respective environmental multiplicities, as "Multiplicities are defined by the outside" (Deleuze & Guattari 1987, 9), so that multiplicities change with and in response to the multiplicities they're embedded in.

As multiplicities engage with each other they are in a process of becoming together, this is evident in the creation of soil. A third to half of the earth's soil is made up of mycelium, making it an integral binding factor. When there is rainfall or a drought, mycelium's unique structure holds the soil together and distributes water across the mycelial network (Sheldrake 2020, 4-5). However, mycelium has no pre-set plan as decisions concerning how to "distribute their bodies is a question fungi face on a moment-to-moment basis" (Sheldrake 2020, 54). Mycorrhizal fungi will adjust to the given circumstances and the multiplicity attached. The mycorrhizal fungus, through interacting with the multiplicity that is its environment, is making sure that the plants and the fungus can keep existing in their habitat, as in the example of holding soil together so that the habitat doesn't wash or blow away or by decomposing leaves on the forest floor. This example can be understood as a case of becoming with partners as Braidotti (2013) describes it; mycelium with their plant partners are becoming soil and thus becoming the environment. This relationship is active and engaged, changing with each situation like extreme rainfall, where the mycelium and environment sustain through their connection.

Tsing writes on how different historical events, trading histories, and habits have influenced fungi and their environment, focusing on the mycorrhizal fungus matsutake. Due to deforestation, travel, trade, and forest ownership the matsutake has spread around the world, thriving in places where logging and forest activity take place. Tsing writes: "Contamination creates forests, transforming them in the process" (Tsing 2017, 29-30). Contamination can be understood as traces left by contact and activity between organisms, be they human or nonhuman. Tsing writes that the current and past capitalist climates of the logging industry and land ownership shape matsutake populations as well as their surroundings (Tsing 2017). Tsing argues that environments are not 'naturally' occurring, but actively created through history, location, and the variety of actors interacting with it. Tsing's work is particularly relevant to my research because it allows us to focus on the no nonhuman perspective in these interactions. “Everyone carries a history of contamination; purity is not an option” (Tsing 2017, 27). Being completely separate from the other is impossible, as traces of the other are carried by actors that connect, or have connected to one another. With this concept of contamination, it is possible to understand how environments are created through actions and relationships between various actors. Pine and matsutake are capable of subsisting in environments of hard rock because of their relationship in which the mycelium breaks down the rock to become soil, slowly changing the landscape into one which is easier for other plants and creatures to inhabit. In the matsutake and pine example, actors become creators through their contamination of the environment. The environment carries traces of the interactions that shape it, as in this case the resulting soil will carry traces of the matsutake and pine.

Because of proximity and active relationality fungi and partners are in a flurry of activity, continually shaping themselves to meet the communicated needs of environment and partners, existing in a continuous feedback loop on a massive scale (Tsing 2017, 195). Matsutake and pine shape their relationship based on their environment, as the fungus slowly weathers rock their relationality will shift with the increase of other actors and change in environment with the increase of soil. Matsutake and pine will re-relate with each other to incorporate and become with their new connections, this happens in a feedback loop where actors change with each other to inhabit environments.

As in the aforementioned example, rhizomatic multiplicities define the transformative relationalities that shape ecosystems. Environments might even be understood as a series of plateaus overlapping in an endless motion of relationality (Deleuze & Guattari 1987, 21). The multiplicity of mycorrhizal fungi, plants, other nonhuman actors all in motion with one another to create an environment, without end, beginning, or centre. Just as our case study demonstrates how strands of mycorrhizal fungi interact with plants catalyse this endless process of becoming the environment. It is the networks of connections to nonhuman actors that renders fungi distinctly capable of creating ecosystems with their partners.

Conclusion

Mapping the ways that mycorrhizal relationality occurs enables us to map the development of ecosystems. These transformations unfold over millions of years of interaction between multiple actors, with fungi often being an invisible partner underneath the ground connecting, communicating, and changing with its environment. This entanglement happens without centre, or orders from a singular actor, instead nonhuman actors relate in a non-hierarchical and asymmetrical manner. Even seemingly independent actors, like trees and soil, are co-creating their habitat while adjusting themselves to networks of relational needs. This is a continuous process, as environments and different actors in the relational chain change. If a boulder falls down a mountain, the fungus may diversify resources to injured trees and start penetrating the rock with its hyphae strands, just as in rhizomatic theory when one point in the rhizomatic chain changes, the rest changes with it. Mycorrhizal fungus continually re-relates itself to its environment until there is a balance where the relational whole can survive. Mycorrhizal fungi play an integral part in constructing their ecosystem and those who inhabit it.

Chapter 3: Building with Termites and Fungi, *On Relationally between Termites and White Rot Fungi Building Eco-systems*

Termites and fungi have formed a partnership that enables their ecosystems to flourish. Termites and fungi partner together for sustenance and habitat. In this chapter I will explore the impact of the relationship between *African Macrotermes* termites and *Termitomyces* fungi on their environment. This entanglement is particularly exemplary because of the explicit effects such as drastic increases in vegetation in the presence of this relationship (Sheldrake 2020, 193). The relationality that termites perform is flexible and adaptive, as in preceding fungal cases. However, the partnership with insects allows for a different expression of relationality than that of lichen and mycorrhizal fungi that connect with plants, bacteria, and yeast because of the difference in mobility and the presence of the termite mound. *African Macrotermes* build complex termite mounds to house the *Termitomyces*, where the fungus breaks down wood that the termites supply, as termites themselves cannot break the wood down on their own. The consequences of the mound and the relationship between fungus and termite ripples out across their environment. To examine the relationship between fungus and termite and how this relationality influences ecosystems, I will first discuss the relationship that the termite and fungus form and continue to how this relationship influences the environment. To conclude I will discuss the influence this relationality has on ecosystems to further explore how relationality between nonhuman actors create ecosystems. To investigate the way that termite and fungus enact relationality I turn to Deleuze and Guattari's rhizomatic theory (1987), Braidotti's (2013) articulation of co-creation, and Tsing's (2017) concept of contamination.

While the relationship that is present here is active, interactive, and highly adaptable like those that mycorrhizal fungi and lichen interact within, the relationality with termites uniquely enables the fungus to focus on other complex tasks. Unlike the mycorrhizal fungal relationality with plants, termites have the mobility to bring back resources like wood and build stable environments to withstand changing environmental shifts. Therefore, the fungus does not have to be as resilient to withstand change to habitat and can instead dedicate most of its energy to creating complex fungal combs, digestion, and creating with the termite. The protective barrier of the termite mound frees the fungus to focus on activities like decomposing wood and building fungal combs with the termites out of mycelium, instead of exploring and looking for minerals with its hyphae strands. This example of a relationality across difference demonstrates intimate relationality that depends on each other for survival. This relationality extends to other actors and ultimately are significant in facilitating their ecosystems.

The Mound, On Relationality between Termites and Fungi

Termites have different types of relationality, depending on the environment and if there is a symbiosis present in their gut or in the nest of termites (Abe & Higashi 2001, 582). For the *African Macrotermes* the nest is a mound that the termites build. *African Macrotermes* cannot digest their food, wood, as they do not have a "symbiotic amoeba" in their gut, instead they form relationships with fungi to digest their food source for them (Abe & Higashi 2001, 584). In this section I will focus on the relationship between *African Macrotermes* termites and *Termitomyces*—white rot fungi, thus the relationality between termites and the fungus that they house in the termite mound. The fungal comb in the mound is a structure that termites and fungi build together. Termites forage for wood, chew it up into a slurry, and regurgitate it into a fungal comb. The fungi grows into the comb completing it by building and shaping the comb with its mycelium in collaboration with the termites. The white rot fungi decompose the wood using irregular enzymatic combustion, due to the chemical structure of wood being so irregular. White rot fungi use non-specific enzymes to break down wood instead of enzymes that lock into specific shapes of molecules like most organisms (Sheldrake 2020, 180 & 193). Termites and fungus in connection with one another are able to sustain each other, exemplifying Braidotti's statement that when actors connect they become with each other (Braidotti 2013, 343). The interaction and consequent creation that termite and fungus undertake can be interpreted as co-creation, where through connecting termite and fungus create each other into an altered being to continue existing together (Braidotti 2013, 343). I argue that this creation is manifested in the termite mound.

Termite mounds are architectural wonders, built to regulate microclimates to facilitate the habitat for not only fungi, but other plant life and animals. Sheldrake writes on termites: "By opening and closing tunnels within a system of chimneys and galleries, termites are able to regulate temperature, moisture, and levels of oxygen and carbon dioxide" (Sheldrake 2020, 198). Thus, termites are able to create conditions where fungi can exist and thrive even in harsh and dry climates like deserts (Sheldrake 2020, 198; Pietroiusti et al. 2020, 14:30-16:30). Some of these mounds are thousands of years old and up to nine metres high (Sheldrake 2020, 193). The termite and fungus work together to build these mounds filled with fungal combs to facilitate a habitat that is mutually favourable. Without the fungus the termite could not sustain itself on wood, while the *Termitomyces* fungus cannot independently thrive in climates as extreme as the *African Macrotermes* termites inhabit. Termite and fungus are becoming together, by co-creating the complex structures of termite mounds, and thus each other.

Like the other fungi I have explored in this thesis, white rot fungi cannot be seen as separate organisms from their partner termites. Termites, which move and act as a whole, also function necessarily as multiplicities. No single termite knows the whole structure and the balance that keeps it going (Sheldrake 2020, 72), yet through collaboration with fungus and the environment, the termites are able to thrive in a network that is intra-active and productive.

Creating Environments Together

Termites and fungi are part of a relationality in multiplicity that interacts with the multiplicity that is the environment, like by creating soil. Soil then is revealed to be an actualisation of the relationality of many different actors, that through the intra-active entanglements of environmental relationality becomes an actor itself. Over time soil is made by stamping down layers of activity, this activity can be many things, like storms, human interventions, interactions between plants, etc. Termites and fungi interact with these layers of soil through the termite mound. As the chimneys in the termite mound bring up water, deep underground nutrients of layers of soil that have been tamped down over time also rise to the surface of the environment where *African Macrotermes* mounds are located. Consequently, minerals which don't formally exist on the earth's surface are introduced to it creating a nutrient rich and active soil. As a result of moisture and nutrients being introduced in the vicinity of termite mounds, the vegetation is more diverse than that of surrounding areas, like trees growing where otherwise only grass can grow (Pietroiusti et al. 2020, 2:20-2:39). Fungi in turn help distribute and incorporate minerals deep underground into the termite mound and soil. Soil, termites, time, and fungi are creating environments in climates where the abundance of life is not possible without the interaction with the termite mound.

Soil is actively influenced by histories, this speaks to Tsing's concept of contamination, as she writes that actors leave traces on one another that alter them and pass on through connection (Tsing 2017, 27-30). Through their system of the mound which carries minerals up from long submerged layers of soil, termites materially bring the past into contact with the present. The soil around the mound has a different and more nutrient rich composition because of its contaminated interactions with the past. This cultivation of soil through interactions between fungi and termites over time forms environments.

The interaction of the *African Macrotermes* mound with the other nonhuman actors is rhizomatic as they extend into each other and make each other possible, as in the principles of connection and heterogeneity' (Deleuze & Guattari 1987, 7). Through contact they create a chain of activity that allows for an ecosystem to flourish. As Takuya Abe and Masahiko Higashi write; "Termites are ecosystem engineers" (Abe & Higashi 2001, 588). *African Macrotermes* and white rot fungi enact rhizomatic relationality, through various interaction with bacteria, animals visiting to eat the vegetation and defecating seeds and fertilising soil, and water deep underground. These different actors can be understood as strands in the rhizome that interact with each other and connect in various ways to other actors in the rhizome depending on activity. To illustrate this I zoom in on the connection between termite mound and soil, where fungi and termites extend into each other in their connection and create the termite mound. This mound interacts with soil over time as it is being tamped down, through this process of interaction nutrient rich soil takes form. I argue that time periods, soils, termite mound, termite and fungus, are strands in the rhizome that connect, relate, and re-relate to other strands based on activity to become the rhizome that is an ecosystem.

The multiplicities made up by a multitude of various strands like fungus and soil, move and change based on activity outside of the rhizome and each other (Deleuze & Guattari 1987, 9). This movement is done on a feedback loop of all actors involved that relate based on activity. This is performed in a non-hierarchical manner, as there is no commanding insect or plant, instead intimate structures of interaction that move with each other. As rhizomes overlap with each other like plateaus, and connect with one another in an entanglement of strands, they change with one another (Deleuze & Guattari 1987, 21). An example of overlapping multiplicities is when birds interact with the rhizome that the termite mound is part of, connect with other multiplicities, through this connection, changing with, and extending into each other between multiplicities is enacted. When a bird eats a seed in an ecosystem 50 kilometres away and then drops its excrement in an ecosystem with a termite mound, becomes an actor in that ecosystem. The actors in the ecosystem will re-relate with each other to incorporate a new plant that grows from the seed, that may turn into a food source for the termite and fungus, fertilisation of the soil, and the newly arrived bird. This activity of connection is numerous and extensive, manifesting in an unpredictable manner depending on the other interactions that are active in the rhizome. The ecosystems that termite mounds inhabit are situational, as are the interactions that create ecosystems. Exploring the synergy that make up these ecosystems with rhizomatic theory and the concept of contamination shows the extension of nonhuman interactivity in creating ecosystems.

Conclusion

African Macrotermes termite and *Termitomyces* fungi co-create with each other through connection, and change with each other to continue existing, resulting in the creation of the termite mound. This soil that houses the termite mound is in a non-linear interactive relationality with time, as well as all visitors and inhabitants of the soil. All termite mounds and their partners are actualising their relationality differently to suit the environment and the relationship they have with the actors that they collaborate with. Like lichen and mycorrhizal fungi, termites and fungi exist in a finely tuned balance that creates environments through their connections, contaminations, and interactions. In this chapter I argue that these ecosystems are rhizomatic and mobile in nature, connecting with each other through interaction with various nonhuman actors. Through multiplicity in relationality, all actors move together to create ecosystems. The termite mound which houses the termites and fungus also plays an instrumental role in the network of relatings that compose its surrounding ecosystem.

Conclusion

Throughout this thesis I have explored three different forms of fungal relationality–lichen, mycorrhizal fungal, and *Termitomyces* fungal relationality–and how relationality creates, maintains, and transforms ecosystems. There are parallels in how these relatings inform their respective environments, yet every form of relationality is still vastly different from the other, because they are informed by their unique partnerships. In this conclusion I will continue to do a synthesised reading of fungal relationality to understand their influence on ecosystems. Then I will discuss what further research is needed after observing the relational patterns of fungi. Using relationality to understand fungi in its interactivity showcases the role fungi have in creating ecosystems as nonhuman actors.

Fungi that are part of lichen are engaged in a relationality which is tightly woven and can appear as only one organism. Even though the interaction between organisms in the lichen is microscopic, the effects of it are not. The lichen's capacity to survive almost anywhere, including the harshest of environments and even space, is due to a relationality that is active and in which the components will re-relate with each other in order to survive. As a result, they are often one of the first organisms to be found in seemingly uninhabitable places, like rocks on a sea shore or volcanic rock. Their presence can slowly make the uninhabitable habitable; they break down hard materials into soil and eventually become soil themselves. Fungi in lichen create environments through their interactions with one another that in turn invite other actors to be connected to the relationality that is lichen. Through their active connections they continue re-relating with changes that they create with their partners. This is seen in the three fungal cases that I investigate, as all the fungi interact with their partners in a way that stays active in fluctuating and changing environments, incorporating other nonhuman actors into their flow.

The soil producing work of fungi is a recurring element of my research. Mycorrhizal fungal mycelium makes up one to two thirds of soil. Additionally, if a fungus inhabits a rocky area with their partners they will slowly weather the rock that becomes soil and decompose organic matter on forest floors into soil. Through entering relationships with plants they exchange resources and information in an environment to change with each other in response to changes in said environment, or the actors in the relationality change. Mycorrhizal fungi facilitate the movement of minerals, nutrients, and bacteria through soil through their connection with their plant partners. These responsive changes of fungi to and with their partners, environment, and other actors help develop into ecosystems. Through partnership with other actors, mycorrhizal fungi are able to exchange resources with plants to sustain each other, while responding with the surrounding environments and actors. Through these various connections fungus and plant extend into each other, entangling their roots in such an intimate fashion one needs a microscope to see where one organism physically ends and the other begins. Still, plant and mycorrhizal fungus cannot be seen as outside of being physically separate because they make each other possible and co-create each other. Fungi extend into their partners through their networks of connections and vice versa, connections by which they mobilise together to continue existing in fluctuating environments and continue the activity that creates ecosystems.

The relationship between termites and white rot fungi is the most highly specified case I have explored in this thesis, limiting my inquiry to *African Macrotermes* termite and *Termitomyces* fungi, instead of termites and fungi in general. I do so because the interspecies relationality that leads to ecosystem formation is explicit. They interact with each other to sustain one another. The termites bring the fungus wood that the fungus digests for the termites, and together they build a mound to create an environment that is favourable to the fungus. The mound's architecture facilitates the carrying of water and minerals to the surface by the termites and fungi, and the resulting access to water and nutrient rich soil causes other plants and animals to flock to termite mounds. As the interaction between the termites and fungi in the mound extends to the soil over time, it creates a beneficial ecosystem for other nonhuman actors who continue the process of ecosystem building and maintenance together with the fungi and termites. The relationality that I address here is different from those of lichen and mycorrhizal fungi as the white rot fungus interacts with insects that have a different mobility range and manifestation than plants. However, in each case study the fungus similarly interacts with its environment and surrounding actors, and co-creates the soil that composes the ecosystem.

Understanding the extent of fungal connections as rhizomatic allows an exploration of the influence of fungal relationality to extend further than where the hyphae strands end. Specifically, using the principles of connection and heterogeneity and asignifying rupture makes it possible to map the influence of fungi past physical connection, and instead explore their relationality as the ways that the effects of these relationships exceed the points of physical connection with their partners. Similarly, the concept of contamination made it possible to understand the influence of actors on each other over time and vast spaces, while exploring the traces that fungi interact with. Braidotti's co-creation allowed for a perspective to see connection as a point of creation in an affirmative manner. To understand the relationship between fungi and partner as collaborative, existing outside of binaries of multiple versus individual, relationally individual articulated how actors extended into each. Through connecting they create each other, as well as their connections through contact. Each case of fungi had a structure of entanglement that was different, yet each connection reached into one another to move and change together. This is done without a centre or hierarchical structure, instead as a series of interactions with which actors change with each other. I described this entanglement where actors move together as co-creation, contamination, and rhizomatic to fully explore the nuances of the relational existence of fungi. My inquiry into the role of fungi in ecosystems is to argue that they are world builders. This sounds like a grand term, yet fungi through their connection and interaction with their partners are actively changing their environments and influencing actors that interact with these environments, like matsutake and pine breaking down the rocky terrain that they inhabit and thus making this area accessible to various actors. Ecosystems are actors interacting with weather, water, and other geographical factors, grounded in a location to create an area of life. Fungi actively participate in this interaction and are expert relationship builders that interact with their surroundings.

Fungi interact with their partners in numerous ways that lead to creation, movement, and changing together. Fungi behave differently according to their respective species, however I have observed that their activity is dependent predominantly on their partners. Through their connections with partners and surroundings, as well as indirect interactions with actors mediated via their partners, they build habitats and create ecosystems. In grounding this research in the posthuman it was possible to explore nonhuman interactions, decentering human intervention, and to give agency to the fungi and their nonhuman connections. Fungi are a vital element in understanding the extent of nonhuman activity that leads to world building.

This research was focused on how three types of fungi interact with other nonhuman actors to create the multiplicities that are ecosystems. Additionally, I would suggest further research on fungal relationality with nonhuman partners as a way to revitalise newly formed deserts due to global warming and increasing plant health and diversity in homogenous farming communities could be a way to combat problems globally as a result of capitalism. However more research needs to be done on how fungi can be parasitic and their long-term effects it has on ecosystems. I would suggest a further interrogation of how human in addition to nonhuman actors create ecosystems together. However, this research must be grounded in posthumanism as to not underrepresented nonhuman actors in this exploration.

Soon the foraging season will start again–in the Netherlands it is around the end of September or beginning of October, depending on the weather conditions. When I go out in search of my favourite mushroom–the boletes–which happens to be one of the few fungi species that I can properly identify, my interaction with them will change. Understanding the extensive interactions that fungi are part of in composing the forest that I forage in will force me to stand still and understand myself as an extension of that interaction. My hands, as I carefully cut the stem from the ground, the bike basket that will transport the boletus and distribute spores along the way to my apartment, and even the mycobacteria in my gut that digest it, will become part of the interactions that connect to the fungus and extend into creation.

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