PLANT PEOPLE Season One Episode Ten 'Decay is an Ally'

MUSIC: "Entangled Life" by Cosmo Sheldrake and Merlin Sheldrake

JENNIFER BERNSTEIN NARRATION: You're listening to a song called Entangled Life. It was made using sounds generated by fungi.

MERLIN SHELDRAKE: I really don't see, the arts and the sciences as separated by some unbreachable boundary. Because really the arts and the sciences, I think, come from the same place of, curiosity and wonder and engagement and a desire to understand and interact with this weird, wild, wet world that we're part of.

JENNIFER NARRATION: Merlin Sheldrake is a mycologist, or someone who studies fungi. But this title seems somewhat limited in describing Merlin. He's more like a fungi evangelist. A conversation with him unlocks a whole world of otherwise hidden life.

MERLIN: There are aquatic fungi in sediments at the bottom of the ocean, in the bodies of sea animals and seaweeds, in the soil, in the bodies of land animals and land plants. And you find them in the atmosphere in the form of fungal spores. Fungal spores are the largest fraction of living particles in the air and can actually change the weather. So even not on the surface of land you find fungi doing their thing.

JENNIFER NARRATION: In 2020, he released a book called Entangled Life: How Fungi Make Our Worlds, Change Our Minds & Shape Our Futures. In addition to many awards and accolades, the book led to a collaboration with Merlin's brother, musician Cosmo Sheldrake.

MERLIN: We thought the book needed a kind of jingle, so that's what we made. But we made it from sounds that were recorded from what we call sonification. So it's when you are turning bioelectrical activity into sound. So what we were recording this activity from were copies of my book that we'd inoculated with oyster mushroom mycelium. We then sent it to a friend of ours called Michael Prime, who's an acoustic ecologist, and he attached electrodes to the mycelium devouring Entangled Life. And then he sonified those electrical signals, and so then we had very unusual sounding real-time sonic representations of the electrical activity of the fungus eating Entangled Life.

JENNIFER BERNSTEIN: Wow.

MERLIN: And so we took those sounds and then we used those sounds to form the basis of this song, which is called *Entangled Life*. And we had a lot of fun doing so.

JENNIFER: Oh, that's amazing. That's amazing. The only part of that that I don't like is that the book got eaten because I absolutely loved the book. But there are many other copies, so it lives on.

JENNIFER NARRATION: Musical experimentation aside, there are countless ways that both plants and humans rely on fungi. Fungi play an important role in decay, breaking down old matter and converting it into brand new resources. If plants and other organic materials didn't decompose, we'd all be buried under billions of years' worth of matter... in fact we probably wouldn't be here at all. And that's just the beginning of the story.

This is Plant People from NYBG. I'm your host Jennifer Bernstein, CEO and The William C. Steere Sr. President at the New York Botanical Garden. In this final episode of the season, we'll find out about the *end* of a plant's life cycle… and the many, many ways plants and people need fungi to thrive.

JENNIFER: Merlin, it is so great to be with you today. Thank you for joining us.

MERLIN: Great to be here. Thanks for having me

JENNIFER: So I think you know, our podcast here is about plants and people and plant people, but I think you may identify more as a fungi person. How did you become interested in fungi?

MERLIN: A long and tangled road. I remember when I was a child, I became interested in decomposition. I would take buckets of kitchen waste from the kitchen and tip them on the compost heap. And then several months later, shovel what had become soil onto the flower beds with my dad.

JENNIFER: Black gold.

MERLIN: Yeah, and I became interested in how these transformations took place. How does the banana peel turn to soil? How does orange peel turn to soil? And he explained that it was to do with organisms like fungi that can decompose and rearrange the world. And this got me really fascinated in them because they seem to have so much power and yet they seem to do what they did out of sight.

But my formal study began at university in the Department of Plant Sciences, where I was doing my undergraduate degree, and it became clearer and clearer the more I studied plants, that plants depend on fungi, and they depend on symbiotic fungi that live in them, and on them. And they couldn't do what they did if they didn't have these fungal partners. So that led me down the rabbit hole. And, I really haven't looked back.

JENNIFER: So you are a plant person after all then.

MERLIN: Well, if you think about plants as fungi that have evolved to farm algae, and algae that have evolved to farm fungi, then I guess, yeah.

JENNIFER: So how should we think about fungi as organisms? Are they plant-like? Are they animal-like? How should we understand them?

MERLIN: Fungi are a kingdom of life. They have some characteristics that might lead us to think of them in more plant-y terms.

So for example, they don't have twitchy muscular bodies like animals do. They don't locomote like animals do. They grow in and around their environment, like plants. But unlike plants, they don't photosynthesize. So they don't have green. They don't eat light and carbon dioxide in the way that plants do. In their nutritional worlds, they're a bit more like animals. They have to find food, ready-made if you like, and then digest it. Which is what we have to do.

They do that a bit differently from us; we tend to find food and put it inside our bodies and then digest it. But fungi put their bodies inside their food. And so they do this by growing, branching, fusing networks of cells called mycelial networks and a lot of what makes fungi so special is rooted in this network-forming ability. And there are lots of ways to be a fungus. I think that's a really key point, that this is a hugely diverse kingdom of life and there's lots and lots of ways to do what fungi do.

JENNIFER: Diverse and still poorly understood. I mean, there's so much that we don't know about this world of fungi. So much research still to be done. You talked earlier about fungi being hidden in a way, doing their work in the background. But we're very dependent on fungi as a species, humans. So can you talk a little bit about those dependencies and how we rely on fungi?

MERLIN: There are so many ways that we rely on fungi. I think of them as ecosystem engineers that underwrite the regenerative capacity of the biosphere. So,

they make soil, they play vital parts in the great nutrient cycles that we live within. They sustain plants and indeed shaped the evolution of plants. So anytime we cultivate a plant, anytime we eat a plant, anytime we depend on a plant, we're depending on fungal relationships.

Fungi themselves are chemically ingenious. They're metabolic wizards that shape human life in very direct ways. So many medicines that we depend on come from fungi. Penicillin is a very famous example, but there are lots of other instances. Foods, you know, humans have eaten mushrooms for a very, very long time, continue to do so. As we look towards reimagining our food systems at this time of crisis, there are plenty of ways that we can work with fungi to try and do this in a more regenerative and nourishing way.

So foods, medicines, alcohol; we think about alcohol in terms of a kind of recreational drug, but in the long history of humankind, it's been a lot more than that. It's been an antiseptic. It's also been a way to hold medicines like herbal beers in the Middle Ages were a way for people to deliver medicinal properties of plants and other organisms.

Social roles, you know, ritual feasting and statecraft; so much of human life has been shaped by alcohol. Other fermented foods – miso, soy sauce, chocolate. Also decomposition. If fungi didn't decompose things like wood, then we would be buried under huge piles, kilometers deep, of unrotted bodies. So, they are--

JENNIFER: That doesn't sound good.

MERLIN: That doesn’t sound good. I mean, we wouldn't really exist in that scenario either. So, you know, whether or not we think about fungi, whether or not we're actually explicitly using a fungal technology, or a fungal medicine, we depend on fungi. So I think that's really a key point.

JENNIFER: Yeah, varied dependencies. You talk about decomposition, I think we think of decay as something in a way to be avoided, but the world depends on decomposition and decay. So, how do you think about the role of decay in healthy ecosystems?

MERLIN: Well, I think it's a really powerful reminder about the way that life and death really aren't these separate categories. You know, we think of them in this quite binary way, but we're dying all the time. You know, the cells that make up your body are dying all the time. And some parts of you are regenerating and staying alive. But the cells that make up your body today are, on the whole,

different cells than the cells that made up your body a few years ago. And that's because a large part of you has died and been regenerated. But you're still you.

In the living world, life is a process, and some of these processes are the journeys of minerals and nutrients as they move through their earthly cycles, and decomposition is really the transformation of, say, a lump of wood into absorbable nutrients, but that means that the nutrients in that wood can enter into the lives of other organisms that can eat those materials. They can do what they do, they then die, what made up their body then can enter the cycles of other organisms. So it's really a vital process, you know we think about decay, it's like, oh, the deck is rotting, or the walls are rotting, or the moldy ceiling of the bathroom. There's so many ways that we think of this as negative, and indeed, if you are trying to stop a house from falling to pieces, then decay is a problem--

JENNIFER: It can be an enemy. Yeah.

MERLIN: It can be annoying, yeah, that's for sure, but generally speaking in the living world, it's a process of vital transformation.

JENNIFER: It's interesting. I mean, we have such a sort of cultural fear of death, and I think that that has led us to avoid exploration of some of these topics. And maybe that's part of the reason why this is a sort of understudied area. It's a cultural hurdle that we need to overcome because it can be part of our thriving, actually.

MERLIN: Very much so, yeah. Fungi are a kingdom of life that have not had a kingdom's worth of attention. And they're neglected in most areas of human endeavor. Fungi hardly feature on school curricula and university curricula.

But where they do feature, they feature as agents of death, decay, and disease. So, this tells you a lot about how we've been understanding the roles of fungi and how we've been boxing them up in these categories which are explicitly negative.

So I think that can lead to people not wanting to study them. It can lead to people feeling revulsed by them. And I think this goes back a long way, you know, if you see fungi living on a dead body, if you see fungi like living on dead things, like it doesn't necessarily draw you towards them. And I think that might underpin a lot of this kind of cultural mycophobia that we can find in some parts of the world.

JENNIFER NARRATION: After the break, we'll learn about the evolutionary relationship fungi and plants have shared for millions of years. Plus, how fungi can impact our own yards and gardens. We'll be right back.

[BREAK]

JENNIFER NARRATION: Welcome back to Plant People. I'm Jennifer Bernstein and I'm speaking with fungi expert Merlin Sheldrake. During our conversation, Merlin and I spoke a lot about the ways that plants and fungi depend on one another. Merlin explained that this is a relationship that goes back to the beginning of life on Earth itself.

MERLIN: Yeah, so broadly speaking, if you were to cast your mind back to about 500 million years ago, you would find most of sort of exciting multicellular life taking place in the water, whether in oceans or fresh waters. Land was an extreme environment. CO2 levels were very high. It was scorched with radiation. There were few places to hide. No shelter. And things are just generally much more easy underwater.

So, but what started to happen is that the ancestors of land plants, which were freshwater algae, so photosynthetic organisms floating in a kind of nutrient broth of freshwater habitats – lakes and rivers and streams – started to wash up on the soggy shores of these water bodies. And on land, there's more light. It's not being filtered by the water. And there's more CO2. And both of those things allow plants to do more photosynthesis to get along. So they face challenges, you know, when you've been floating in a nutrient soup and a freshwater algae in a nutrient soup, you have to do photosynthesis, you have to have access to light, but you're not seeking your nutrients and you're not sort of having to interrogate this complex labyrinth of soil, you don't worry about water because you're in the water.

On land, there are all sorts of challenges. And what happened was, we're fairly sure, is that, these early plants, they struck up relationships with fungi. And these fungi are forming these chemically ingenious networks, which can scavenge in the labyrinth of the soil in ways that these algae can't. And what you find happening is that the fungi and the algae strike up a relationship where the algae are feeding the fungi with products of photosynthesis, energy containing carbon compounds like sugars or fats. And the fungi are feeding the algae with mineral nutrients like phosphorus and nitrogen, helping to defend them from drought, from drying out.

And this really is a fundamental relationship. You know, plants took tens of millions of years to evolve their own roots because fungi behaved as their root systems for tens of millions of years after their passage onto the land. So, it's a very, very fundamental relationship. It's, you know, a relationship that lies at the base of plant life on land and makes it perhaps a more fundamental part of plant

life than many of the things we think of as plant traits, like leaves, or fruit, or flowers, or wood. So, it deepened and expanded biological possibility, and transformed the future of life on Earth.

JENNIFER: Wow. That's amazing. So you talked a little bit earlier about the mycelium networks and the ways in which they were working in a sort of symbiotic way with plants. Can you talk a little bit about the degree to which plants or ecosystems writ large are still dependent on these networks?

MERLIN: Yes, so almost all plants form relationships with what we call mycorrhizal fungi. *Myco* meaning "fungus", *rhiza* meaning "root". And mycorrhizal fungi live in and around plant roots. They grow their branching, fusing, chemically ingenious networks into this very complex environment of the soil.

They find nutrients in the soil, they transport these nutrients through their networks, and they trade them with plants. Plants supply the fungi with energy containing compounds like fats and sugars. So it's that old pact, they've been at it since the earliest days of life on land. But it's still as important as it always was. And these mycorrhizal fungal communities are hugely important in the soil. You know, they make up as much as half of the living biomass of soils.

JENNIFER: Half the biomass of soils is mycorrhizae?

MERLIN: Yep. And obviously it depends on the environment you're in, and this data will fluctuate, but it can be as much as that. So plants are transferring carbon to their fungal partners and so mycorrhizal fungi are stationed at the entry point of carbon from the above ground world into the soil. The soils are a hugely important repository for carbon, you know, about 75 percent of terrestrial carbon stocks are in the soil. So there's vital juncture between the below ground worlds, between the above ground worlds, they're doing all of this, they're making plant life possible, they're nourishing soil food webs, and they're holding soil together, they're a kind of circulatory system. So that's one way that plants depend on fungi today.

Another way is, there are fungi that live in and around plant cells above ground. So in their shoots and their leaves. These get much less attention. They're called endophytic fungi, *endo* meaning "in" and *phyte*, "plant", and they play really important roles in plant life as well, defending plants from disease, producing chemicals that help attract other vital organisms or repel them, and there are actually an increasing number of chemicals that we used to think of as being

produced by plants but actually turn out to be produced by fungi that live inside those plants.

Plants share their bodies with fungi. Let alone the, all the various ways that plants depend on fungi for other things. For example, decomposing fungi to make the soils in which the plants can live and so on.

JENNIFER: Yeah, I think gardeners, for example, have always known that there's a big difference between dirt that's dead and soil that's alive through the function of this mycorrhizae. But you can see lots of opportunities for a more refined understanding of these relationships informing ecological restoration efforts and other efforts that we need to pursue at large scale to start to repair the Earth. How do you think about that and the role that that research should play as we think about this period where we're going to be doing a lot of work to restore?

MERLIN: I think about this a lot. I work with an organization called the Society for the Protection of Underground Networks, or SPUN. Website is spun.earth. And what SPUN does is it tries to take research into mycorrhizal communities, who lives where, and what is everyone doing, and to take this research and to translate it into a form where it can influence decisions, and those decisions might be decisions made in boardrooms, they might be decisions made in courtrooms, but we're trying to match the mycorrhizal communities of the planet, advocate for the protection of below ground ecosystems and find ways that mycorrhizal datasets can deepen and expand our understanding of the world around us. To equip us better to protect it and help it recover where it has not been protected.

It's hugely important to take these communities into account because, we're kind of blind to what goes on below the soil and what we're blind to is very easy for us to destroy. So I think moving forward, it's going to be hugely important to raise awareness about them, and to find ways to turn mycorrhizal research into useful and usable information.

JENNIFER: I mean, you talk about that blindness, we think about that related to plants as well. And so many of the conservation frameworks have been based on density or very broad calculations about biodiversity, but understanding even the understory environment is not often factored into those frameworks and then much less the mycorrhizal networks, you know, so it's great that you're doing that work, Merlin. It really is.

What is the biggest mycelium network that you have ever encountered?

MERLIN: There are a couple of very large ones in the States, which are networks of *Armillaria*, or the honey fungus. These can sprawl over kilometers. These are fungi that kill trees and then digest their wood. I haven't actually been to either of these super famous, you know, vast networks in the States myself, I haven't visited in person. I don't actually know how big the biggest one that I personally have encountered is, because it's very hard to know.

JENNIFER: How do you see it?

MERLIN: Exactly. So, you'd have to take soil samples in different parts of the area where you think this network is, but then you'd have to do a genetic analysis to find out, are these the same fungal genotype? And then you have to deal with the question of, well, are they actually connected in one contiguous network? And that's very difficult to know, because you might have a big network that was once was one network, but you know, a warthog's come through and broken it up into two pieces, but it still remains the same genotype, but it might not actually be connected. So it's very difficult to answer that question.

JENNIFER: Are there new technologies that are emerging that allow us to have more understanding of what's happening below the surface?

MERLIN: Yes, but still, it's hard to do this work outside in the field. I work with a wonderful group of researchers in Amsterdam doing lots of imaging of mycorrhizal fungi, looking at the flows and information transfer within these networks. But these are in dishes in the lab, and so these are highly simplified environments, which we need because we need a simple situation, and we also need a visible situation. When they're in the soil, they're in and around, this opaque and heterogeneous soil matter, so it's very difficult to see what's actually going on outside. So this remains a great challenge but I hope things change soon because this is one of the things that I'm most excited to learn.

JENNIFER: Mm hmm. So when we see a mushroom on the ground or growing out of a tree, what are we seeing? Is that a branch of a fungal network? What is it?

MERLIN: It's a reproductive structure of a fungal network. Plants produce fruits and flowers, and in flowers you have pollen, which allows them to undergo sex. Fruit have seeds which allow them to undergo dispersal. And mushrooms are like a little bit of a cross between both. They're a bit about sex, they're a bit about dispersal but they're reproductive structures. A small fraction of fungi produce mushrooms overall. And even those species of fungus that produce mushrooms only produce mushrooms, on the whole, for a small time every year. So,

mushrooms are the most apparent part to us of fungal life, but it's really just a small part of fungal life.

JENNIFER: I hesitate to ask this question because, you know, I don't think that there's a sort of morality to nature in the way that this question implies, but are there bad fungi? Are there fungi that are in particular bad for the plants that we're trying to cultivate, for example, in our landscapes?

MERLIN: Yeah, I mean, I stay away from good and bad, because I feel like it's all very context dependent. You know, we like to think about good bacteria in our gut, versus bad bacteria. But, if you were to get a trauma wound and some of the bacteria that live in your gut were to get into your bloodstream, these might be the vitally important bacteria in your gut. But then when they get into your bloodstream, they'll cause a life threatening sepsis and kill you. So are they good or bad? You know, it's not about the bacteria, it's about where they happen to find themselves in relation to you, the judge, of whether they're good or bad.

So, yeah, there are lots of fungi that cause lots of problems for humans, in the form of diseases of human bodies, or diseases of the plant bodies that we depend on. The rice blast fungus, for example, is a disease of rice. It ruins a quantity of rice large enough to feed 16 million people every single year. It's a huge problem. Fungal diseases have caused famines. They have transformed landscapes by killing off trees of various species, thinking of chestnut blight in the States or Dutch elm disease in Europe. And there are fungal superbugs of human bodies. These are on the rise at the moment. You know, we're creating the conditions for the evolution of new types of fungal superbug, partly because of the way that we over apply fungicides, a bit like the way we over apply antibiotics.

I think a lot of the time when those fungi do cause problems for us it's often to do with the way that we are behaving which has made that possible. I also should point out that the fungi that do cause problems for us are a tiny minority of the full kingdom of fungi, but nonetheless a highly significant minority, and a minority that we should be thinking more about.

JENNIFER: Yeah. Well, I hope you'll visit here one day and we can show you the first specimen collected identifying the fungus that ultimately caused the chestnut blight. We have it here in our Herbarium actually. So, as you say, it is all context. And if we ask the fungi to categorize us, they might have their own opinions about the way humans are operating in the ecosystem.

MERLIN: Exactly.

JENNIFER So you have an IMAX film that you worked on. Can you tell us a little bit about that?

MERLIN: Yeah, so it's a film that is made for giant screens. It's in 3D. And it really is led by extraordinary time lapse footage of mushroom growth and mycelial growth by some of the most amazing fungal photographers working today, Steve Axford and Wim van Egmond. And their footage reveals fungal life in a way that, you know, when you see things sped up you can pay attention to it in a different kind of way. And you can see them as real behaving organisms. These sequences have really blown my mind again and again. And the film is narrated by Bjork, the artist musician, who speaks the story with incredible magic, and is a wonderful host in this weird world.

And it's just been a thrill to work on this, so I'm really excited it's coming out. It's trickling into IMAX cinemas across the world, across the States, and so you can find out more about that on my website, or search for Fungi: Web of Life.

JENNIFER: Great, and your website is?

MERLIN: MerlinSheldrake.com.

JENNIFER: Merlin, you are so fun to talk to. Your work has really inspired so many people to pay more attention to this aspect of our world and I think has opened people up to the idea of fungi and what's happening in the fungal kingdom being essential parts of how we think about conservation, protecting our environment, even gardening and thinking about how we care for our own landscape. So, it's such a pleasure to talk to you. Thank you for making the time.

MERLIN: Pleasure to be here. Thanks for having me.

JENNIFER: I should ask you, what is the correct pronunciation of fungi?

MERLIN: Oh, you can say it how you like. People take their pick. I say “fung-ghee”, other people say “fun-jai”, “fun-guy”.

JENNIFER: “Fung-ghee”, “fun-jai”, “fun-guy”. So you heard it here, we can say any of those three and still be right.

JENNIFER NARRATION: Want to immerse yourself in the fascinating world of fungi? Come to NYBG! Our fantastical Wonderland exhibit features fungi in all kinds of ways. Now through the end of October, you can check out art that

explores the relationship between fungi, lichens, and plants. To dive even deeper, we also have lots of fungi-related classes through our Continuing Education Program. More information in our show notes, along with links to Merlin Sheldrake's work.

Thank you for listening to the first season of Plant People! We'll be back in 2025 with a new batch of episodes. Until then, tell your friends about us! Leave us a review on Apple Podcasts! And make sure you're subscribed.

Plant People is a co-production of NYBG and PRX Productions. From PRX, Plant People is produced by Jessica Miller, Courtney Fleurantin, Genevieve Sponsler, Adriana Rozas Rivera, and Pedro Rafael Rosado. The executive producer of PRX Productions is Jocelyn Gonzales.

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