FUNGI FORAGERS

No. 15, June 2019

OUR PURPOSE: TO RAISE AWARENESS AND INTEREST IN FUNGI OF THE CAIRNS REGION

This newsletter is not associated with any club or organisation but is emailed free of charge to anyone who may be interested. Anyone who wishes to contribute to the newsletter with observations, anecdotes, corrections, comments or photographs is welcome to do so. Although this "newsletter" is science-based we try not to make it too "scientific". We recognise that there are school children, bush-walkers and others just interested in fungi, and we hope this leaflet will become a medium for furthering that interest. **The emphasis is on fungal biology and ecology** rather than identification.

Barry Muir, Editor Jenn Muir

BEENAKIA aff. *FULIGINOSA*: A NEW FUNGUS RECORD FOR NORTH QUEENSLAND

By Peter Newling

Beenakia fuliginosa (Order Gomphales) has only been found previously in Africa (Zambia) and India on living host trees. In India it has been recorded on the trees *Shorea robusta* (Family Dipterocarpaceae) and in Africa on *Lannea antiscorbutica* (Family Anacardiaceace). It has now been confirmed in tropical Australia in the Cairns Region in association with Candle Nut *Aleurites moluccanus* (Euphorbiaceae) on or near standing living trees.

Based on what I have seen in the field, *Beenakia* aff. *fuliginosa* (it has no common name) is a saprophyte (decomposer). Under one tree at Stoney Creek, Cairns, it has been fruiting for three consecutive years and the tree seems to be unaffected. The fungi emerge at the base of the *Aleurites* tree or nearby rocks, or any vegetation near the subterranean roots of the host tree. All the "host" trees are situated in seasonal water courses or soaks. The surface of the fungi is very moist, much like a "wet sponge", and may persist long after the last rains and are often the only fungi found, suggesting the fungal hyphae may be located deep underground possibly in the root system of the host tree.

I first photographed the fungus in Smithfield Conservation Park in February 2009. It has velvety, bracket-shaped fruiting bodies 5-8 cm wide and are often joined into larger white to pinkish semi-translucent masses. The underside is covered in spines. It was originally identified by Dr Bruce Fuhrer as *Beenakia* sp. in 2009. Recently it was formally identified by Dr Matt Barrett, a mycologist based at James Cook University, Cairns as *Beenakia* aff. *fuliginosa*

Upper surface of fruiting body of *Beenakia fuliginosa* near *Aleurites* tree. Stoney Creek, Kamerunga (Cairns).

The *Aleurites moluccanus* Candle Nut tree is found naturally occurring in Asia and the Pacific Islands and is also a common, widespread and fast-growing tree in North Queensland's Wet Tropics. The timber is not durable and, once on the ground is fully decayed in approximately 12 months. The bark often persists longer than the wood. The tree can obtain heights in excess of 20 m and is vulnerable to damage from winds. This causes long-term, sometimes fatal, damage to the base of the tree. This vulnerability, combined with the soft properties of the timber, provides an opportunity for saprophytic fungi like *Beenakia fuliginosa* to become established. Although commonly seen on *Aleurites moluccanus,* there may be other host trees in North Queensland as, based on global records, this seems to be a very adaptable fungus.

Fruiting body at base of standing *Aleurites* tree, Cheepi Creek, Redlynch Valley (Cairns). The spines on the underside are clearly visible.

Damage to the base of an *Aleurites moluccanus* tree which was growing on a rocky wind-prone slope. Such damage predisposes the tree to fungal attack. Large amount of woody debris can be seen under the compromised wound.

The following technical information is provided to facilitate anyone wishing to do further research.

Beenakia fuliginosa (Maas Geesteranus) Parmasto & Ryvarden, Windahlia 18: 39. 1990 = *Psathyrodon fuliginosus* Maas Geest. Kew Bull.31: 417. 1977.

Basidiocarps 5-8 cm wide and long, stipitate to dimidiate, often fused into larger, more compound structures, individual pilei up to 2 cm wide, upper surface white to pinkish translucent when fresh, drying greyish brown to dark ochraceous, tomentose to velutinate and soft when fresh, hispid to scrobiculate or even finely crested in parts when dry, azonate, stipe, if present, strongly expanding towards the pileus and covered with spines almost to the base, up to 2 cm long and 5 to 12 mm in diameter in the sterile part, white when fresh, cream coloured to ochraceous when dry, hymenophore hydnoid, spines crowded, white when fresh, ochraceus when dry, simple, occasionally forked, 1-3 mm long, round to slightly flattened in parts, context white to faintly olivaceous with some darker, fuscous zones, soft and fibrous, homogeneous, up to 1 cm thick at the base. Hyphal system monomitic, generative hyphae with clamps, hyaline, 3-9 u.m wide, not conspicuously inflated, partly covered with rounded warts in the spines, not dissolving in KOH. Cystidia absent.

Basidia 20-30 x 5-8 mm, clavate and with a basal clamp. Basidiospores 6-7(8) x 4-5 mm, oblong ellipsoid to slightly pip-shaped, thin-walled, finely warted, hyaline to faintly coloured in mass, cyanophilous.

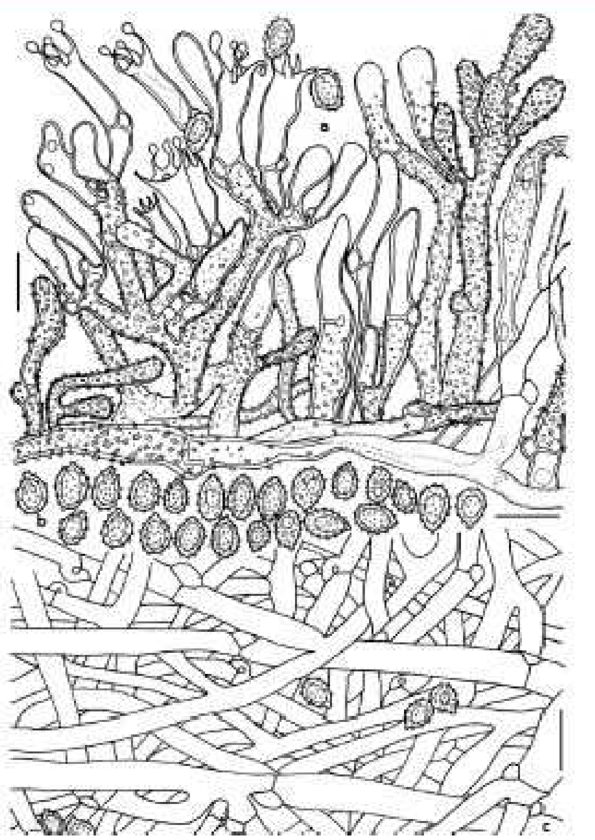


Figure 2. *Beenakia fuliginosa*. a - section through the hymenium showing basidia; basidioles, basidiospores and incrustation on subicular hyphae; b - basidiospores; c - interwoven hyphae in context; Scale bars: a–c = 10µm

Diagram from: Hembrom, M.E., A. Parihar & K. Das (2016). Three interesting wood rotting macro-fungi from Jharkhand, India. *Journal of Threatened Taxa* 8(2): 8518–8525; http://dx.doi.org/10.11609/jott.2133.8.2.8518-8525

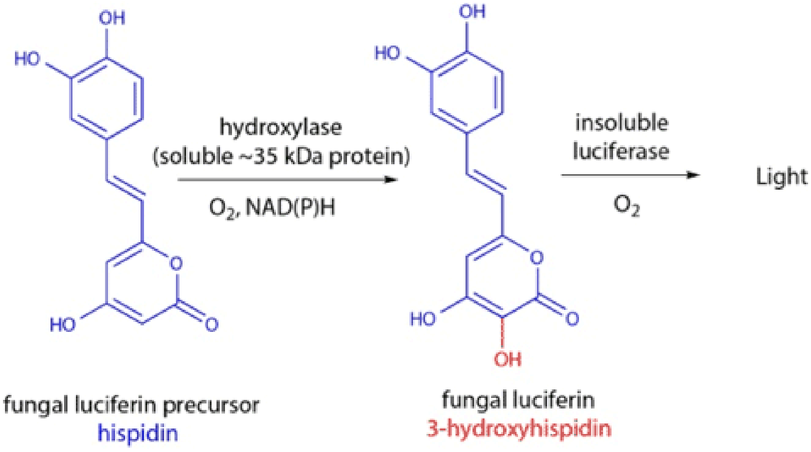
FUNGAL LUMINOSITY: WHAT IS IT AND HOW DOES IT WORK?

by Linda Reinhold

Editors note: in Cairns Fungi Foragers (No. 14 April 2019) we published Linda Reinhold's paper "In Search of Foxfire Fungi: the Glowing Forest". In this article Linda provides more information on that amazing phenomenon.

Bioluminescence (light emission) is a chemical process that has evolved many times in many types of organisms, employing the light for a dozen different uses. It is harnessed by creatures both flitting through forest canopies and in the darkest depths of the ocean. The ability to bioluminesce, or to harness other organisms that can, is evidently useful, being so popular that the majority of deep-sea creatures use the feature. It makes sense that light-emitting organisms can see their own light, yet it has also evolved in algae and fungi. Higher plants have only been made luminescent by scientists transplanting them with genes from marine bacteria.

Bioluminescence comes in several colours; in the sea it's often blue or bluish-green; the glows of fireflies and a land snail are yellowish; there's even a larval beetle, known as a Railroad Worm, whose body glows green and whose head glows red! The luminescence of fungi is greenish, at a wavelength of 520–530 nm although it may appear more bluish to the human eye. Bioluminescent fungi are found on all continents that have tropical and temperate climates and there are more than 100 species of fungi in which some part of their structure glows. In some species, the mycelium glows but not the fruiting body, and vice versa. In others, both glow. Different parts of the fruiting body, or just the spores (as in the Slippery Mycena found in Russia), may glow. Significantly, they are all white-rot wood-decay fungi that break down the lignin in wood, a unique ecological role not shared by other bioluminescent organisms. For a discussion of white-rot fungi see CFF No. 13 Feb. 2019 pages 6-8.



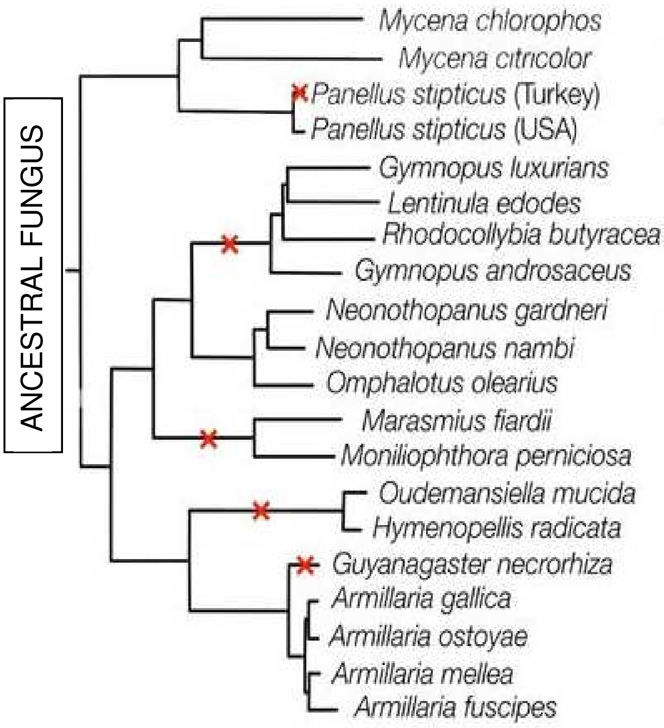
Luminous fungi produce a heatless light using a biological chemical reaction. The cells must be *living* to emit light. All bioluminescent organisms create their light using a chemical reaction whereby a substance called luciferase (any of several slightly different enzymes) acts on a chemical called luciferin (any of several small organic molecules) and oxygen. This produces unstable chemical intermediates, which, during break-down lose their excess energy as visible light. The luciferin is recycled, so the light continues indefinitely if there is oxygen present. There are probably more than 30 different bioluminescent mechanisms operating in various organisms.

Four lineages of fungi (*Armillaria*, *Lucentipes*, Mycenoid [species similar to *Mycena*] and *Omphalotus*) of the fungal order Agaricales (Basidiomycota) have bioluminescence, along with one ascomycete of the order Xylariales (Ascomycota) found in Costa Rica. Fungi probably colonised the land during the Mesoproterozoic Era, about one to one-and-a-half billion years ago, well before the woody plants that modern fungi rely on. The Basidiomycota and the Ascomycota diverged anywhere from less than half a billion to one-and-a-half billion years ago. If fungi's ability to make light results from the breakdown of lignin, then fungi would not have been able to start glowing until the appearance of the first plants with lignin about 425 million years ago. They may have "cut their teeth" on ferns before moving onto conifers and flowering plants. In any case, fungal luminosity may not have conferred any advantage until the first insects evolved, a bit less than half a billion years ago around the first estimate of the Basidiomycota/Ascomycota split.

New research tells us that fungal bioluminescence evolved more than one hundred million years ago. Its evolution came about through stepping-stone non-luminescent biochemical reactions. The primary enzyme was formed through a gene duplication at the Basidiomycota split, then other enzymes evolved a few million years later. Gains and losses in the long evolutionary pathway eventually resulted in the right combination for chemical reactions to create bioluminescence. After acquiring bioluminescence, the Basidiomycota lineages continued to evolve, with several independent gene loss events leading to secondary losses of bioluminescence.

The gene involved in the recycling of fungal bioluminescence possibly appeared twice in the non-mycenoid mushrooms. This evolutionary mosaic may mean that the advantage of fungal bioluminescence is ecologically transient, depending on and adaptable to the environment going on around it.

Both biochemistry and genetic research suggest that bioluminescence evolved only once in Kingdom Fungi, with a single glowing fungus ancestor. As to where the luminescent Ascomycota fungus fits in has yet to be studied.



We can only imagine fungal luminosity came into existence when a primitive fungus stumbled upon the particular chemical pathway to break down the lignin in wood, and the light it emitted was attractive to primitive insects, which spread the spores about. Thus, that particular fungus became more numerous, even if its internal chemical processes were clumsy. The system worked, so the fungi that used it had no pressing reason to use an alternative non-glowing mechanism. The initial glowing would probably have been an accidental by-product, but it spread because it happened to give an ecological advantage. Whatever trait makes an organism become more numerous in its environment will survive and multiply.

The common ancestor of all bioluminescent Basidiomycota species appeared first (left hand side of diagram). Branches of the tree that eventually **lost** bioluminescence are marked by crosses.

In the north-west of USA, "mushroamers" admire luminescent fungi in the autumn rains. The famous glowing mushrooms of Japan appear in the rainy season, in their summer. Luminous fungi in the Australian tropics, too, reportedly glow in the wet season, in summer and into autumn. In the southern states of Australia, the Ghost Fungus glows after good rain a little later, in late autumn/winter. One study noted that the luminosity of *Neonothopanus gardneri* in Brazil (an Agaric and the sister taxon to our own *Neonothopanus nambi*) depends greatly on the size and age of the mushroom, and on humidity, with optimal conditions being "night time following a hot day with an afternoon rain storm and a light evening/night breeze", conditions which also occur in the rainy season around Cairns. Other researchers point out that tropical Australia is a particularly good place to see luminescent mushrooms, with a variety of species. Research into the evolutionary tree, however, found the primary enzyme in fungal bioluminescence loses its activity at temperatures above 30°C, which has implications for us here in the tropics.

These researchers also note that all luminescent mushrooms emit light 24 hours a day. There are certainly reports of people picking a mushroom and having it glow in a dark cupboard in the daytime, meaning they glow *all the time*. But there have been conflicting reports of whether other mushrooms glow *only at night*. This point is important as to the purpose of glowing: if fungi are found to glow all the time, then the emission of light could be considered a mere by-product of breaking down wood. Alternatively, it may confer an evolutionary advantage but may not be that expensive energy-wise to produce, so there's no point in switching the light off in the daytime. If fungi were found to glow only at night, it could be reasoned that they have retained and harnessed the ability to bioluminesce because nocturnal insects, etc., attracted to the light disperse their spores. The chemical reaction of bioluminescence provides some antioxidant protection, which may be enough of an advantage in itself. But if bioluminescence gave a stronger evolutionary advantage to fungus, it should be more common.

Environmental conditions such as pH (wood acidity), light and temperature, that affect the growth of fungi, have also been found to affect bioluminescence, meaning fungal bioluminescence could be tied to biological activity. Some researchers think the theory of fungal bioluminescence being solely a mere by-product of wood breakdown is seeming less likely, especially since the discovery of the specific chemicals luciferin and luciferase, and recent insights into the daily timing cycle of glowing.

Whilst fungi can't flash their bioluminescence on and off like some other organisms (such as fireflies), at least some species can vary their bioluminescence in a rhythm. Researchers in Brazil brought bioluminescent fungi into the laboratory and after adjusting the mycelium on agar plates to a 12/12 hour light/dark cycle, recorded them peaking their brightness after about 10 hours of darkness. The fungi kept glowing through the artificial daytime, but with much less brightness than at night. Their brightness peaked after the bioluminescent components had reached maximum intensity (with a 3 to 4 fold amplitude) in their daily cycle. The light intensity was *maximised* at night. Thus, they minimise the wastage of energy that could occur if the intensity of glow was maintained continuously. Fungi, therefore, have some *control* over their brightness. As to why the *mycelium* in the laboratory study glowed to a cycle is not as readily explained as why the fruiting bodies of a species would control their glow. Perhaps the glow of the mycelium warns off grazing animals. Fungi only want to attract small spore-dispersing insects, not herbivores like snails and slugs. Ideally, smaller spore-dispersing animals would see the green glow as an attractant, and larger destructive animals would see it as a deterrent, and maybe this holds just enough on average to make a difference. Different species may glow for different reasons, depending on which part of the fungi glows. Maybe mushrooms glow to attract, and mycelium glow to repel?

The researchers in Brazil also placed artificial green LED-lit replica mushrooms into the forest. The decoy mushrooms had a size, emission spectrum and intensity of luminescence equivalent to typical fruiting bodies of *Neonothopanus gardneri*. These "robo-shrooms" attracted a range of insects, just like real mushrooms. All the insects found were from groups capable of seeing green light, known because of the types of colour receptors across their retinas. The insects included staphylinid (Rove) beetles, which are common amongst the gills of our fungi glowing around Cairns. Particularly in dense forests, where the humidity is high and there is little wind, mushrooms that can disperse spores via nocturnal insects could have an advantage.

A battery-operated "robo-shroom" glowing in the forest.

Fruit-bodies of the Ghost Fungus, *Omphalotus nidiformis*, in the south of Australia glow both day and night in natural conditions. The mycelium does not glow. This research was conducted during the winter (with night time temperatures around 6°C) when the Ghost Fungus was glowing but there were less insects around. Field trials using actual luminous fruiting bodies and sticky traps found insects to **not** be attracted to the glow. The researchers concluded that spore dispersal is not achieved via the attraction of insects and is not related to bioluminescence in that species. However, beetles have been observed gathering on the same species glowing further north.

Perhaps such fungi originated in the tropics, but as they spread to temperate regions they lost the association with tropical insects, but kept the ability to luminesce because they were not compelled to lose it. In South Australia, Ghost Fungus grows in open woodland, so would be more able to have its spores dispersed by wind than in our glowing tropics, so perhaps spore dispersal was affected by wind more than insects as the species spread. This makes earlier observations that the Ghost Fungus doesn't glow in the tropics even more puzzling. Some fungi can vary the expression of brightness within a species, meaning they may use brightness "as required" in different environments. We know that for the Ghost Fungus, it has different colour forms which vary in how much of the fruiting body glows within the same species. Perhaps in some forests a fungus wants to stand out and be noticed, and in other forests with different insect fauna it is more prudent to keep dark and save energy. There are many species and geographic differences which are only just being discovered.

WHAT IS GLOMALIN?

In a recent article (CFF No. 13 February 2019 pp2-5) about the benefits of organically farmed soil we mentioned that soils with higher carbon content stored more moisture. The mechanism for this is glomalin, a sugar-protein that was only identified and named in 1996. It was discovered by Sara Wright, a scientist at the United States Department of Agriculture (USDA) Agricultural Research Service. Later studies by American researcher Kristine Nichols found that glomalin levels were higher in soils under native grasses than soils under introduced grass species, and that moving cattle before they over-grazed an area helped to restore soil glomalin levels. Her cropping study found that cultivation of the soil and leaving crop areas unfarmed (fallow), lowered glomalin levels because cultivation destroyed the hyphae, and fallowing starved them. Glomalin takes 7 – 42 years to biodegrade and is thought to contribute up to 30 percent of the soil carbon where mycorrhizal fungi are present. The highest levels of glomalin found naturally were in volcanic soils of Hawaii and Japan. When mycorrhizal fungi are eliminated from soil, for example in grasslands treated with fungicide, the glomalin declines. In fact, glomalin is so good at trapping carbon it is being investigated as an "absorbent" to extract carbon dioxide from the air.

Glomalin is produced by mycorrhizal fungi that live inside plant roots and extend hairlike filaments or hyphae into the surrounding soil to obtain more nutrients. The sticky glomalin proteins sit on the hyphae like small globs of chewing gum. Together, the hyphae and glomalin form a sticky net that traps particles of sand, silt, clay and organic matter and holds them together to form lumps or aggregates of soil.

On the surface of these lumps or aggregates, the glomalin forms a waxy coating to stop water pouring into the aggregate and breaking it up. Aggregates are important in soils because they allow water to filter in, hold water for plant use, and provide organic carbon for soil organisms to feed on. At the same time, the aggregates also store carbon deep inside the aggregate where bacteria cannot access it, yet "tie" the soil together and reduce erosion.

Glomalin has other benefits as well. It coats the fungal hyphae to protect them from decomposition and bacterial attack and thus ensures that water and nutrients reach the host plant. Scientists are now thinking that glomalin also helps hyphae stay rigid enough to extend into the soil and span the air spaces between soil particles. So how do you know how much glomalin is in your soil? Basically, the more you have, the better your soil texture and structure. If you'd like to read more about glomalin and Kristine Nichols' work go to www.ars.usda.gov/Research/docs.html

Text partly extracted from Wikipedia and other sources

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