

THE QUEENSLAND MYCOLOGIST



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The Queensland Mycological Society

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Society Objectives

The objectives of the Queensland Mycological Society are to:

1. Provide a forum and a network for amateur and professional mycologists to share their common interest in macro-fungi;
2. Stimulate and support the study and research of Queensland macro-fungi through the collection, storage, analysis and dissemination of information about fungi through workshops and fungal forays;
3. Promote, at both the state and federal levels, the identification of Queensland's macrofungal biodiversity through documentation and publication of its macro-fungi;
4. Promote an understanding and appreciation of the roles macro-fungal biodiversity plays in the health of Queensland ecosystems; and
5. Promote the conservation of indigenous macro-fungi and their relevant ecosystems.

Membership

Membership of QMS is \$25 per annum, due at the beginning of each calendar year, and is open to anyone with an interest in Queensland fungi. Membership is **not** restricted to people living in Queensland. Membership forms are available on the website, <http://qldfungi.org.au/>.

Could members please notify the membership secretary (memsec@qldfungi.org.au) of changes to their contact details, especially e-mail addresses.

The Queensland Mycologist

The Queensland Mycologist is issued quarterly. Members are invited to submit short articles or photos to the editor for publication. It is important to note that it is a newsletter and not a peer-reviewed journal. However we do aspire to high standards of accuracy.

Material can be in any word processor format, **but not PDF**. The deadline for contributions for the next issue is **15 June 2018**, but if you have something ready, please send it **NOW!** Late submissions may be held over to the next edition, depending on space, the amount of editing required, and how much time the editor has. The standard font used for text is Gothic 720BT, 9pt, with other sans serif fonts used for headings and captions. Font sizes may vary if required to make articles fit the available space, and text may be edited for the same purpose.

Photos should be submitted separately at full-size to allow flexibility in resizing and cropping to fit the space available while minimising loss of quality. Authors who have specific preferences regarding placement of photos should indicate in the text where they want them, bearing in mind that space and formatting limitations may mean that it is not always possible to comply. Material from published sources (including the internet sites such as Wikipedia) may be included **if that complies with copyright laws and the author and source are properly acknowledged**. However extensive verbatim copying is not acceptable.

Cover Illustration

Cookeina tricholoma (Mont.) Kuntze found during a Tropical Fungi Project foray. See page 4. Photo © Frances Guard.

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QMS Activities

Meetings

Meetings are held in the F.M. Bailey Room at the Queensland Herbarium, Mt Coot-tha Botanic Gardens, Mt Coot-tha Road, Toowong, commencing at 7pm on the second Tuesday of the month from February (no January meeting), unless otherwise scheduled. Check the website for details and any changes. There will be 3-4 guest speakers invited during the year and other meetings will be informal. Suggestions from members for topics or names of potential speakers or talks will be welcome at any time. Please contact a member of the Committee.

To assist those unable to attend meetings, notes on the talks are included in the Queensland Mycologist and on the website if possible. However, the notes never do justice to the topic as they do not reflect the enthusiasm of the speaker or cover the discussion that follows, and not all talks are written up for the newsletter. So remember, where possible it is better to attend the meetings, get the information first hand and participate in the invaluable information sharing opportunity.

Suppers are provided by volunteers. Please bring a plate if you can.

Forays

QMS hold regular forays during the first half of the year. The dates are nominally the 4th Saturday of the month, but actual dates may vary and additional forays may also be held. Field trip details may change as a result of drought or other unforeseen circumstances. Check the website for changes.

Members are invited to suggest venues for additional forays. If you have any suggestions (and especially if you are willing to lead a foray), please contact Susie Webster or another member of the Committee.

Workshops

What do you, our members, want to learn more about that could be presented in a workshop? QMS is always on the lookout for workshop ideas. Members are encouraged to suggest topics, whether new or reruns of past workshops.

Send your ideas to Judith Hewett or Wayne Boatwright (info@qldfungi.org.au).

Details of workshops will be included in newsletters and on the QMS website as they become available.

QMS Calendar – 2018

| MONTH | MEETINGS | FORAYS/WORKSHOPS |
|------------------|---|--|
| August | 14th: TBA | 18 th . Workshop: Polypores (Nigel Fechner) |
| September | 11th: Jed Calvert – Fidelity and the Fungus – Orchid Mycorrhizae that are One Plant Lovers | |
| October | 9th: Kaylene Bransgrove – Endophytes | |
| November | 13th: Dr John Dearnaley – Serendipita – Mycorrhiza with a Commercial Future | |
| December | 11 th Dr Diana Leemon – The Santa Claus story, witchcraft, economic boom and bust, Irish diaspora: how fungi have shaped human history. Christmas Party | Christmas Break |

Editor's Comments

After an article drought, the heavens finally opened and I now have almost enough for two newsletters, promised or sent. So I still need material for the already overdue second issue.

If you are preparing an article, please send it in as soon as you can as I want to get started as soon as possible.

We really do need more foray reports. PowerPoint presentations on the QMS website are no substitute as they are photos without the comments made during presentation. The comments can be included in newsletter articles.

I can help prepare a report so long as I have photos and at least an outline of what was said.

Highlights, such as rare, beautiful or unusual species, or other points, can be used to build a story, however brief.

In this issue Fran reports on the Tropical Fungi Project, with a wonderful photo gallery, and an account of fungi she has collected around her home, a major project in its own right.

Finally, Vanessa has written up her “Introduction to Fungi” that she presented to QMS in April. Part 1 (fungi) is in this issue; part 2 (lichens), will appear in a future issue. That material was written for a non-mycological audience but I hope new members and people outside QMS who see it (e.g. who pick up a copy of the newsletter at the Herbarium) will find the two articles informative. There is so much to know about fungi even at the basic level.

Tropical Fungi Project Progress Report

Frances Guard

In 2017 a group of us decided it was time to follow up a long held desire to do more work on the fungi of north Queensland. This would be in preparation for Tropical Fungi pocket field guides, while engaging with interested local North Queenslanders. We planned to offer training in identifying and documenting fungi, and understanding their roles within the ecosystem.

The project was at least nine months in the planning. We applied for, and were successful in obtaining, \$10,000 from Queensland Government's Advance Queensland Engaging Science Grants. This was supplemented by donations from Bush Heritage Australia (\$750), Friends of Trees for the



Project workers L. to R. Fran Guard, Sapphire McMullan-Fisher and Matt Barrett. © Frances Guard.

Evelyn and Atherton Tableland (TREAT) (\$500), an anonymous donor (\$2000), Playing Queensland Fund in collaboration with Donna Davis (\$2420), and at least \$40,000 worth of in-kind contributions by many supporters and participants, from local hosts to professional mycologists.

The on-ground activities took place in March. The monsoon season was kind to us, and good rain fell just before our visit, so fungi were fruiting everywhere. Then heavy rain fell during our visit. (That did prevent a few people from joining the workshops and proved a challenge in the drying of specimens!). However, all activities went ahead as planned. Over 120 people from the region were involved in workshops and a public presentation. It was very well received and they are keen for a further series next year when we hope to launch the pocket guides.

There were a number of rewarding aspects to this project:

- collecting 260 specimens, some of which have not been previously described in Australia, or even in the world, and seeing the fungal diversity across the monsoon tropics.
- watching people engage with fungi for the first time and see their “light bulb” moments as they got the importance of fungal relationships.
- enabling underfunded and underappreciated mycologists to get together and share their common passion for a short time.

The spin-offs from this project, which is a long way from full completion, are ongoing. They will hopefully feed into the Decadal Plan¹ for increasing our knowledge of this hyper-diverse Kingdom of Fungi, and education of the public as to its importance.

As the specimens are worked on (with microscopy and DNA), more information will be shared both here and in scientific journals.

¹. <https://www.science.org.au/support/analysis/decadal-plans-science/discovering-biodiversity-decadal-plan-taxonomy> .

A gallery of some of the most extraordinary fungi that we found is included on pages 6-8, with comments on page 8.



Polypore and Microscopy Workshop participants at James Cook University. © Frances Guard.



Sandra Abell at Kuranda Beginners' Workshop. © Frances Guard



Beginners' Workshop, TREAT Nursery, Lake Eacham. © Frances Guard







Captions

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a. *Amanita egregia* D. A. Reid. This pure white species was common, even occurring in fairy rings. It has been collected most often in northern Australia, but occurs as far south as New South Wales. It is in Section Caesareae, and the same group ('Stirps' Hemibapha) as the next specimen.

b & c. *Amanita hemibapha* (Berk. & Broome) Sacc. The stunning colour of this fungus made it stand out wherever it was found, mostly in drier woodlands. Its form is quite similar to *Amanita egregia*.

d. *Austroboletus austrovirens* Fechner, Bougher, Bonito & Halling. The dry green cap and green reticulate stem are obvious and not to be confused with the sticky green cap of *Austroboletus viscidoviridis*.

e. *Favolus tenuiculus* P. Beauv. "Honeycomb Fungus", originally described from Africa, is a complex that has not yet been fully clarified.

f & g. *Cookeina* sp. probably *sulcipes* (Mont.) Kuntze. and *Cookeina tricholoma* (Mont.) Kuntze. Not only the bristly hairs, but also the inrolled margin of the cups and the shorter stipe separate these two species. *C. tricholoma* is featured on the front cover.

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a. *Auricularia* sp. This is in the *mesenterica* group, but is definitely not that and looks different from the South East Qld species, which is aff. *asiatica*, so it is probably a new species.

b c, d. *Pseudofistulina*. Fruitbody top, bottom and the individual tubes on the underside (similar to *Fistulina*), but microscopy and DNA (done by Matt Barrett), says this is a separate genus. We really need more specimens of this undescribed species.

e. *Marasmius* sp. probably Section Globulares.

f. Dark blue *Entoloma* sp. Beautiful, but possibly unnamed.

g. A colourful *Ramaria* sp. that probably occurs from north to South East Queensland, but has never been described.

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a, b. *Multifurca* sp. is in the family Russulales, and some *Multifurca* spp. produce milk. Progressive enlargement of the cap as the fruitbody grows is shown as rings when the flesh is cut.

c. Small unknown agaric with cross venation between gills. Is this in the genus *Filoboletus*? More specimens are needed. More work is needed to check all characters, including bioluminescence, and on variability in the species we call *Filoboletus manipularis*. Are pore size and bioluminescence distinguishing characters?

Copyright: Photos of *Pseudofistulina* © Matt Barrett. All other photos © Frances Guard.

Fungi of Dilkusha Nature Refuge - the Growing List

Frances Guard

Approximately 12 years ago, I became hooked on fungi. I had suggested to Patrick Leonard that I would like a list of the fungi on Dilkusha, our 72 acre property near Maleny. We had a bird list and a plant list, so why not a fungi list? Pat laughed at me and declared that that was the work of a lifetime!

I decided that I liked a challenge and so would set about the task.

Since then I've photographed, collected, recorded, described, become frustrated, learnt a lot and almost given up. Then I've set off again with renewed interest, been encouraged by some friends, and daunted by the enormity of my foolish decision. At times I've thought that instead of one lifetime, it might more realistically be three lifetimes to list all the fungi on this one small but amazingly diverse place.

Just recently I've finally got down to making a spreadsheet of my finds, a thing I should have started years ago. I am fascinated by when the fungi fruit and how often I see them, so I have included columns for each month of the year, and space to check recurring species. Of course there are many species that I have to use tag names for, as it appears that they are not yet described, or the literature is just not available for amateurs like me. Whenever I find something new I try to collect, photograph and describe it and make a specimen for the Herbarium in the hope that some day it will be identified.

I've been amazed to find that my list is already over 200 species. This reflects the diverse habitats on Dilkusha, as well as the time I've spent looking. Most of the property is regenerating or remnant subtropical rainforest on basalt, with quite an extensive riparian zone. This supports many saprotrophic fungi. However, there are small patches of sandstone and brush box forest. One such patch is on a steep ridge and it is my favourite place for both unusual flora and mycorrhizal fungi. This year the ridge has been brilliant.

Two amanitas have fruited there, and with some difficulty, I have identified them as *Amanita luteolovelata* D.A.Reid and *A. albovolvata* A.E.Wood. In my experience amanitas never seem to tick all the boxes for the described species. However, these were the closest fit. Both were new for Dilkusha.

Around the same time in March I found a pair of fruiting bodies of a species belonging to the

Lactarius clarkeae Cleland group. Although I've found a number of russulas in the past, these were the first *Lactarius* I've seen. This species has of recent times been moved to the genus *Lactifluus*.



Amanita albovolvata (top) and *A. luteolovelata*
© Frances Guard.



Lactifluus clarkeae. © Frances Guard

Another prolific fruit producer this year has been a grey coral, which appears to be *Clavulina cinerea* (Bull.) J. Schröt. This specimen had variable fruitbodies, from grey with blunt tips, to others a

mix of grey and pinkish-buff, with off-white stems and pointed tips. There did appear to be some intermediate specimens as well. The spores were the same for both forms, i.e. subglobose to broadly ellipsoid, 7-8.5 x 6-8 μm . So I am not sure if there is only one species or two, which may indeed be different from *C. cinerea*, a northern hemisphere species.



Clavulina cinerea -form 1 (top) and form 2. © Frances Guard.

My most exciting find was in April, when I came upon two bright yellow balls half hidden in the leaf litter under a brush box tree. They were 20-25mm diameter, with a small blood red central disc, and a tiny pink stem. Handling caused immediate intense blueing of the yellow pores. On sectioning one, it was obvious that this was a secotioid bolete with a pale blue central column, blackening flesh and red stem. It is *Gymnogaster boletoides* J.W.Cribb, a mycorrhizal, truffle-like species described by Joan Cribb in 1956 from Mt Glorious.

Among the saprotrophic fungi I have found this season, was the beautiful, soft, white laterally attached polypore, *Echinochaete ruficeps* (Berk. & Broome) Ryvardeen. This little fungus has distinctive brown, branched, lanceolate, pointed setae on the



Gymnogaster boletoides © Frances Guard.



Echinochaete ruficeps © Frances Guard.

upper surface. Its white pores are large, angular and decurrent. I was delighted that Matt Barrett was able to recognise it from my notes, and confirm the identity with DNA.

The above examples are just a few of the many species growing on Dilkusha, some of which are either new to science, new to Australia or this

region! We do live in a richly diverse part of Queensland.

My thanks for help with this article and the one on Tropical Fungi, and continuing mycological encouragement, go to Nigel Fechner (BRI), Matt Barrett (Kings Park WA), and Sapphire McMullan-Fisher (MEL).

In April 2018 I gave a rather lengthy talk about fungi and lichen. For ease of publishing in the "The Queensland Mycologist", I've broken my presentation into two articles. This, the first part, is about fungi. Part two on lichens will be published in a later issue. *Vanessa Ryan*

Fungi - An Introduction

Vanessa Ryan

Images © V. Ryan unless otherwise noted.



Some of you might recognise this colourful mushroom. It is quite common in some areas. But have you ever stopped to look at it closely? Have you ever thought about what it is and what it does? Most people don't, which is a shame as fungi are really amazing and, quite frankly, we can't live without them.

Now I have to admit that is a pretty big statement to make about something which is so often overlooked and poorly understood. What makes fungi so important? To understand that we first need to understand what they are.

What are fungi?

In the early days of science all living things were classified into two groups or kingdoms. This division goes back at least as far as Aristotle who lived around 350 BC – that's over 2,300 years ago. He distinguished between plants - which generally do not move, and animals - which do move. Over time, these observations were expanded upon by others. It was generally agreed that animals:

- need to digest food such as plants and other animals to survive;

- have specialised sensory organs for recognising and responding to stimuli in the environment;
- they can move about voluntarily;
- they have live young or lay eggs.

There are always exceptions to the rules, but for our purposes I'm keeping it simple.

So following that description it is obvious that fungi aren't animals and therefore must be plants. Let's look at the early scientists' observations about plants. Plants:

- don't digest food;
- don't have specialised sensory organs;
- they have very limited movement, if any;
- and they reproduce via seeds or spores.

This broad description also seems to fit fungi and so for many hundreds of years fungi were thought to be simple or lower plants like the mosses and liverworts. It wasn't until the early 1700s when scientists started using microscopes to look at cellular structures and processes that they realised that plants and fungi really are quite different from each other.

It was discovered that fungi actually do eat things. Unlike animals which engulf their food and digest it internally, fungi feed by external digestion and absorption.

Fungal cells, like animals cells, don't contain chlorophyll. Plant cells do. Plants use chlorophyll to make their own food.

The spores of some fungi are quite mobile. They have little tails and can swim – yes, just like animal sperm cells can swim.

Fungal cell walls are rigid like plant cell walls, but they contain chitin while plant cell walls contain cellulose and lignin. By the way, chitin is the same stuff the exoskeletons and wings of insects are made of. It's also in the scales of fish and the beaks of octopuses.

So fungi are organisms that:

- Feed by external digestion and absorption;
- Some can move voluntarily;
- Reproduce by spores;
- Have rigid cell walls that contain chitin.

Fungi were duly reclassified and put into a kingdom of their own. Recent DNA analyses have confirmed that fungi are actually more closely related to animals than to plants.

Estimates vary, but it's thought that plants and animals diverged in their evolution around 1.5 billion years ago. At that point, fungi were still a part of the animal branch. It wasn't until maybe about another 10 million years later that fungi separated from animals and began their own evolutionary path.

Fungi probably colonised land over 500 million years ago. Until then, it is thought that bacteria were pretty much the only things living on dry land. Plants still lived in the sea and only a few molluscs represented the animals along the shorelines.

Fossil fungi up to 420 million years old have been found all over the world. These fungi, named *Prototaxites*, were giants standing over six metres tall and about one metre wide at the base. At that time the tallest plants were only about a metre high so these fungi would have dominated the landscape. Also at that time, the only land animals were small invertebrates – things like millipedes, insects, snails and worms. Fungi were around long before there were any dinosaurs.

Most modern fungi are a lot more modest in size.

The kingdom includes microfungi such as yeasts, moulds, mildews, smuts and rusts and macrofungi, which are the more familiar mushrooms, puffballs, crusts and brackets.

Little is known about the true biodiversity of fungi. They seem to have endless ways to interact with the environment, have hugely varying life cycles, and come in so very many different shapes, sizes and colours.

Let's look at your typical little brown agaric that you might find out in the bush.

It has a cap, gills and a stipe. But it doesn't end there. Like all macrofungi, the structural component of the fungus is hidden away beneath the fruiting body, in the form of a mycelium. The mycelium is made up of a network of tiny threads called hyphae that live on or within the food source. What it grows on, or in, is called the substrate. The mushrooms, puffballs, crusts and brackets we see are only the fungus's fruiting bodies, like apples on a tree.



Fungi aren't compact, distinct organisms like the animals or even plants we see around us. Their mycelia are open networks that can grow through each other. It is quite possible for more than one fungus to share the same area of substrate.

If we could see the fungi beneath the surface of the soil, it would be something like a patchwork of overlapping and interwoven mycelia. The following image is a representation of that. What is not shown in the image would be a similar mosaic of fungi on and within the trees.



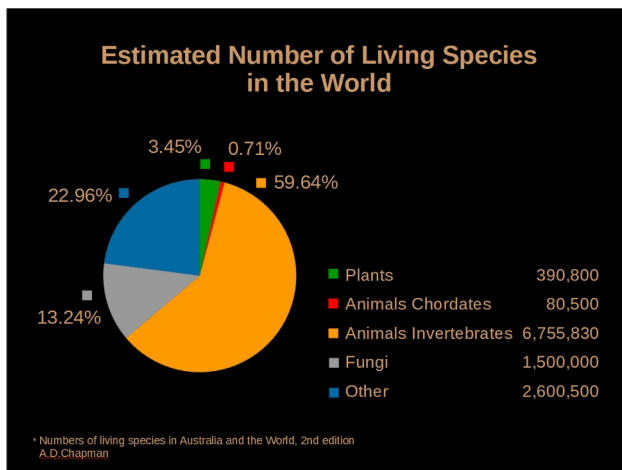
© Mark Newbound

It's not all peace and harmony however. Like all organisms, fungi compete with each other for food. Some fungi fight for their territory by producing chemicals in their hyphae that poison the substrate around them to deter foreign invaders.

How many species of fungi are there?

It has been estimated that fungi outnumber plants by ten to one. That is, for every plant species there are ten fungi. In the Australian context, with our often harsh dry climate, that number has been reduced to about four fungi for every plant. In 2009, 11,846 species of Australian fungi had been described. Estimates for Australian fungi as a whole range from 50,000 to 250,000 species.

This graph is a bit out of date as the information is from 2009, but it gives you an idea of the relative numbers of the different kinds of living species world wide.



According to this diagram, there are roughly four times as many fungal species (shown in grey) than there are plants (green). The fungi far outnumber vertebrates (red). The invertebrates (yellow), which includes insects, molluscs and worms, outnumber everything. The category "other" (blue) includes things like bacteria, viruses and slime moulds.

The graph depicts that there is an estimated 1.5 million species of fungi, but others have estimated that there may be as many as 5 million or even more. So far, only about 100,000 have been described and named. If we go with the more conservative 1.5 million species, that's less than seven percent that have been identified.

Where do all these fungi live?

The simple answer to that is... everywhere.

The obvious places are where we can see them – on the ground and on plants. Fungi also live in the soil, in both fresh and salt water and their spores fill the air. They live on our skin and hair and even inside us in our blood, organs and bones. Fungi have been found on every continent, from jungles to deserts, and from both polar regions to the equator. Fungi have also been found living kilometres deep underground, inside the rock that makes up our planet's crust. Experiments have shown that fungal spores can even survive in the void of space.

Humans are responsible for the transportation of many species around the world and fungi are no exception. The anemone stinkhorn was introduced to English and North American gardens from Australia. The death cap was introduced to Australia from Europe and the fly agaric also originates from the Northern Hemisphere. Both of those species are poisonous. A recent arrival in

Australia is the wood rotting *Favolaschia calocera*, the orange ping-pong bat fungus. Molecular analyses indicate that it originated in Madagascar. We don't yet know what its impact will be on competing native fungal species, but it has spread rapidly. Myrtle rust, a South American pathogen of plants in the family Myrtaceae, is another recent arrival. It has spread rapidly, can infect over 350 Australian native plant species, and could drive some to extinction.

What do fungi do?

Fungi are a lot like us in some ways.

- They eat things.
- They grow.
- They reproduce.
- They can have friends...
- ...and enemies.
- They can get sick.
- They get old.
- They die.

Let's start with what they eat...

Mycorrhizal Fungi

Many fungi that live in the soil get their food from plants, attaching themselves to the roots of grasses, herbs, shrubs and even large trees in a (usually) symbiotic relationship. The fungal mycelium is able to gather more water and nutrients from the soil than the plant's roots could alone. Fungi can also draw minerals such as nitrogen and phosphorus from the soil, something that plants aren't very good at. In return, the plant gives the fungus sugars that the fungus can't make. It's been estimated that plants give their fungal partners 15-30 percent of their sugars. This relationship is called a mycorrhizal association.

It is a very ancient relationship. Evidence of mycorrhizas have been observed in 400 million year old fossil plants.



Mycelium and roots. André-Ph. D. Picard CC BY-SA 3.0 https://en.wikipedia.org/wiki/Ectomycorrhizal_extramatrix_mycelium

It has been estimated that up to 95% of existing plant species need fungal partners to be healthy or to even stay alive. Such a relationship is essential in areas where there are poor soils. Orchids especially need their fungi. The seeds of many species won't even germinate unless they have the right mycorrhizal partner.

Some Australian plants which don't have mycorrhizal partners belong to the protea family – that includes the banksias, grevilleas, hakeas, and geebung.

Many mycorrhizal fungi can partner with different species of plants and many plants have more than one mycorrhizal partner. Thus, plants and fungi are interconnected by a complex underground network. Nutrients can flow through this network, enabling, for an example, an adult tree to provide sugars to its seedlings. Other chemical signals can also be transmitted. Recent research has shown that plants can warn other plants on the same mycorrhizal network of insect or herbivore attack.

Fungal mycelia benefit plants in another way by binding the soil particles together. This helps to prevent erosion and also creates spaces in the soil that improves both water retention and drainage. In one square meter of healthy soil there may be up to 20,000 kilometres of fungal hyphae.

Endophytic Fungi

Some fungi have another kind of close symbiotic relationship with plants. These fungi live completely inside plants – in their leaves and stems – for at least part of their life cycle. They are called endophytes.

It's thought that they help plants grow better in poor soils and to better tolerate stresses such as heat and drought, diseases and being eaten by insects and larger animals. Again in return, the fungus is given the sugars it needs. A lot of research is going in to how endophytes can help us by improving the health and strength of the crops we grow.

Parasitic Fungi

Now fungi also have a darker side. Some are greedy. They take from their partner or host and don't give anything back. These are the fungal parasites and they infest plants, animals and even other fungi. Most are microfungi. Some live on the surface of their host while others live deep inside them. A great many actually don't significantly harm their host (at least at first) as they need them to stay alive so that they, in turn, can survive and develop. Others quickly make their host sick or even kill them, and even those that start out relatively benign can become pathogenic.

8,000 species of fungi are known to be detrimental to plants and together they cause 80% of plant diseases in agriculture. Some have caused crop failures that have led to famines – such as the Irish potato famine of 1845-49 when over one million people died.

300 species of parasitic fungi are known to cause diseases in humans. Common fungal infections are ringworm, thrush and athlete's foot. It's been estimated that 1.6 million people die each year of fungal infections.

One parasitic fungus that has been brought to public attention in recent years is *Ophiocordyceps unilateralis*. You might know it as the zombie ant fungus. It is found in the rainforests of Thailand and Brazil and it is associated with only a few ant species. The spores of the fungus attach to an ant, germinate and force their way through the ant's exoskeleton into its body. As the fungus grows, it affects the ant's behaviour. It makes the ant climb up a stem and bite very hard into the vein of a leaf that's positioned just at the right height and position for dispersal of the fungus's spores. After a couple of days, the ant dies with its jaws still locked in place on the leaf. The fungus then produces a fruiting body. The ants bite so hard into the leaf vein that they leave a unique dumbbell-shaped mark on it. This distinct mark has been found on a 48 million year old fossil leaf. While this is a spectacular example, quite a lot of insect pathogenic fungi cause their hosts to climb to the top of plants before they die. Some glue them on, and some even cause their hosts to die just before dusk, as the high humidity they need to produce spores and infect new hosts sets in.

Some parasitic fungi spread their mycelium through the soil to move from plant to plant. One aggressive parasitic species, the honey fungus (*Armillaria solidipes*), can spread at the rate of up to one metre per year. The largest single living organism in the world is regarded by some to be a honey fungus that lives in Oregon, USA. It covers an area of about 8.8 square km, was estimated to weigh between 6,900 and 31,800 tonnes, and is thought to be between 2,000 and 8,000 years old.

Other parasitic fungi take advantage of damaged trees. They enter through wounds in the bark and proceed to eat away at the wood underneath, causing cavities to form. The external, living part of the tree may remain quite healthy despite having some quite large hollows in it. These holes become homes for many animals. In Australia, 86 mammal species, 111 birds, 78 reptiles and 29 amphibians are known to use tree hollows. About 100 of these species are now endangered, due partly to the removal of hollow trees.

Here's a twist. About 400 kinds of flowering plants and one conifer parasitise fungi. The plants may get only some of their food from their fungal host, or they might get all of it. The plants that are totally reliant on their fungal hosts often don't have well developed leaves (if they have leaves at all) and they have lost the ability to photosynthesise. Some of these plant species are orchids and we have a number of them here in Australia.



Erythrorchis cassythoides is a parasite of fungi.

Carnivorous Fungi

Some fungi take their search for food even a step further. They trap and eat tiny animals. More than 200 carnivorous species have been described so far. Carnivorous fungi live in nutrient poor soils or dead wood poor in nitrogen. They get some or most of their nutrients by consuming microscopic creatures such as nematodes – which are tiny worms, springtails - which are microscopic insect-like creatures, and amoebae. They have three basic trap types:

- constricting rings that squeeze shut when tripped;
- toxic structures which lure and paralyse;
- sticky structures that act like fly paper.

Saprotrophic Fungi

The great majority of fungi obtain their food from dead organic matter. I read somewhere that 80% of all fungi are decomposers – saprotrophs. Some endophytic and parasitic fungi are opportunistic and can change their feeding habits to saprotrophic after their host dies.

I mentioned earlier that plant cells contain cellulose and lignin in their walls. These organic compounds are very tough and resist degradation. Fungi are just about the only things that can break these compounds down. Some fungi species prefer feeding on cellulose and others prefer lignin. This causes two easily identifiable kinds decay.

Brown, or cubical rot, is caused by the breakdown of cellulose in the wood. As a result, the wood shrinks, turns brown and cracks into roughly cubical pieces. White rot fungi break down all components of wood – cellulose, hemicellulose and lignin, leaving a soft, spongy or stringy material, which converts to humus. Occasionally white rot fungi do not decompose cellulose and they cause pocket rot. The wood becomes soft, spongy, or stringy and its colour changes to white or yellow. Fossil evidence suggests that when fungi evolved to break down lignin many millions of years ago, the rate of coal formation slowed drastically.

Fairy rings may also be made by decomposer fungi. The fungal mycelium starts in the centre and grows outwards as it searches for food. In places like this (photo below) where there is an even distribution of nutrients, the mycelium grows into a circular shape. It can take a number of years for it to get this big. The fungus, depending on the species, can either kill the grass by starving it of nutrients or make it grow more lushly by providing it with nutrients. Some rings are visible even when they aren't fruiting just by the colour of the grass. Some fairy rings are huge – over 35 metres across.



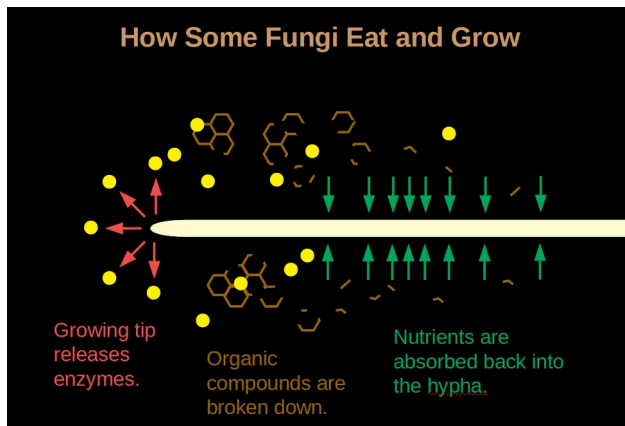
Mrs skippy Public Domain
https://en.wikipedia.org/wiki/Fairy_ring

OK, we don't eat wood, but fruit and veges can still be hard to digest. We need fungi to help us get the most from them. More than 100 different kinds of fungi live in the human gut. That might sound a lot, but it's really only just 0.1 percent of our gut microbe population – the rest are bacteria, viruses and other single celled organisms. However, without these decomposer fungi, a lot of plant nutrients would simply be inaccessible to us.

Needless to say, if we find gut fungi important, then herbivores are totally dependent upon them. Animals have been consuming plants with the help of their fungal symbionts for a very long time. Fossils have shown that plants were being eaten by arthropods about 410 million years ago. Four-legged animals probably started eating plants about 300 million years ago.

How Fungi Eat and Grow

So that's what fungi eat. *How* they eat is also related to how some fungi grow. This diagram illustrates the process used by a typical decomposer fungus.



As I mentioned earlier, the fungal organism is made up of a mass of tiny threads called hyphae. These hyphae grow through the fungus's food source, the substrate.

Initially, the nutrients in the substrate are locked away in large and complex organic molecules. The fungus has to break these molecules down into smaller parts before it can absorb them. The growing tip of each hypha releases enzymes into the substrate around it. The enzymes break down the complex organic compounds. As the tip grows forward, the part of the hypha behind it absorbs the nutrients from the now broken down or "digested" compounds.

Fungal Sex and Reproduction

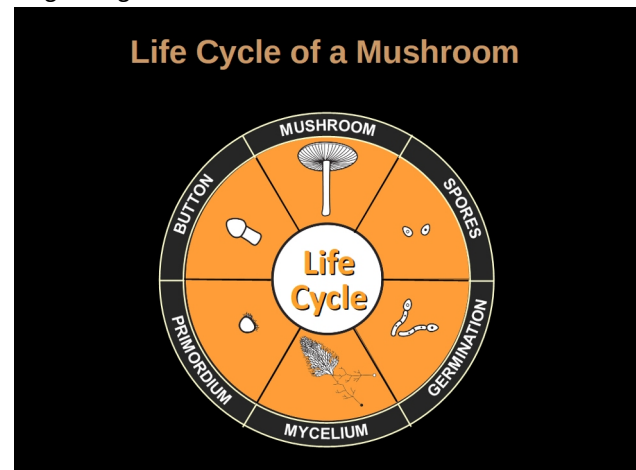
As they grow through the substrate, fungal hyphae are not only looking for food, they are also looking for a suitable partner to mate with.

More than one individual of the same species of fungus may be growing in the same area. Should their hyphae meet, and if they are compatible mating types, they fuse together and share their cell nuclei. Fungal mating types are akin to sexes, although there's no way to tell them apart by looking at them. Meeting isn't totally by chance. Hyphae secrete chemical attractants – pheromones – into the substrate.

Some fungi have only two mating types, but others have a lot more. *Schizophyllum commune* has 23,328 known mating types! Individuals of any type are compatible for mating with all but their own type.

The diagram below illustrates the life cycle of your typical mushroom. I've just covered fungal mating, so let's start at mycelium on the cycle. Compatible

hyphae mate and form a new mycelium that contains two sets of chromosomes. The mycelium grows and spreads. When the mycelium is mature enough and all other conditions are suitable, the fungus produces tiny nodules, called primordia, on the substrate surface. The primordium grows larger and becomes a button, which in turn expands into a mushroom. The fruiting body is more than 90% water, so it can expand very quickly. The fruiting body produces spores which are dispersed by air, water and animals. These spores contain only one set of chromosomes. If the spores land on a suitable site, they germinate and grow hyphae which search for food and a mate... and the cycle begins again.



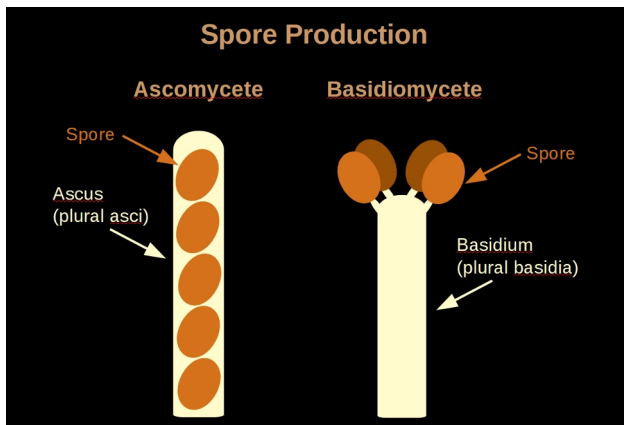
Fungimap. Adapted from: www.namyco.org/images/fungus_files/The_Fungus_Files.pdf Images by Ian Bell.

Fungal spores are tiny and can't be seen with the naked eye. Each species of fungus produces spores that are unique in size, shape and colour. To help make sense of the fungal kingdom and tell one species of fungus from another, mycologists look at spores as part of the identification process. (Mycologists, by the way, are people who study fungi.)

Mycologists also look at *how* the fungus produces its spores on its fruiting bodies. Some fungi produce their spores inside a special cell called an ascus. These fungi are known as ascomycetes. Other fungi produce their spores on the ends of special cells called basidia. These fungi are called basidiomycetes (see diagram on the next page). Most of the larger fungi we see in the bush are basidiomycetes. The so-called 'lower' fungi are even more diverse.

It gets more complicated. Some fungi have both asexual (anamorphic) and sexual (teleomorphic) forms that look very different and are often not found together. For that reason, the two forms were given different scientific names even when they could be associated together. DNA

sequencing has since allowed the different forms to be reliably matched as the same species and new rules require that both are given the one species name.



The fruiting bodies themselves come in many different sizes, shapes and colours. Again, to help identify the different species, mycologists group fungi by their different kinds of fruiting bodies and the structures they produce their asci and basidia upon.

- Fungi with gills are called agarics.
- Fungi with folds are called chanterelles. The folds might look a bit like gills, but they are much thicker and less even.
- Fungi with soft tubes and pores are called boletes.
- Fungi with very tough tubes and pores are called polypores.
- Those with pegs or spines on them are called toothed.
- And tough, leathery fungi with smooth reproductive surfaces are called leathers.
- Jelly fungi also have a smooth reproductive surface, but they are easily identifiable by their soft texture and gelatinous appearance.

The following fungi also have smooth reproductive surfaces, but instead of noting their texture, mycologists group them by their shape.

- Clubs are simple upright spikes.
- Corals have a few or many branches. Some look like tiny cauliflowers and others like the upright branches of trees.
- Icicles look like tiny icicles, hanging from their substrate.
- Cups are simple cups open at the top.
- Discs look like tiny flat discs or buttons.
- Pins have upright stalks with an uneven ball at the top.

- Oozes look like smears of grease or jelly.

Some fungi distribute their spores in some very unusual ways.

- Bird's nest fungi look like tiny cups with eggs in them. The fungus's spores are inside the "eggs" which are flicked out of the cups when they're splashed by raindrops.
- Puffballs and earthstars also use raindrops to spread their spores. The fruiting bodies act like tiny bellows when raindrops hit them, puffing out their spores through an opening at the top.
- Earthballs crumble away, exposing their mass of spores to the open air.
- Stinkhorns have been grouped together because they all, well, stink. Stinkhorns produce their spores in a smelly slime that attracts insects. The slime sticks to the insect and is carried away to a new location, similar to how flowers use insects to spread their pollen. Their fruiting bodies can have some very strange shapes.

A lot of fungi that fruit underground also use insects and other larger animals to spread their spores.

True truffles are the edible species from the northern hemisphere (most famously Europe) that are highly prized delicacies. Other underground fruiting fungi are sometimes called "truffle-like" to distinguish between them, but are also commonly just called "truffles". Australia is very rich in truffle-like fungi. They look like puffballs, but they form underground.

Brackets look a bit like shelves or fans. They can be quite large or small and they may be only a single shelf or composed of many rows of shelves growing in tiers along the substrate – usually on tree trunks and logs. Brackets can be agarics, polypores, leathers or even toothed jellies!

Crusts are fungi with flat fruiting bodies that lie close to the surface of their substrate. They are also called paint or patch fungi. These fungi are usually leathers or polypores.

By the way, the largest single fruiting body in the world is a crust. It is also a polypore and a decomposer species. It is located on Hainan Island, China. When it was found in 2010, it was over 10 metres long and its estimated weight was between 400 and 500 kilograms. It was thought to be about 20 years old at the time.



The world's largest fruiting body is a crust. Dr. Bao-Kai Cui
 CC BY-SA 3.0 https://en.wikipedia.org/wiki/Phellinus_ellipsoideus

Diseases of Fungi

Fungi, just like plants and animals, are susceptible to a large range of diseases. Mycoviruses make an infected fungus grow more slowly, be malformed, fruit less, produce fewer spores and those spores have less a chance of germinating. Bacteria can also infect fungi and are responsible for deformities and rot. There are also fungi which infect other fungi. Some of these fungi start out as parasites that don't harm their host, but in a later stage of the relationship, they turn nasty and become mycopathogens. Finally, an unhealthy environment can cause diseases. Rosecomb gill is a deformity that can be caused by diesel fumes.



Rosecomb gill, a disease caused by pollution.

Other Dangers

When you think about it, fungi are very vulnerable. They can't run away from danger. The only thing they can do is stand and fight. They use chemicals to get their food and to stave off competing fungi, so it's only a natural step for them to use a chemical arsenal to protect themselves against pathogens and parasites. Several of these chemical compounds are even toxic to plants and large animals. They are called mycotoxins.

I've already mentioned the death cap as a poisonous species. It's deadly to humans and is responsible for the majority of fatal mushroom poisonings worldwide. However, other creatures, such as slugs and many insects and their larvae, find them quite harmless.

Some fungi produce chemicals that do other things, like glow in the dark. We don't know why they do this. It might be to attract grazing animals such as insects to help spread their spores. Or it might be to scare fungi-eating creatures away. Or it might simply just be a beautiful side-effect of the chemical processes these fungi use to feed on wood. What we do know is that over 75 species have this ability, all are white rotters and all but one are mushroom-forming agarics. The light is greenish in colour and may be produced in the cap or in the mycelium. It only occurs in living cells and it is continuous – so they still glow in the daytime, we just can't see it. Bioluminescent fungi live in temperate to tropical parts of the world. We are lucky that we have a couple of different species here in Southeast Queensland.



Mycena chlorophos, Springbrook National Park.

Death

Like all living things, fungi also die. Cause of death may be malnutrition or starvation, dehydration, disease, poisoning, predation, terminal injury or simply old age.

We don't know how long most fungi live. The lifespans of fruiting bodies are most likely to be much shorter than those of the organism that produced them. Remember, they are like the apples on a tree, not the tree itself.

A fruiting body being eaten can be a good thing for the fungus. Its spores will most likely be distributed away from the fungus, possibly with a generous dose of fertiliser.

Many different kinds of creatures eat fungi. These include mammals, birds, reptiles, fish, insects,

slugs and snails, bacteria and, as I mentioned earlier, even other fungi. Some are occasionally mycophagous, while others are specialists. Reindeer are well known for surviving on lichen during the harsh northern hemisphere winters. They also like to eat mushrooms in late summer. In Australia, about 90% of potoroo and bettong diets consists of truffle-like fungi. Fungi are also an important part of the diet of cassowaries. And of course, many smaller creatures eat fungi too. How many times have you turned over a wild mushroom to find it riddled with all sorts of slugs, grubs and bugs?

Some insects such as beetles, termites and ants have learned to farm fungi. Over 200 species of ants farm fungi and the most well-known would be the leaf cutter ants of South America. These ants carefully cultivate fungi in their underground colony. They feed the fungi with freshly cut plant material, remove any waste and try to keep it free of dangers such as pests and infection. These ants and the fungi they farm are totally dependent upon each other. It is a very old relationship thought to go back 45 million years, possibly even more.

Did you know that a snail also farms fungi? The snail lives in the marshes of southeastern United States where it deliberately damages grass blades to encourage fungal growth. It even deposits faeces in the wound to feed the fungus. Experiments have shown that snails raised on uninfected leaves don't grow and are more likely to die. So the snails have become dependent on the fungus.

Why do we need fungi?

Again, we have a simple answer. We need them because plants and animals need them.

Plants need fungi because:

- Fungi bind the soil together and prevent erosion.
- Fungi decompose organic matter so nutrients are released back into the soil.
- Some plants have a partnership with fungi from which they mutually benefit.
- Some plants use fungi as their sole source of nutrients.

Animals need fungi because:

- Herbivores eat plants that need fungi.
- Predators eat herbivores and so indirectly need fungi.
- Fungi make nutrients available for animal consumption, either into the soil or into guts.
- Some animals eat fungi.

- Fungal decay makes holes in trees that become homes for some animals.
- Some animals live inside fruiting bodies.

For a very long time, we humans would have needed fungi for much the same reasons as other animals. We then began to use them for other things. Some time in the distant past, we began to use them for heightened recreational or religious experiences, for medicines to make us feel better and dyes to make our possessions look nicer.

About 10,000 years ago, we discovered how to use yeast to bake bread and make beer and other fermented drinks. A little later came cheese, wine and wine vinegar.

A 5,300 year old frozen body found in the Alps, dubbed Ötzi the Iceman, had some fungi with him when he died. Two pieces of medicinal polypore were tied to one of his wrists and his fire-starting kit contained another polypore that was used as tinder.

By Roman times, bread, cheese and wine making were well developed industries. The ancient Romans also loved eating mushrooms. They possibly knew how to cultivate them and we do know there was a big trade in truffles from Africa. For the Romans, wine wasn't just a pleasant beverage. It was also the base ingredient for many medicines.

The Romans also applied mouldy bread to wounds to fight infection and poisonous mushrooms were used more than once for political gain.



Ancient Roman floor mosaic Mark Cartwright CC BY-NC-SA 3.0 <https://www.ancient.eu/image/4463/>

We still use fungi for food and medicines, but since we've learned how to extract specific chemicals from them, our uses have become a lot more sophisticated. Over 100 fungal enzymes are used commercially.

- We use them to make flavourings and preservatives for our food.
- We use them to make vitamins to boost our health, antibiotics to control infections, statins to lower cholesterol, and other drugs to prevent organ transplant rejection and to fight cancer.
- They are also ingredients in our toothpaste, cosmetics, laundry detergents and bleaches.
- We are finding ways to use parasitic fungi to control weeds, plant diseases and insect pests. Special strains of mycorrhizal and endophytic fungi are being developed to help make our crops more robust.
- Some decomposer fungi can degrade pesticides, solvents, dyes and even explosives. White rot fungi are very good at removing toxic organic compounds such as oils from the soil. They also have a huge potential for turning our agricultural wastes into biofuels.
- Research is being done as to how we can use mycelium as building materials, packaging and clothing.

As more research goes into fungi, we are finding more things we can do with them. Every day new species are being found with potentials yet undreamed of.

How can we look after them?

I don't need to tell you that species all over the world are becoming extinct because of the pressures we humans are putting on them. Sadly, that also includes fungi.

Protecting the Great Barrier Reef, or saving the whales or a rare and beautiful orchid are all equally noble causes and generally accepted, but mentioning that you also want to save the mushrooms tends to raise a few eyebrows. Fungi are just as important and in their own ways are just as vulnerable.

So what can we do? If you think about it, most of it is just common sense. Like us, fungi need clean air and water, good food, good friends and a safe place to live in.

- We need to protect them from the overuse of fertilisers and fungicides, not only in agriculture and forestry, but in our own gardens as well.
- We need to think about how much we dig the earth over in our forests, farms and gardens.
- We need to protect the plants and animals that interact with them and are a part of their lives.
- And we need to conserve where they live – the forests and wild places. Microhabitats are also very important to preserve, such as a patch of leaf litter in your garden or a fallen tree in a park.
- And then there's the big one, climate change. That just affects everything.

Finally, we need to learn more about fungi. Not only about all those undiscovered species, but the ordinary common species as well. So much of what they are and what they do is so poorly understood. All around the world there are organisations, large and small, professional and non-professional, all dedicated to mycology.

So what can you do?

The next time you come across a fungus, stop a moment to look at it. Think about what I've said. If you are with someone, point it out to them and talk about it.

Spread the word.

Fungi truly are amazing things and we really *can't* live without them.