FUNGI FORAGERS

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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

Field meetings to find interesting species of fungi (not necessarily edible species) are known as 'forays', after the first such meeting organized by the Woolhope Naturalists' Field Club, Herefordshire, England, in 1868 and entitled "A foray among the funguses" [*sic*]. The Woolhope Club was an early member of the British Mycological Society founded in 1896. (Wikipedia)

BIRDS AND TREE HOLLOWS – THE ROLE OF FUNGI

Many young people today consider us oldies as a waste of space. It is the same attitude applied to elderly trees by farmers, councils and foresters who just don’t see the value of hollows in tree trunks and branches and cut the trees down as firewood, for “aesthetics”, or for real or imagined public safety.

This attitude ignores that over 300 native mammals, birds, reptiles and frogs **in Australia alone** use tree hollows (Gibbons & Lindenmayer, 2002). Approximately 13% of all terrestrial amphibians, 10% of reptiles, 15% of birds and 31% of mammals may at some time use tree hollows as a resource. It is estimated there are 303 native hollow-using species on the continent, or around 15% of all terrestrial vertebrate species, with an additional 10 introduced species that also use hollows (Gibbons & Lindenmayer *ibid*).

Elliott *et al.* (2019), working in North America, have shown that birds form varying levels of associations with fungi for cavity excavation. However, unlike North America, there are no primary excavators in Australia (e.g., woodpeckers) and most Australian bird species lack the anatomy and behavioural repertoire to excavate hollows in hardwood trees (Saunders *et al.,* 2014). Consequently, the fauna rely almost entirely on other producers of hollows, such as fungi.

Most living wood contains antifungal compounds that prevent fungal decay, but the heartwood of trees is effectively ‘‘dead’’ and does not produce these same chemical defences found in the sapwood. If the outer bark (which serves as a protective barrier) is broken by an injury, saprotrophic (decay) fungi may enter through the wound and begin to break down the sapwood and heartwood. Using specialised enzymes, these fungi typically break down the lignin and cellulose in the wood and cause it to become soft.

Decay can be restricted by the living tree to small areas, and the trees can live for decades or longer after being infected with decay fungi and serve as important habitat for a variety of animals. It is advantageous for cavity-dwelling animals to have sturdy live wood as the exterior of their cavities instead of excavating hollows in highly decomposed dead trees; strong exterior wood helps to prevent predators like native or feral cats and black rats from gaining access into cavities and reduces the chance of trunk breakage in periods of high wind.

Hollow formation is dependent on a tree's history, its species and environment. Small hollows with narrow entrances suitable for Pardalotes may take about 100 years to form. Hollows of a medium size and suitable for parrots may take around 200 years and the larger and deeper hollows occupied by Black Cockatoos and Sooty Owls, for example, may take much longer, perhaps up to 400 years (NPNSW 2009). Mountain Ash trees (*Eucalyptus regnans*) from the Victorian Central Highlands, for example, don't even **begin** to develop cavities for approximately 120 years, emphasising the vital need to preserve old-growth forest (Rogers 2019).

Features of white and brown rot

	Chemistry	Color	Texture	Other
White rot	All wood components removed, either simultaneously or lignin preferentially, in early stages	Generally white, but can be yellowish to reddish brown	Varies: spongy, stringy; some types are called laminated, pitted, or pocket rot based on texture/appearance	Texture types vary among white rot fungi; some produce zone lines in wood; there may be mats or rhizomorphs; pocket rots may have black flecks in pockets
Brown rot	Cellulose and hemicellulose chains broken early, then removed; lignin remains	Brown, often with a sheen on split surfaces early on	When advanced, wood shrinks with cubical checks and can be crumbled to a powder	Decay is fairly uniform; some fungi produce white mats or felts or wispy fine cords in checks, causes **rapid** strength loss

Main fungal decay types and their characteristics. A third type, Soft Rot, decays everything

In inland environments River Red Gum (*Eucalyptus camaldulensis*) is a well-known hollow producer, as is shown in many Hans Heysen and Albert Namatjira paintings. Similarly, eucalypts in sub-tropical rainforest or in drier rainforest contain hollows, but, overall, tropical rainforest trees are poor in hollows (Gibbons & Lindenmayer 2002), so those that do occur are if enormous value to fauna.

It has been suggested (Parfitt *et al.,* 2010) that all or most trees have wood decay fungi present in sapwood and that development of a particular fungus is regulated by environmental factors. In other words, many trees may "carry the seeds of their own destruction" and that decay only commences in earnest when the wood is damaged, such as might occur with storms, parrots tearing bark or scraping of bark from standing trees when nearby trees are felled by logging.

An Australian Ringneck Parrot (*Barnardius zonarius*) about to enter its nest hollow in a large River Redgum (*Eucalyptus camaldulensis*) tree. Pic Jenn Muir

Fungi are often the instigators of tree hollows because they soften the wood, allowing insects to burrow and for birds and mammals to renovate the hollow using beaks, teeth or claws.

Fungal diseases, sometimes called heart rots, sap rots, or canker rots, decay wood in tree trunks and limbs. Under conditions favouring growth of specific rot fungi, extensive portions of the wood of certain species of living trees can decay in a relatively short time. In the long-term, decay fungi reduce wood strength and may kill storage and conductive tissues in the sapwood, making it easier for animals to excavate but sometimes making infected trunks and limbs unable to support their own weight and fall, especially when stressed by wind or heavy rain. A 10% loss of wood weight can result in 70 to 90% loss in wood strength. This may open up hollow branches that were previously inaccessible to wildlife.

Decay fungi can destroy the living (sapwood) or the central core (heartwood) part of the tree. Decay isn't always visible on the outside of the tree, except where the bark has been cut or injured, when a cavity is present, or when rot fungi produce fruit bodies. These fruiting bodies take several forms, depending upon the fungus that produces them, but most of them are mushrooms, brackets or conks (fruit bodies shaped like horse's hooves). The mushrooms are short-lived, but the brackets and conks are long-lived and can be used as indicators that the tree is damaged by fungi and may have hollows that otherwise are not readily apparent. Bird watchers search for fungal brackets or conks high up in trees because there may be inconspicuous hollows nearby.

There are three types of fungi that benefit birds in these ways.

- TYPE A…..Primary role is in **making nest hollows** in trees (three types; Brown Rot, White Rot and Soft Rot fungi – each decays wood in a specific manner)

- TYPE B…..Important in **nest cleanliness**. They decompose droppings and consume shed feathers and waste food. Some nests are notoriously filthy – e.g., Buff-breasted Paradise Kingfisher (Muir JH 2021).

Sporocarps of a Type B fungus growing on the inside wall of a Buff-breasted Paradise Kingfisher nest in a termite mound. Source unknown.

- TYPE C…..Have **antibiotic effects**. The fungi produce gases, vapours and exudates that are toxic to viruses, bacteria, other fungi, some mites and insects. These fungi are mainly transported by mites on birds or by nest flies.

These latter fungi "sterilise" the hollows, reducing skin or feather parasites to the advantage of the occupants. In return, the fungi are spread as fragments or spores being transported to new hollows or to branches or trunks where they may be dopped by the animals and provided with new habitat in which to develop.

In other words, there is strong evidence that there is a symbiotic (mutually cooperative) relationship whereby the birds benefit from the fungi and the fungi benefit by dispersal and by consuming animal waste in the nest cavities.

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FUNGI AND BIRD EVOLUTION

The skin and feathers of birds support many fungi, mostly harmless, but some that damage the feathers - called keratinophilic fungi because they consume keratin, the main protein that makes up the feathers. There are also fungi that may prevent or distort feathers as they grow out of the bird's skin. These fungi also consume keratin, but mostly the softer keratin of which bird skin, and ours, are constructed. Humans also have dozens of species of keratinophilic fungi that live on our skin, but it is not until they become troublesome, e.g., tinea, that we notice them.

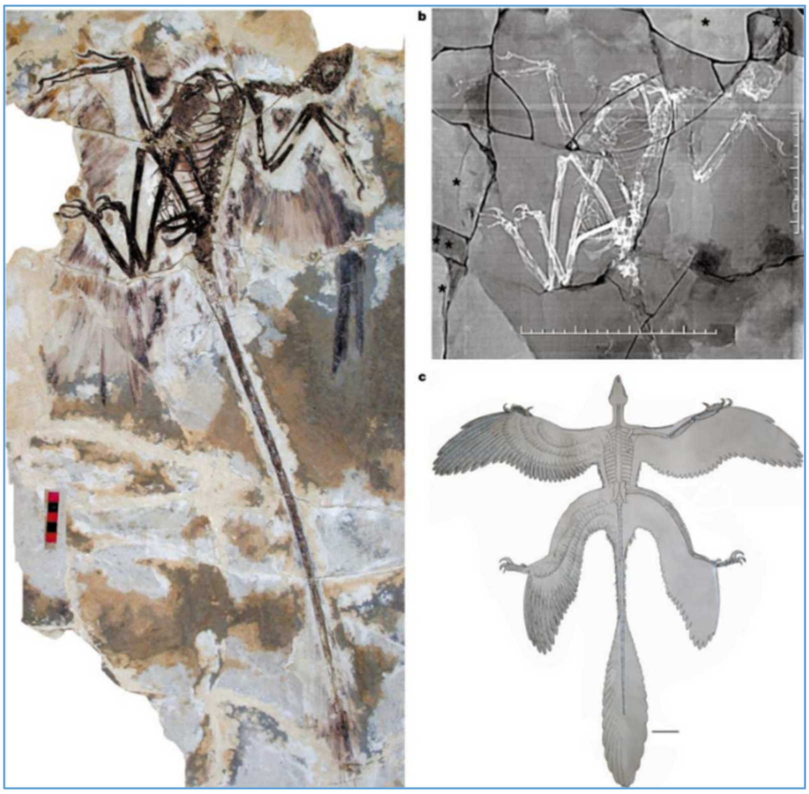
Keratinophilic fungi growing on feathers of Orange-footed Scrub Fowl Pic B. Muir

A study in Europe (Rubalee *et al., 2017*), examined Wood Pigeon (*Columba palumbus*), Eurasian Jay (*Garrulus glandarius*) and Blackbird (*Turdus merula*) and how feather damage by fungi affected predation of these birds by Northern Goshawk (*Accipiter gentilis*), the predator chosen for the study. These researchers hypothesized that birds with a higher abundance and/or diversity of skin and feather inhabiting fungi may have compromised feather surfaces that could reduce the ability of the prey species to evade the Goshawks.

Male Goshawks prey on the pigeons, jays and blackbirds and present them to the female and she removes the feathers and sheers off pieces of meat to feed to the chicks. The female chucks the feathers over the edge of the nest for fungus researchers to collect! The researchers examined feathers from under 50 Goshawk nests and compared them to feathers of living birds captured elsewhere. In total, the feathers from 47 woodpigeons, 20 jays, and 20 blackbirds were analysed.

In total, 27 different fungal species were isolated from the 87 bird individuals. Feathers from birds that failed to evade predation had 50% more fungal colonies growing on them than did birds that were still alive. It was more than just coincidence that the fungi reduced bird fitness and may act as drivers within avian predator-prey interactions. Feather degrading organisms like keratinophilic fungi enhance the survival of the Northern Goshawk, while negatively impacting populations of the three-prey species it feeds on. Fungi may also play a role in the rate at which birds moult seasonally; the faster the moult the less likely fungi and bacteria can get a hold on the new feathers.

The most primitive dinosaur feathers known —those of *Sinosauropteryx*—are the simplest tubular structures but more than 12 species of dinosaur fossils clearly show fully modern feathers and a diversity of primitive feather structures. An Early Cretaceous fossil called *Microraptor gui* belongs in the group of dinosaurs most closely related to birds. These creatures were about 70 cm long and had asymmetrical feathers on both their arms and legs. In living birds, feathers with asymmetrical vanes are required for efficient flight. *Microraptor* had four wings—one on each arm and one on each leg — that apparently had an aerodynamic function. The researchers hypothesize that *Microraptor* was an advanced glider, and because *Microraptor* is in the group that is most closely related to birds, they further propose that the two-winged powered flight of birds evolved through a similar four-winged gliding ancestor.



Fossil, computerized tomography (CT scan top right) image and reconstruction of *Microraptor*. Extracted from Xing Xu *et al.* (2003).

All this aside, the conclusions are inescapable: feathers originated and evolved their essentially modern structure in a lineage of terrestrial, bipedal, carnivorous dinosaurs long before the appearance of birds or flight. Feathers most likely evolved originally as protection, insulation or as display features. These dinosaurs would have been terrestrial, or, at best, tree climbing. Therefore most, if not all bird ancestors would have been, we assume, terrestrial and exposed to all the fungi and bacteria present in the soil, and on understorey plants. There would be a distinct advantage in getting above these high-risk habitats and it is conceivable that tree-dwelling (i.e., foliage feeding) and aerial feeding would be a distinct advantage.

Research carried out by Burtt & Ichida (1999) showed that the feeding ecology of different bird species had a significant influence on the composition of fungi and bacteria living on their plumage. Nearly 11% of ground foraging birds had infestations of feather degrading organisms, while foliage-gleaning (4.7%) and aerial foragers (2.4%) had markedly lower infestation rates. These results suggest that although food resources found on the forest floor may be abundant, accessing this environment may come with a serious cost; the accumulation of feather degrading bacteria and fungi.

These findings raise the question of whether higher incidences of bacterial and fungal infection on the forest floor played a role in shifting the feeding ecology of bird ancestors, and then proto-birds, to access resources with less parasitic threat and encouraged the evolution of flight.

But wait – there's more! There are known to be more than 2,500 species of feather mites that live inside the hollow quills of feathers, in the fluffy down, and on the vanes of wing and tail feathers of birds. Previously, it was assumed that feather-dwelling mites were parasitic, just as feather lice are. It is known that feather lice are harmful to birds, but a study of feather **mites** has shown their gut to contain the spores of keratinophilic and other fungi. Dona *et al.* (2018) examined the gut contents of 1,300 individual mites representing 100 different species, collected from 190 bird species. They found that the diet of the mites suggested they may be beneficial by consuming feather and skin fungi and may explain why birds observed to be heavily laden with feather mites have plumage that is in excellent condition.

In 1933 an ornithologist by the name of Gloger noted that birds in climates with high relative humidity were darker in plumage than similar species in climates with low relative humidity and Gloger's Rule was born. Studies in the USA and Canada (Zink & Remsen, 1986) confirmed this – individual birds in 94% of the species examined were darker in areas of high relative humidity than in areas of low relative humidity. Clearly there are other factors, such as birds being dark in dark understorey environments, but, because bacteria and fungi thrive in humid habitats such as the forest floor and because dark feathers containing black melanin resist bacterial and fungal degradation better than light-coloured feathers that lack melanin, they suggested that the geographic correlation of dark coloration with high relative humidity may be a response to selection for feathers that resist bacterial and fungal degradation.

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