

MUSHROOMING



The Future of Mushrooms for Immunity
People and Planet

by The UK and Ireland Mushroom Producers

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Foreword



We are fungi.

With our ubiquitous networks of mycelium and fungal fruiting bodies, we have lived on this planet for more than a billion years. We are older than the plants, older than the dinosaurs, and much, much older than you.

We are nature's engines of regeneration and renewal, the bridge between life, end of life and rebirth. We are food, medicine, friend and foe. And we are everywhere: in the soil, in the air, in the depths of the ocean and the frozen wastes of Antarctica. We also live on the surface of your body and inside you. In fact, you're not really a 'you' at all; you're an 'us'. And when it comes to improving the health of the planet we all share, we can be one of your greatest allies: we play a key role in helping you live healthier lives, and boosting your immunity.

Foreword

The Not-So-Humble Mushroom

The largest organism on earth is the size of 1,665 football fields¹ and is thought to be around 2,400 years old. It's also a close cousin of the mushrooms you had for breakfast this morning.

This enormous honey fungus was discovered in Oregon just over a decade ago. Like many species of fungi it lives underground, invisible to human eyes except for the golden fruiting caps it pushes up through the soil.

What we recognise as mushrooms are, in fact, just one small part of these incredible organisms. Fungi mostly live and work behind the scenes, but the services they perform are invaluable to the health of both humans and the planet. As we shall see, we are only just beginning to discover the potential of this powerful force of nature, and to understand its key role in helping us live healthier lives.

Human and Planetary Immunity

The pandemic has put human health firmly at the forefront of the global conversation. As COVID-19 began to spread around the world, the question on everyone's lips was simple: how can we best protect ourselves and each other?

If human beings have a superpower, it is our immune systems. Every minute of every day, our bodies are fighting off pathogens that, left unchecked, could do us harm. The stronger and healthier our immune systems are, the better chance we have of fighting off infection and illness – and that includes COVID-19. The good news is that we don't have to be passive when it comes to boosting our immune systems. We can do so actively, especially through the foods we eat – and as this report explains, the not-so-humble mushroom can be a significant ally.

As well as human health, fungi can also help us restore the health of the planet. These organisms are being used as a sustainable building material, a low-carbon meat substitute, a muncher of plastic waste – and more.

The past year has reminded us of our own fragility, and of our deep interconnectedness with the planet on which we all live. As we look forward to a brighter, healthier future, we might want to take a glance downwards, too – because the answer to many of the challenges we face could be right under our feet.



Chapter 1

Humans & Immunity



In 1928, a Scottish bacteriologist named Alexander Fleming went on holiday and left a Petri dish uncovered. I was a tiny spore then, floating through his lab, when I found my way into that dish and settled down to feast on the delicious agar jelly within.

When Fleming returned, he noticed I had stopped the growth of the bacteria he was studying – and thus was penicillin discovered. It was certainly a turning point in medical history, but in truth you humans have known about the curative properties of us moulds for thousands of years. The Egyptians used bread mould to treat wounds; the ancient Chinese used mouldy soya beans.

I am sorry for spoiling your sandwich, though.



A history of yeast

Yeast – which is a fungus – was one of the first organisms to be domesticated by humans. It didn't happen in one place at one time; the use of yeast, particularly to create alcohol, emerged in various places around the world. Mead was being produced in Asia around 1700-1000 BC; the Greeks, Celts, Saxons and Vikings all made a mead-type drink, too. In places like Egypt and Mesopotamia, people were making wine from grapes and beer from malted barley.

Brewing beer is a very efficient way of processing grains to create a calorific drink. It's rich in carbohydrates, vitamins and proteins, and the alcohol kills detrimental organisms - which makes it safer to drink than water. That's why it was so important to those early civilisations.

Beer, bread and wine have been fundamental to the success or proliferation of particular societies at particular times – but also to their religious beliefs. There is a hymn to the Sumerian goddess of beer, Ninkasi: "It makes the liver happy and fills the heart with joy." Beer was very much seen as sacred and bound up with religious practice, but it was also part of everyday life. It has been incredibly important in sustaining cultures and communities.

In fact, it could be argued that yeast – this microscopic organism – has shaped the world as we know it.

Polly Russell

Food historian, curator, consultant & writer

Over the past year, human health has been pushed to the front of our thoughts as well as the front pages. For many of us, the pandemic has raised questions about the concept of immunity; in fact, the word has never been on so many lips.² Whilst the purpose of the lockdowns was to slow the spread of the coronavirus, many people were concerned about the impact this lack of interaction with other humans and the outside world would have on their immune systems. One recent study found that 22% of people admitted to being worried about developing a weak immune system during lockdown.³

The Meaning of Immunity

Our immune system is essential to our survival. It protects us from infection and disease by fighting off constant attacks from bacteria, viruses and other microscopic nasties.

There are different types of immunity: innate (this is the first line of defence, skin and mucous membranes of the throat and gut); adaptive (our bodies build up a library of antibodies to different pathogens, through exposure

to them); and passive (immune responses that are “borrowed” from another source, such as babies receiving antibodies from their mother both in the womb and in breast milk following birth).

But because the immune system is so complex, there are many potential ways in which it can misfire and end up working against you. We can develop autoimmune illnesses, for example, in which the immune system attacks and overworks itself. Factors including age, obesity and malnutrition; even our emotional state can weaken our immune systems.⁴ Luckily for us, however, we can improve the health of our immune systems in several ways. Nutrition is perhaps the best-known route – but there are some more surprising methods, too, such as spending time in nature.

Your immune system health is thought to be connected to your physical, gut (see Chapter 2 for gut health-boosting foods), and mental health.⁵ All of these are connected – and they can all be enhanced by better diets, more active lifestyles and spending time in the great outdoors.



Image courtesy of Mushroom Bureau

Vital Vitamins

Vitamin D is an essential factor in our immune health that can be found outdoors. Sunlight reacts with compounds in our skin to manufacture vitamin D, essential for building and maintaining bone strength – but our contemporary, mostly indoor lifestyles mean our bodies don't get enough sun exposure. On top of this, the recent lockdowns have kept many of us inside for long stretches of time, leading some 13% of Brits to worry about vitamin D deficiencies.⁶ Luckily, our fungal friends are here to help. Mushrooms, like us, are able to convert sunshine (or ultraviolet light) into vitamin D – in fact, they're even better at it than we are. When passed under artificial sources of ultraviolet light, mushrooms can create a significant amount of it, and vitamin D-enriched mushrooms can now be found in many familiar shops. You can also make your own vitamin D-enriched mushrooms - simply leave regular mushrooms in direct sunlight for an hour or two,⁷ and they will develop higher levels of vitamin D than can be found in artificial supplements.⁸ If you follow a non-meat diet, aside from fortified foods, mushrooms might be one of the best ways of staving off osteoporosis in later life.⁹

Green Goodness

Evidence suggests that time in nature can be an antidote to stress. It can lower blood pressure and stress hormone levels, reduce nervous system arousal, enhance immune system function, increase self-esteem, reduce anxiety, and improve mood.¹⁰ Exposure to nature switches the body into “rest and digest” mode, which is the opposite of “fight or flight”. In the latter mode, the body shuts down everything that is immediately nonessential, including the immune system.

Nurturing Nature

The pandemic has increased our desire to spend time in nature. This is reflected in an increase in nature-based hobbies during the lockdowns – not just spending time in nature, but interacting with it, too. Interest is growing in species-identifier apps such as iNaturalist, Candide Gardening and Picture Mushroom. Research from Cumbria University found that 77% of people had taken a photograph or video recording of nature during lockdown, and that lockdown has made us appreciate nature more than ever before.¹²

This galvanising of public interest in nature is helpful for scientists who study species and habitats. Much of the data collected by the British Mycological Society – a scientific body devoted to fungal research, conservation and education – is provided by amateur mycophiles (mushroom devotees), for example.¹³ This exchange of knowledge mirrors the symbiotic relationships found in mycelial networks – the webs of fungal fibres that permeate soils and which, as we now understand, enable communication and collaboration between plant species. We are all part of a much larger system of learning and understanding. People are driving science; and science, in turn, is driving us – towards a greater understanding of the natural world and our place within it.



Image courtesy of Mushroom Bureau

“When we feel completely safe, our body devotes resources to long-term investments that lead to good health outcomes - growing, reproducing, and building the immune system.”¹¹

Ming Kuo

Professor of natural resources and environmental science

Human History

While the pandemic has foregrounded the intrinsic link between the natural world and human health, the link is as old as humanity itself. Nature has been our pharmacist for thousands of years – and mushrooms and fungi have been used as medicines and treatments since the dawn of humankind (see chapter 2 for more examples).

Nowadays, mushrooms and fungi are key ingredients in many pharmaceuticals. The accidental discovery of penicillin – a compound derived from a fungus – in 1928 was one of the defining moments of modern medicine. Examples of fungi in modern medicine include cyclosporine (an immunosuppressant that makes organ transplants possible), cholesterol-lowering statins, and anti-viral and anti-cancer compounds (such as the chemotherapy drug Taxol, which was originally extracted from fungi that live within yew trees). Even more recently, psilocybin – the active ingredient in psychedelic mushrooms – has been found to be an extremely promising treatment for severe depression and anxiety.¹⁵

Fungi are used to make vaccines, too; 15% are produced using engineered strains of yeast. Analysts predict the global medicinal mushroom market will grow from \$50.4 billion in 2019 to \$84.8 billion by 2026.¹⁶

Today, mushrooms have earned ‘superfood’ status thanks to the multitude of vitamins and nutrients they contain – and as such, they are being used more and more as a form of preventative medicine. As we will see in the next chapter, mushrooms are now at the forefront of many of the latest food trends.

“We divided from fungi 650 million years ago. One branch led to fungi and the other branch led to animals [...] we are more closely related to fungi than we are to any other kingdom. What this means is that we’re descendents of mycelium. Mycelium is the mother of us all.” - Paul Stamets, mycologist and entrepreneur.¹⁴

Paul Stamets
Mycologist, entrepreneur and author

Chapter 2

Food & Immunity

"Let food be thy medicine"

Hippocrates



I begin life as one of millions of tiny spores. When I germinate, I send tiny threads called hyphae deep into the dark, moist soil; these intertwine and meld to form a thick mat of fibres called mycelium. This is my body and my source of strength. Like you, I digest my food – only I feast on nature's waste, like fallen leaves and dead wood. When I'm strong enough, I gather my hyphae into knots and push them up out of the soil into the light, where they bloom and grow into ghostly pale caps. These fruits are packed with health-giving nutrients – and best of all, when sautéed in a little butter they taste utterly magical.



Mushrooms as Medicine

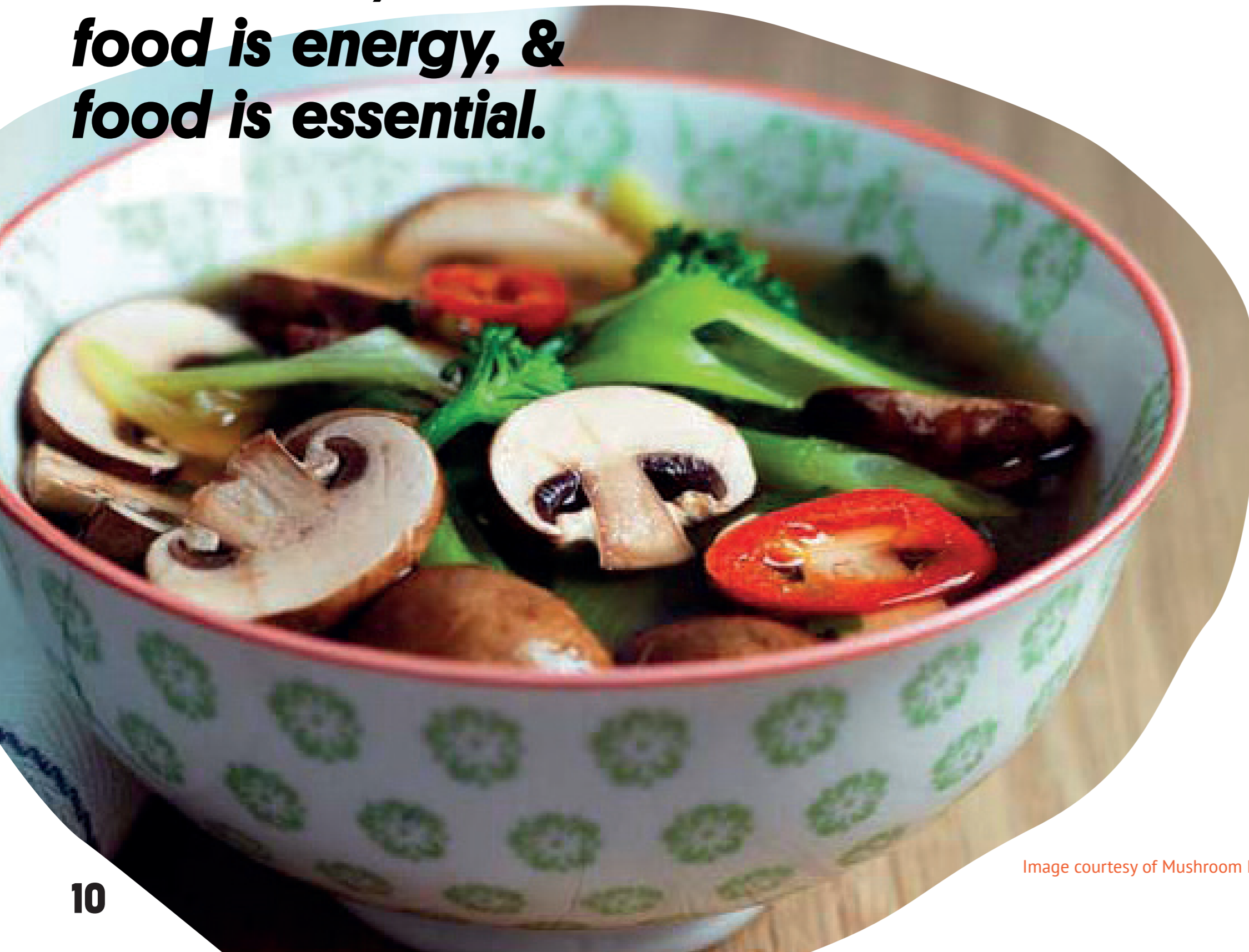
Humans have been ingesting mushrooms as food for hundreds of thousands of years - and the history of mushrooms as medicine probably goes back at least 5,000-7,000 years. It largely originated in Korea, China and Japan. But in the last 20 years, people have become intrigued with mushrooms, because we are beginning to look at ways to help keep ourselves well. When it comes to preventative health, people are now recognizing that taking natural substances can help keep themselves healthy – and edible mushrooms, of course, fit very well into that category.

The concept of medicinal mushrooms is also blossoming. Last year I wrote a book – Medicinal Mushrooms: the Human Clinical Trials – in which I cite a couple of hundred double blind, placebo-controlled trials in which people took medicinal mushrooms before, during and after chemotherapy or radiation treatments. They not only found that these mushrooms improved their quality of life - they actually increased the patients' survival rates. And doctors are beginning to look at using psilocybin (the active ingredient in psychedelic mushrooms) therapeutically for a number of conditions including depression and anxiety; recent research at Johns Hopkins University has shown that there is real promise there.

Robert Rogers

Herbalist and author of The Fungal Pharmacy

Food is sustenance, food is energy, & food is essential.



Food Fads

Food is sustenance, food is energy, and food is essential. No living organism on Earth can survive without nourishment.

As well as energy, what we eat provides the building blocks and ammunition for our immune systems. Some foods are known to be particularly good for boosting our immunity, as well as improving our gut, physical and mental health. Today we describe them as ‘superfoods’ – but humans have been using food as medicine since before recorded history. In 1991, a man frozen in ice since 3300 BCE (nicknamed Ötzi)¹⁷ was discovered in an alpine glacier. He was carrying several species of mushrooms, including a medicinal birch polypore used to fight parasites and other infections.¹⁷

And while the ancient Egyptians may not have known much about microorganisms, they did know that bread mould poultices could be used to fight infection (now regarded as the first kind of penicillin).¹⁸

Image courtesy of Mushroom Bureau

Covid Connections

Sometimes the tiniest organisms can change the course of human history. Without the microscopic fungus called yeast, for example, there would be no bread or wine. More recently (but less happily), another vanishingly small microbe has once again fundamentally changed the way we live. COVID-19 has forced us to adapt to new ways of working, new routines, new ways of shopping, new ways of socialising, and – perhaps most importantly – new ways of having fun.

Many of us have responded to being cooped up during lockdown by spending more time in the kitchen – another well-known antidote to some of our mental and physical health challenges, both of which are key to a healthy immune system.

Kitchen Comforts

Our relationship to food and nutrition is changing. In 2019, 31% of the average UK household's weekly food and drinks budget was spent in restaurants.¹⁹ We love to eat out – and since our pubs and restaurants were forced to close, we have been looking

to recreate that experience by getting more creative in our own kitchens - for breakfast, lunch and dinner. Recipe boxes to the rescue!

Sales of recipe food boxes have continued to surge throughout the pandemic, according to Kantar research, doubling the number of meals delivered between September 2020 and February 2021.²⁰ Clearly we are keen to get back to basics and rediscover the pleasures of cooking from scratch. Additionally, for those whose routines have been thrown into chaos, mealtimes help punctuate the days and give some form of structure. Many of us have had more time to consider and nurture our relationship with food, health and nutrition. According to research, COVID-19 has pushed consumer behaviour towards healthier and more sustainable patterns, with many consumers paying more attention to safeguarding their health during the pandemic²¹, and looking for foodstuffs to boost their immune system. These newly acquired healthier eating habits seem to be sticking, even after the easing of lockdowns, with customers showing a desire to increase their intake of fresh fruit and vegetables.

The Guardian believes that local farmers proved “more reliable in a crisis than the industrial food supply chain”.²² Because of this, we foresee an increase in community-based apps and services which connect local people to local producers, and cut out the (often fragile) long supply chains. Future-facing, problem-solving, start-ups have emerged from the crisis, for example Bulkify²³, which groups nearby orders and delivers them in bulk to a local ‘click & collect’ point. This, in turn, creates a hub where local producers, local communities and delicious food meet.

Image courtesy of Mushroom Bureau



Healthy Humans

Mushrooms are the superfood at the heart of this nutritional awakening. They can help with everything from managing our weight and cholesterol levels to reducing our risk of developing cancer. A study published this year by Penn State University²⁴ looked at 17 cancer studies from between 1966 and 2020 – and found that overall, people who eat just 18g of mushrooms a day (roughly equivalent to a single closed cup mushroom) have a 45% lower risk of cancer than those who do not.

They also help us to ensure our immune systems are in the best possible shape.²⁵ This might explain the meteoric rise in mushroom consumption, which has increased more than 30-fold since 1978.²⁶ It's not just the quantity of mushrooms that has grown; there are an increasing number of varieties on sale these days, too. The days of button mushroom domination are well gone. Supermarket shelves nowadays are awash with a wide variety of fascinating fungi including oyster, portobello and shiitake (currently at the top of the cultivated mushroom leaderboard²⁶) for our culinary delight. This superfood has even found its way into crisps, biscuits, granola, chocolate, yoghurt, coffee and much more.

And there are other health benefits too: swapping mushrooms for meat can be helpful for people wanting to control their weight. Mushrooms can contain up to 7% dietary fibres and other non-digestible polysaccharides, including chitin, which have been associated with increased satiety (feeling fuller for longer) and could potentially prevent obesity.²⁷

Swapping mushrooms for meat can be helpful for people wanting to control their weight. In 2010, Dr Larry Cheskin, an expert on obesity and weight management at Johns Hopkins Bloomberg School of Public Health, conducted a study in which people were asked to substitute mushrooms for meat patties in their burgers. For those on a low salt diet, mushrooms again can offer a helping hand.

But fungi aren't just good for our health – they're good for the planet, too.



Image courtesy of Mushroom Bureau

“One of the problems with substituting foods is that we can compensate for those missing calories. Mushrooms have a low energy density – as opposed to, say, cheese, which is very energy-dense. In our study, we found that when people ate mushrooms instead of beef, they did save most of the calories – and that people with weight problems saved even more.”

Dr. Lawrence J Cheskin
Adjunct Professor of Medicine
at the Johns Hopkins School of Medicine

Mushroom Meat

Driven by a combination of environmental concerns and health awareness, many people are switching from animal proteins, high in unhealthy compounds, to meat-free substitutes – including mushrooms. According to the Harvard Medical Journal, there is a clear link between a high intake of red and processed meats and a higher risk of heart disease, cancer, diabetes and premature death.²⁸ The EAT-Lancet Commission (2019) recommends a 50% cut in the global consumption of red meat by 2050, for a sustainable and healthy food system in line with the Paris Agreement's targets of limiting global warming to 1.5°C. Livestock accounts for an astonishing 14.5% of global greenhouse gas emissions²⁹, and according to the Food and Agricultural Organisation (FAO), each 1kg of beef that reaches our plate has left 300kg of CO2 emissions in its wake.

Mushrooms make delicious and environmentally friendly meat alternatives. In fact, specifically treated mushrooms are also packed with nutrients, which can be rich in vitamins D and B12, and are right at home in a burger bun or on a

barbecue. And their environmental footprint is tiny. In terms of alternative proteins, the environmental impact of mushrooms compares favourably to other vegetarian options such as soya, the geographically distant production of which is frequently associated with the destruction of vast swathes of rain forest. Furthermore, growing mushrooms requires much less water than other commercial crops - beef production requires a thousand times more water³⁰ - and emissions are low compared to other foods. It only takes 0.7kg of CO2 to grow 1kg of fresh mushrooms, and they don't take up much room.

Mushrooms are grown in vertical farms, so they have a smaller land footprint than other protein-rich crops. According to the Mushroom Council³¹, a single acre of land can produce 450,000kg of fresh mushrooms, occupying just 0.29m2 per kilo of product compared to 369.81m2 per kilo taken up by lamb.³⁰ And because vertical farms are controlled environments, all resources required to produce the mushrooms can be exactly determined to minimise waste.

Our UK and Ireland Mushroom Producers are particularly committed

to sustainability, committed to reducing carbon emissions by over 50% over the next ten years, with a growth strategy in line with the European Commission and the United Nations 2030 Agenda for Sustainable Development Goals.

Cheap, nutritious, good for the planet and delicious – what's not to like?

Mega Mushrooms

As our understanding of the huge potential of mushrooms increases, a plethora of new companies are emerging to satisfy (and stimulate) growing demand for edible alternatives that can support health while reducing environmental impacts of our food. The Mighty Mushroom Co was created to bring a range of mushrooms supercharged with vitamins and minerals that boost immunity and has launched its first range of meat-free Burgers on Amazon Fresh, as well as its Cumberland Style Sausages. The new range is shaking up the meat-free market, packed full of umami flavour and made with up to 85% mushrooms, grown on sustainable Irish farms.

The range is a great source of fibre, full of key vitamins and minerals and contains less than 150 calories per portion. It also includes Mighty Mushroom Meat-Free Mince, containing 85% juicy mushrooms and flavoured with a mixture of herbs and spices to give you the very best meatloaf or spaghetti bolognese. Meat-free meatballs are also in the Mighty pipeline.

The range offers a more sustainable solution to the environmental impact of the meat industry, offering a great-tasting meal option for flexitarians, vegans and meat-eaters alike.

Brain Boosters

The way we think about food – what we eat, and what it can offer us – is shifting. As we adapt to the sedentary and often solitary routines of working from home, it's vital that we nourish our brains as well as our bodies. Many of us have been taking online yoga or exercise classes during lockdowns, but how can we also keep our brains in tip-top condition? We can start by making the right food choices. Studies have linked eating mushrooms with improved cognition³², which can only be good news for home-workers looking to boost their productivity and concentration.

Eating mushrooms might even reduce the risk of developing dementia.³³ Scientists have observed reduced levels of an antioxidant called ergothioneine in people with mild cognitive impairment (MCI) – and people with MCI are at greater risk of developing dementia. Mushrooms are a great source of ergothioneine, and a 2019 study in Singapore³⁴ found that people who eat 300g of mushrooms a week were 50% less likely to develop MCI. It's not enough to prove a definitive link – but it's certainly food for thought.

The pandemic has also driven an increased interest in 'preventative health' – that is, making choices today to ensure we're in the best shape tomorrow – and that begins with switching to healthier eating patterns. In China, 71% agree that eating healthily has become a higher priority for them since the beginning of the pandemic, while 36% of people in the US and 34% of Italians think the same.³⁵ According to a report by Waitrose, meanwhile, there were 2.3 million online searches for the term 'healthy recipe' in the UK last year.³⁶ Just as our health has become the number-one global story, it seems many of us understand instinctively how best to look after ourselves and our families.

It's certainly proving popular. According to The Vegan Society, the UK market for meat alternatives is set to, er, mushroom, with a predicted annual growth rate of 7.7% between 2020 and 2025.³⁷

Furthermore, mushrooms can be grown in conditions that are unsuited for other forms of agriculture, as exemplified by the increasing number of mushroom farms located in empty underground urban spaces.

UK startup Mycoloops are taking a unique circular and regenerative approach to mushroom growing. They are producing huge volumes of nutritious oyster mushrooms **[image 01]** using waste products such as coffee grounds as a growing medium. Their various growing spaces range from rural farms to disused urban spaces.

As 57% of people are making more of an effort to reduce their carbon footprint and take better care of the environment, mushrooms make a good swap.³⁸



Image courtesy of Dr. Vincent Walsh, Mycoloops

Mushroom Supplements

Supplements are a quick and easy way of getting nutritional goodness. Mushroom-based supplements are purported to contribute to immune health, heart health, bone strength, cognitive health and muscle repair. Fungi-derived probiotics feature strongly in a current health trend – that of restoring the natural balance of bacteria in your gut when it has been disrupted by an illness or antibiotic treatment. Other products under development include Vitamin B12 powder to fight fatigue and enhance energy levels; Selenium powder, that improves immune function and mental health; and protein powders, that contain all of the essential amino acids for a balanced diet, muscle building and satiety.

Studies have shown that mushrooms' nutritional properties can boost athletic performance and recovery.³⁹ Several brands are emerging in the health and wellness market with a raft of physical health and immune boosting supplements, including Super Shift⁴⁰, New Chapter⁴⁰ and Host Defence⁴⁰. New Chapter Supplements, master herbalists, have formulated herb and mushroom

blends, containing sustainably harvested cordyceps, for athletic health and sports recovery.⁴¹

Mushrooms' team of nutrients and health profile are ideal for a sports performance diet and some elite athletes are switching animal protein for mycelium alternatives, recognising mushrooms as nutritious powerhouses.⁴² The likes of Venus Williams and Novak Djokovic (tennis),

David Haye (boxer), Patrik Baboumian (strongman) and Hannah Tetter (snowboarder), follow plant-based diets and it is likely many more athletes and sports teams will follow suit.

But if you think the healing power of mushrooms is reserved to the elite few in the athletic world, think again. Mushrooms are going mainstream as football clubs begin to promote mushroom-based foods. Quorn recently

partnered with Liverpool FC to become the club's official sustainable protein partner.⁴³ Forest Green Rovers, the world's first fully vegan football club, made the move to meat-free matches based on the environmental and animal welfare impact of livestock farming, but the club also saw it as a way to improve player performance and give fans healthier, tastier matchday food. Today they serve up mushroom-based meals for players and fans alike.⁴⁴



Defence Drinks

Mushrooms are not only starring more frequently on our plates - they are also playing supporting roles in a whole host of innovative health products. Mushrooms have even dipped their hyphae into the latest health trend amongst young people: teetotalism. Today, almost one-in-four 18-24 year olds say they don't drink.⁴⁵ This has helped to drive sales of no or low-alcohol ("nolo") beverages up by 30% in the past year⁴⁶ – and mushrooms have joined the party. It turns out yeast isn't the only fungus needed to make beer; London's Fungtn Brewery brews gluten and alcohol-free beer using three varieties of edible mushrooms [image 02].

It's not just beer, either. Mushrooms can now also be found in many varieties of 'functional drinks' – that is, beverages that offer health benefits, a market that is projected to grow by 6.96% between 2021 - 2026.⁴⁷ It includes teas, coffees, energy drinks, powder supplements and more. Some functional drinks claim to boost immunity and gut health, and are marketed as 'preventative health' treatments – so it's no wonder that mushrooms are a key ingredient. The evidence suggests mushrooms can support healthy immune and

inflammatory responses by interacting with the microbes in our gut, both enhancing our adaptive immunity and strengthening the function of our immune cells.⁴⁸

These new drinks companies are hardly reinventing the wheel. Immunity-boosting mushrooms and fungi have been brewed into beverages for thousands of years. Kombucha teas, for example, which are produced by fermenting sugared tea using a symbiotic culture of bacteria and yeast, are thought to have originated in China as early as 220 B.C.⁴⁹ Kombucha is packed with antioxidants, probiotic bacteria, vitamins and minerals, making it a growing favourite among nutrient-conscious consumers.⁵⁰



02

Image courtesy of
The Fungtn Brew Company

Chapter 3

Vitamin D

In the top layer of your skin is a type of fat that your body metabolises from cholesterol. The ultraviolet light in sunshine reacts with this fat and converts it into a form of vitamin D. That form goes to your kidneys and is converted to another form; then there's a third step where it is converted to yet another form. That's because our bodies control exactly how much vitamin D is made and where it is active, because its action is very potent. It's a brilliant masterstroke of evolution; our bodies only produce as much Vitamin D as, when and where we need it, in a very tightly controlled way.

Ursula Arens
nutritionist and writer



Nutritionist and author Rob Hobson explains just why vitamin D is so important – and how we can ensure we are getting enough of it.

What is vitamin D, and why is it important for our immune system?

Vitamin D is the Swiss Army Knife of nutrients. It performs lots of vital functions: it helps our bodies absorb calcium, which is necessary for the health of your teeth and bones. It contributes to our muscle function, helps children grow and develop – and it is crucial to the normal functioning of the immune system in both adults and children.

Vitamin D is a vital foundation of our bodies' natural defences. When we have it in sufficient amounts, it may help to protect against upper respiratory tract infections such as colds and flu; one US study involving almost 19,000 adults found that those with the lowest levels of vitamin D were 36% more likely to develop a cold compared to those with higher levels.⁵¹

This wonder nutrient can also protect against infections by increasing the synthesis of proteins required for the body's natural microbial defences.⁵² Vitamin D can activate our immune cells and modulate our various immune responses.⁵³

How can we make sure we get enough of it? What should we be eating?

We get most of our supplies of vitamin D from sunlight, which is why our intake fluctuates throughout the year. Wintertime is when our levels are at their lowest, given the absence of sunlight with enough strength to promote the production of this nutrient in the body. The UK Department of Health and Social Care recommends that we take a supplement of 10mcg per day during the winter in order to maintain healthy levels of vitamin D – but including certain foods in our diet can also help to keep you topped up.

It is almost impossible to get all the vitamin D you need from your diet, however; this is because it is only found in a select few foods. These include certain oily fish (herring packs an incredible 26 mcg per 140g of fish, while sardines, tuna and salmon are also good sources), eggs, bran flakes and other fortified breakfast cereals – and of course mushrooms, one of the few fruit or vegetable sources of this critical vitamin. New technology that exposes commercially-grown mushrooms to additional UV light means we can now all find mushrooms supercharged with Vitamin D in our local stores. (see chapter 1). A three year study on Vitamin D currently underway at Trinity College in Dublin is sure to yield more interesting developments in the world of mushroom growing.

Image courtesy of Mushroom Bureau



“People who ate shiitake mushrooms on a daily basis improved the function of their immune cells and showed reductions in markers for inflammation”

What else do mushrooms do for our health?

Mushrooms contain certain compounds that have shown to help modulate the immune system. These include beta glucan polysaccharides, a type of soluble dietary fibre found in the cell walls of certain fungi that may help to reduce the risk of disease.⁵⁴ Mushrooms are also a good source of B vitamins, especially riboflavin and niacin which are required for the conversion of food into energy as well as maintaining healthy skin and red blood cells.

They also provide us with the mineral potassium, which is important for the proper functioning of the heart, muscle and nervous system. Mushrooms are also rich in another mineral, selenium, which is required by the body for the normal functioning of the immune system and healthy thyroid function.

Selenium also works as a powerful antioxidant, helping to protect against the damage caused by excess free radicals which can damage cells and increase the risk of disease.

Shiitake Happens

Growing numbers of vegans and vegetarians are fuelling a boom in all kinds of exotic mushrooms – including shiitake, which appear to be especially beneficial. One study carried out by the University of Florida found that people who ate shiitake mushrooms on a daily basis improved the function of their immune cells and showed reductions in markers for inflammation.⁵⁵ This is probably why in China they are referred to as the ‘medicinal mushroom’.

Despite increased consumer awareness of the health properties of mushrooms, the exact mechanisms are unclear. As many of the illnesses reported to be alleviated by mushroom based products, such as infection, inflammation and cancer, involve dysregulation of our natural immune response, it is likely that mushroom components can modulate our immune system. Researchers at Trinity College Dublin and Jude Wilson PhD Chief Scientific Officer, Research and Development at mBio are collaborating to develop a deep understanding of the anti-inflammatory and immune modulating functions of mushroom components.

Chapter 4

Planetary Immunity



My name is *Aspergillus tubingensis*. I'm a very common type of soil fungus, and I don't expect you've heard of me – but that might be about to change. I live in a garbage dump in Islamabad, Pakistan. This suits me perfectly as I'm rather partial to a type of plastic called polyurethane. You humans use it in everything from foam cushions to fake leather; more importantly, you throw an awful lot of it away, and while I'm grateful, it seems to have become a bit of a problem for you. Today, scientists think that I – and other fungi like me – could help to munch through the mountains of plastic pollution you leave in your wake. Saving the planet with an all-you-can-eat buffet? I'd be happy to help.



Our ecosystems are out of balance for a number of reasons. We have misused the elements fire and water; our industrial agriculture techniques have caused biodiversity loss; and we have colonised the places of native peoples across the globe silencing generations of knowledge of land management. All of these things have had an impact on the climate and have led to more extreme wildfires, droughts, floods, and the resulting domino effects such as desertification, acidification, run-off of toxic ash etc. Above all, they have caused a dramatic decline in certain mycorrhizal fungi species, which are fundamental connectors of species and life forms, capable of boosting ecosystem resilience both before and after disasters. At CoRenewal, we are harnessing the magical properties of fungi to help restore the balance of nature. We are developing wattles - kind of fabric tubes stuffed with straw and other plant waste - inoculated with fungal mycelium, commonly called "mushroom spawn", to make myco-filters, which help, for example, remove biodegrade toxins running off the land before they pollute waterways, or help deal with the contamination caused by oil spills. Humans have a critical role to play in the restoration of this lost balance: like fungi, we are incredible networkers, with the potential to redistribute resources throughout ecosystems, and capable of introducing mycorrhizal fungi (post-disaster) in order to support ecological regeneration.

Maya Elson

Executive Director of CoRenewal

Introduction

Our bodies tell us when we're under the weather, if we're overworked or under too much stress. Right now, the Earth is telling us the same thing. Rising global temperatures, pollution, the exploitation of global resources, habitat and biodiversity loss and mass extinction: our planet is under extreme pressure, and the stresses are showing.

Since the industrial revolution, human activity has largely followed a linear 'take-make-waste' model, in which raw materials are used to produce goods that are thrown away at the end of their lives. Large amounts of our waste ends up in landfill. A tiny percentage of our materials – only around 8.6%, according to the *Circularity Gap Report*⁵⁶ – is recycled, while a small amount is composted and the rest is sent to landfill or burned. We now understand that this is unsustainable. The Earth's resources are not infinite. Nature can't keep up with the rates at which we are depleting its natural resources. Our planet is out of balance.

This linearity doesn't exist in nature. Every byproduct, process and material in the natural world has value as a

resource for another life form. Energy and nutrients are recycled and reused in a cycle of perfect efficiency, and fungi are one of the most powerful engines driving this process. The good news is that we now recognise the need to reduce the rate of consumption of our raw materials. Many entrepreneurs and thought leaders are turning to nature to provide us with innovative ways of addressing these imbalances in an attempt to move away from the 'take-make-waste' model of production and towards a 'circular economy'. As in nature, this new way of thinking about our consumption views the waste from one process as the input for another – and we can draw on our human superpowers of innovation and creative problem-solving to make this happen. And, yes, you guessed it: fungi are a huge source of inspiration for many of these solutions.

Fashionable Fungi

Leather – once a life-long purchase – has now entered the fast-fashion scene. As we saw in chapter 2, eating less red meat is essential if we are going to meet the Paris Agreement⁵⁷ targets – and we need to approach our leather consumption in the same

way. Consuming less leather will not only reduce the greenhouse gas emissions associated with cattle farming, it will also minimise the environmental impact of the toxic chemicals used in leather tanning. To tackle this, new materials research is spearheading what promises to be a fashion revolution. Philip Ross – artist, designer, bio-technologist and founder of MycoWorks – has developed a 'mushroom leather'⁵⁸ by engineering and compressing mycelium in order to create a biomaterial replica. Spearheading the mushroom leather revolution are some top fashion brands such as Hermes, ready to ditch traditional leather for a more bio-based material.⁵⁹ With handbags and clothing already sported publicly by numerous Hollywood stars, we can expect this material to become mainstream in the next decade.



Image courtesy of Ecovative

03



Image courtesy of Danielle Trofe

Fungi Furniture

Mycelium has also been used as the main building block to create an array of household items, including lampshades [image 03], stools and benches, spearheaded by innovation companies such as Ecovative.⁶⁰ [image 04] Whilst they might currently look like pieces of modern art, our changing understanding of the connection between human activity and nature are leading to a shift in aesthetic values.

These products are far lower in greenhouse gas emissions than their traditional counterparts. They don't take up valuable agricultural land, can be grown from 'waste' products such as spent coffee, and will decompose at the end of their life cycle. It won't be long before these planet-friendly pieces appear in our homes and offices, as commonplace as they are beautiful.

Dirt Rich

Around one-quarter of all the animal species on Earth live beneath our feet. They perform a vital role, breaking down organic matter and releasing the nutrients contained within. And as well as these subterranean critters, the world's soils draw down and store huge amounts of carbon – as much as all the plants above ground, in fact – and therefore have a critical role to play in tackling the climate emergency.⁶¹

These abilities, however, depend on the soil's health. Just like the ecology of the microbes that live in your gut and keep you healthy, a similar delicate ecology exists underground.

Our industrial farming methods are disrupting that rich ecology with pesticides and fertilisers. It's a vicious circle: the more of these products we use, the weaker the plants become, and the greater the amount of chemicals we need to apply to protect them. We are damaging the health and balance of the soils on which we and the rest of nature depend – and once again, it could be fungi that ride to our rescue.

Fungal biology plays a critical role in boosting soil health.⁶³ Mycorrhizal fungi, coined 'ecosystem engineers', have shared symbiotic relationships with plant roots for 460 million years. They aid in the decomposition of organic matter, facilitate nutrient cycles and the storage of carbon. They help to build soil structure and protect plants. By not tilling or using chemicals on the soil, farmers let fungi do the work instead. In doing so, they can break out of the vicious cycle of chemical use and restore soil health. Researchers have even discovered bug-eating fungi that could eventually enter the agricultural scene as natural insecticides – protecting soil health and boosting biodiversity, while also removing the pests, or the few 'bad' microbes, from agriculture.⁶⁴

“Disrupt the ecology of microbes that live in your gut, and your health will suffer - a growing number of human diseases are known to arise because of efforts to rid ourselves of ‘germs’. Disrupt the rich ecology of microbes that live in the soil - the guts of the planet - and the health of plants too will suffer.”⁶²

Merlin Sheldrake

The author of *Entangled Life*



Image courtesy of Mushroom Bureau

Grow Up

Above-ground, meanwhile, the cultivation of edible mushrooms is at the forefront of a new agricultural revolution: vertical farming. Rather than using acres of precious farmland, vertical farming is done indoors in a controlled environment, with the crops growing on stacked rows of shelves. This approach vastly reduces the land footprint, CO2 emissions and the need for pesticides compared with conventionally-grown food crops – and mushrooms suit it perfectly, as all resources required to produce them using this method can be carefully calculated to minimise waste.

Nature's Mop

Cleaning up waste and pollution is another area of expertise for our humble mushroom. World-changing organisations such as CoRenewal⁶⁵ are working to harness the power of mushrooms and mycelial networks to restore natural habitats that have been damaged by environmental disasters such as forest fires or oil spills. Following the recent catastrophic wildfires in California, many people became concerned about sediment

erosion and toxic ash being sluiced into critical waterways, harming aquatic ecosystems and polluting drinking water. CoRenewal are using below-ground microorganisms, such as plant-supporting mycorrhizal fungi, to restore these environments and protect threatened waterways – and these fungi could work the same magic on oil spills at sea, too.⁶⁶

“Ecological restoration and bioremediation research employing microbial components is crucial to preserving biodiversity and protecting local communities.”

Maya Elson

Executive Director and co-founder of
Amazon Myco-Renewal



Image courtesy of Marcus Lange

Plastic Munchers

Plastic pollution is one of the most visible side-effects of our take-make-waste economy. We produce enormous amounts of the stuff: half the plastic ever manufactured was made within the past 15 years.⁶⁷ Globally we produce 381 million tonnes of plastic every year,⁶⁸ and just 9% is recycled.⁶⁹ The remainder takes about 400 years to break down, and every year, 8 million tons finds its way into the ocean. According to the Ellen MacArthur Foundation, at this rate there will be more plastic particles than fish in the sea by 2050.⁷⁰

As well as using less plastic and recycling more of it, we need to tackle the growing mountain of plastic waste – and it seems fungi could be our secret weapon. A growing number of species have been found to ‘eat’ plastic waste, breaking it down into organic matter within weeks rather than decades. Scientists have discovered 50 such strains in the past few years alone.⁷¹

That’s not the only way fungi can help us solve our plastic pollution problem. Not only can these incredible organisms munch on plastic; they can replace it, too.

A number of companies are developing innovative applications using mycelium to substitute environmentally toxic materials across all aspects of our lives. Irish scientist and co-founder of Paradise Packaging, Ciaran McCarthy, is using Ecovative technology to create mycelial packaging products that break down in just 30 days on your garden compost heap.⁷² This could one day replace polystyrene, which in contrast never completely biodegrades.⁷³

[image 05] Other entrepreneurs are building surfboards and canoes **[image 06]** out of similar mushroom-based materials⁷⁴ in place of some of the toxic resins currently used. These products are truly circular: they have a very low environmental impact, and break down harmlessly at the end of their lives.

And while we’re on the subject of end-of-life, an organisation called Loop of Life has created mycelium coffins that speed up the natural decomposition process.⁷⁵ As we know, mycelia are nature’s great recyclers; they can turn organic matter into rich nutrients. These coffins truly embrace the circle of life. They are much less energy-intensive and use far fewer raw materials to make than traditional

coffins, and they break down in the ground in just 45 days, gently returning us to Mother Nature in the process. With our increased awareness of humanity’s impact on the planet, such environmentally positive end-of-life choices are set to gain traction in the coming years. When it comes to solving our most pressing environmental problems, it seems the capabilities of fungi may be limitless.



05

Image courtesy of Paradise Packaging Company

06

Katie Ayres, image courtesy of M.Ayres



Fungal Foundations

After water, concrete is the most widely used substance on Earth – and it is an environmental disaster. If the cement industry were a country, it would be the third-largest CO2 emitter in the world at 2.8bn tonnes a year, surpassed only by China and the US.⁷⁶ Even worse, concrete is forever. Once made, it cannot be disposed of.⁷⁷ Once again mushrooms come to the rescue as a key ingredient in the development of more planet-friendly materials. Mycelium bricks which fuse together, therefore also eliminating the need for binding cement, could be the future of construction.⁷⁸

A 2014 project in New York provided a tantalising glimpse of this future. **[image 07]** Hy-Fi, a 13-metre tall tower, was built using 10,000 bricks made from mycelium fused with agricultural waste. It was used to host public cultural events for three months. The structure, said to be stronger than concrete, was then disassembled and composted, and the resulting soil returned to local community gardens. This successful experiment offers many possibilities for future construction.

Research and development is also underway into the creation of insulation panels made from mycelium and ‘waste’ products such as spent coffee and cardboard.⁷⁹ As well as being circular by nature, these products emit far less CO2 during their manufacture.

It is possible to conceive of a future where our streets and homes are made from, and alive with, mycelium materials.



Hy-Fi The Living, MoMa PS1, New York, 2014. Photo by Amy Barkow, courtesy of The Living

Future Weird

It's clear that the problem-solving capabilities of mushrooms and their networks are extensive. As Tradd Cotter, microbiologist and owner of research company Mushroom Mountain, has said: "As far as [mushrooms'] versatility in agriculture, medicine, and in the laboratory, there's not much they can't do."⁸⁰ Eben Bayer, the CEO of Ecovative, reckons we will one day be able to create medical products – even human organs – from mycelium.

For now, these advances may be in the future. But we can be sure that fungi will be key players on our quest towards human and planetary health.

Martian Mushrooms

Are mushrooms growing on the surface of Mars? A group of scientists has made this startling claim based on images of small, puffball-like objects on the Martian surface taken by NASA's Perseverance Rover.

Sadly, they're almost certainly mistaken.⁸¹ These objects, NASA scientists say, are most likely rocks that are revealed when either wind or

the rover itself brushes away the dust that was covering them.

But although fungi haven't yet made it to Mars, they could be a big part of its future. NASA has been funding research⁸² into whether astronauts can 'grow' habitats for Martian and lunar missions using mycelium. Rather than expending precious energy launching heavy structures into space, this approach would use foldable, lightweight frames threaded with dormant fungi. On arrival, the frames would be unfolded, and – by adding water – the mycelium would grow around the structures, forming strong and airtight habitats.

We may only be a few years away from the first crewed mission to Mars. Elon Musk, the founder and CEO of SpaceX, says he is extremely confident of making this happen by 2026.⁸³ Could those first human visitors find themselves living in habitats made of fungi? What a giant leap for mycelium that would be...

“My dream is to one day grow a lung and seed it with lung cells and use the mycelium to create the capillary network and use the human cells to create the actual lung”⁸⁴

Eben bayer
CEO of Ecovative

Conclusion

4 things to take away from this report

Current and future mushroom nuggets

1. Humans and Immunity

Packed to their gills with vitamins and nutrients, mushrooms are paving the way for a new age of food supplements. The healthy functioning of our immune systems has never been more important – and the role mushrooms can play in strengthening our immunity makes them the superfood on everyone’s lips. They are good for our brains as well as our bodies; studies have linked eating mushrooms with improving our cognitive abilities.

2. Food and Immunity

Low in calories and high in nutritional value, mushrooms are growing in popularity as a delicious and sustainable alternative to meat. Environmentally speaking, they make mincemeat of beef. One acre of land can produce 450 tons of mushrooms a year – and as British start up Mycoloops are demonstrating, they can be farmed in forgotten urban spaces using waste products such as coffee grounds. A raft of new ‘functional drinks’ - boosting our immunity and gut health - are in the process of taking the drinks market by storm as we strive to keep illness at bay. And mushrooms are even playing a part in protecting our drinking water, filtering pollution out of our waterways after natural disasters.

3. Vitamin D

Vitamin D is the Swiss Army Knife of nutrients. Not only does it perform vital functions like helping our bodies absorb calcium, it is crucial to the normal functioning of the immune system and forms a vital foundation for our bodies’ natural defences. When we have this wonder nutrient in sufficient amounts, it can protect against infections. It even increases the synthesis of proteins required for the body’s natural microbial defences. Mushrooms, like us, are able to make vitamin D and do so when grown under UV Light. Vitamin D-enriched mushrooms are now sold by many retailers. A three-year study on Vitamin D currently underway at Trinity College in Dublin is sure to yield more interesting developments in the world of mushroom benefits.

4. Planetary immunity

Mushrooms have a huge role to play in the future health of our planet. Mushrooms could help farming go back to its roots and change the face of modern agriculture, whose practices have done so much to destroy the soil and biodiversity over the last decades. Their resourcefulness with ‘waste’ materials and otherwise unused space makes mushrooms exemplars of the circular economy. Bug-eating fungi could eventually enter the agricultural scene as natural insecticides – protecting soil health and boosting biodiversity, while also removing the pests, or the few ‘bad’ microbes, from agriculture.



And since you are here...

why not try Dr Rupy's Medicinal Mushroom and Garlic Broth Using M&S Vitamin B6+ & Vitamin D Mushrooms 300g

SERVES: 2

Ingredients:

- 2 **tbsp** extra-virgin olive oil
- 1 whole garlic bulb, cut in half across the bulb
- 1 **litre** boiling water
- 15g fresh sage leaves
- 15g fresh flat-leaf parsley leaves
- 1 red chilli, sliced in half
- 80g Vitamin D mushrooms, finely sliced
- 80g Chestnut mushrooms, diced
- 160g Swiss chard, roughly chopped
- 160g baby spinach, roughly chopped
- 100g vermicelli rice noodles, broken
- Sea salt and freshly ground black pepper

Method:

1. Heat the oil in a large saucepan over a medium heat, add the diced chestnut mushrooms and garlic halves, cut side down, and fry gently for 6 minutes until golden brown.
2. Add the boiling water to the pan along with the herbs, chilli, season with salt and pepper and cook very gently for 30–40 minutes until you have a deeply fragrant broth.
3. Add the chard, sliced mushroom and spinach and cook for a further 5 minutes.
4. Add the rice noodles, remove from the heat and leave to stand for 5 minutes until the noodles are tender.
5. Remove the whole garlic and serve.



Image courtesy of Dr. Rupy

About this report



About Department 22

Department 22 is an innovation and trend forecasting consultancy, specialising in sustainability, food and design. They help food companies across the entire system identify future challenges, transforming them into exciting business opportunities based on circular economy principles.

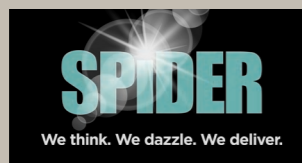
www.department22.uk



About The Mushroom Bureau

The Mushroom Bureau is the collective voice of mushroom growers across Ireland and the UK. They promote and educate the public about the value and health benefits of mushrooms, and how to incorporate them in daily diet. They commission and disseminate the most up to date and scientifically-verified research from around the world.

www.justaddmushrooms.com



This report has been coordinated by **We Are Spider**

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