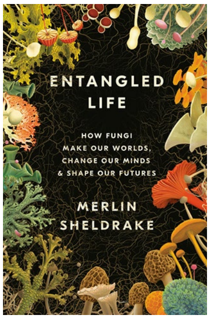
A cure for ‘fungus blindness’



Entangled Life: How Fungi Make our Worlds, Change our Minds and Shape our Futures

By Merlin Sheldrake

RANDOM HOUSE: 2020. 368PP. £28.

What is it like to be a fungus? This is the question continually posed in an engaging new book by first-time author Merlin Sheldrake. The book, entitled *Entangled Life: How Fungi Make our Worlds, Change our Minds and Shape our Futures*, is a celebration of the intricate lives of fungi and the remarkable array of interactions in which they take part.

The world around us would not be the same were it not for fungi. They are after all the principal degraders of biomass in most terrestrial ecosystems — without fungi we would quite literally be overwhelmed by waste — and they are familiar to us as mushrooms, toadstools and the moulds on food we don’t consume on time. Fungi also form a huge variety of interactions with plants, ranging from mutualistic mycorrhiza and the endophytes that live in plant tissues, to a wide variety of plant diseases — both subtle and devastating. What is often overlooked though, even among many plant scientists, is just how pivotal fungal interactions have been (and still are) to the success of plants. The colonization of land by plants, for example, could not have occurred without fungi. Mycorrhiza were critical to mineral and water uptake from soil, facilitating the proliferation of plants across the planet. Likewise, formation of soil itself involves weathering of rocks by fungi and lichens.

It is, in fact, difficult to overstate the importance of mycorrhiza to plant growth and ecology. The extensive networks of mycorrhiza that link together plant root systems have even been termed the ‘wood-wide web’, with plants corresponding to the web-pages and fungi the hyperlinks that join them together. However, as Sheldrake argues, this hardly describes how such fungal networks actually operate. Fungi are living organisms with their own interests, and evolution of plant-to-plant networks has been the result of selection acting on fungal species, as much as the plants involved. The ground-breaking work of David Read established that carbon can be passed from plant-to-plant via mycorrhiza, and Suzanne Simard went on to observe such carbon transfers in natural ecosystems. We now know that these nutrient transfers between plants can be substantial. A recent study showed, for example, that 280 kg of carbon per hectare of forest can be transferred between trees by their fungal connections — around 4% of the total carbon fixed from the atmosphere by the same hectare of forest[1]. Sheldrake also highlights how some plants, such as the beautiful white ‘ghost pipe’ plant *Monotropa uniflora*, have given up photosynthesis completely, relying instead on mycorrhiza for all their nutritional needs. This mycoheterotrophic lifestyle is, in fact, not even that uncommon. It has arisen independently in at least 46 plant lineages, and all of the 25,000 species of orchid, for instance, adopt a mycoheterotrophic lifestyle as some stage in their development, adopting a ‘take now, pay later’ approach to fungal interaction, as described by mycorrhizal expert Katie Field. As Sheldrake points out, the function of mycorrhizal networks has been predominantly described, however, from a plant-centric perspective.

Plant scientists are very aware of ‘plant blindness’. How many times have processes first identified in plants been hailed as breakthroughs when discovered much later in animals? From RNA interference and immune receptors (to name but two instances), there are many examples of plant science discoveries being overshadowed in this way. But Sheldrake argues that plant scientists are equally guilty of being ‘fungus-blind’. Plant ecologists tend to think of fungi as mere pipelines between plants, describing the transfers of minerals, nitrogen and carbon exclusively from the perspective of ‘donor’ and ‘receiver’ plants — hence the ‘wood-wide web’ analogy. But an alternative and compelling argument is proposed by Sheldrake, who suggests that fungi may exert greater control of such ecosystems than currently appreciated, manipulating plants for their own advantage. Such distorted thinking does, of course, go even further: into the fungal biology research community itself. I would argue that ‘fungus blindness’ is as common among yeast molecular biologists, who are more likely to think of *Saccharomyces cerevisiae* as a ‘unicellular human’ than a fungus. It is, after all, a better strategy to emphasize the generality of conclusions for all eukaryotic life, which tends to impress grant panels and editorial boards. But this creates an equally distorted view when considering the relationship of budding yeast to its filamentous relatives and the evolutionary processes that have produced the wonderfully diverse fungal tree of life[2].

Even at a planetary scale, fungi exert a powerful influence. The decomposition of woody plant material is of vital importance to the contemporary global carbon cycle, releasing 85 Gt of carbon to the atmosphere each year, an essential component of our climatic system. White rot fungi use specialized lignin peroxidase-dependent free radical chemistry to degrade the highly recalcitrant lignin component of wood, while brown rot fungi degrade the cellulose. During the Carboniferous period, 290–360 million years ago, when woody plants began to proliferate, huge forests grew and then died, but un-rotted material accumulated for millions of years, producing the rich coal seams that (much later) fuelled the industrial revolution. The absence of fungal-mediated degradation of woody plant material was very likely a factor in this accumulation, which led to a fall in atmospheric carbon dioxide levels, cooling the global climate[3]. So, the activity of fungi has had a longstanding global impact, again somewhat overlooked.

What sets this book apart from previous celebrations of the fungi, of which there have been several, is that the author really tries to imagine what it is like to be a fungus. His rich text evokes an understanding of what it would actually be like to be a filamentous microbe, forming interwoven networks that permeate, invade and feed upon the substrates that surround them. Sheldrake works hard to shake off the anthropomorphic viewpoint and see things from a microbial perspective. This is perhaps most powerfully illustrated when he is talking about lichens in the wonderfully titled chapter, *The Intimacy of Strangers*.

Lichens are truly extraordinary; an interaction between an alga and one or more fungal partners, which collectively form an anatomically complex organism quite unlike anything that the constituent partners can develop on their own. Indeed, as Sheldrake argues, it is hard to understand where the symbiosis ends and the lichen starts, because lichens appear as such complete organisms. In the words of curator and enthusiast Kerry Knudsen, lichens "look like fairy tales". Sheldrake tells the story of Simon Schwendener and the formulation of the dual hypothesis in 1869, which first described lichens as a union of fungus and alga, with Albert Frank coining the new term 'symbiosis' to describe them. Lichens really are the holy grail of plant–microbe interactions, and there is so much about them we don't understand. How many microbial partners constitute a lichen? How can such morphogenetic complexity arise from anatomically simple microbes? How do complex lichen tissues develop without cellular differentiation by either mycobiont or photobiont? They are truly fascinating but also very successful, covering around 8% of the Earth's surface, including some of the harshest environments on the planet. Lichens survive where few other living organisms would stand a chance — from the sea sprayed surfaces of rocks to the coldest mountain tops. They can even survive in space where temperatures range from –120 °C to +120 °C, with intense gamma irradiation and, of course, a vacuum. Lichens are extremophiles par excellence.

Throughout the whole book, Sheldrake describes complex fungal biology with great clarity, but there are few authors who would illustrate the effects of fungal secondary metabolites on the human mind by describing their own lysergic acid diethylamide (LSD) trip, or who would celebrate the publication of their book by seeding a copy with spores of the oyster mushroom, recording the sound of the book being devoured and then eating the resulting crop of mushrooms (to quite literally 'eat their own words')[4]. These actions really do exemplify the fun aspects of this book. From his account of the borrowing of the wonderful Paul Stamets to become the 'astromycologist' character (and inventor of the 'spore drive') in Star Trek to the book's beautiful illustrations drawn with ink from a shaggy ink cap mushroom, and his interviews with some of the great characters and opinion formers in mycology, we are taken on a quite magical tour of all things fungal, with due respect given to the mind-altering qualities of psilocybin and alcohol.

What really stands out for me about this book is that its author is so young and yet has been able to put together a comprehensive and scholarly analysis of fungal biology, but also to do so in such an accessible and fun way. This is an extraordinary achievement. As a fungal enthusiast I am, of course, captivated by the subject matter, but also recognize that this book is not really aimed at me but rather at a much wider audience. I hope this will include some 'fungus-blind' plant scientists — some of you may see the light. ❒

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Published online: 11 September 2020
https://doi.org/10.1038/s41477-020-00767-z

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Competing interests

The author declares no competing interests.