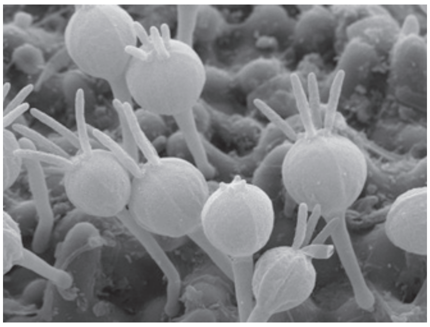
Bartheletia confirmed as basal in *Agaricomycotina*



Basidia of *Bartheletia paradoxa*. Photo: Edith Stabentheiner.

Maximum likelihood tree based 26 of the 67 orthologous loci studied showing the position of *Bartheletia paradoxa*. Adapted from Mishra *et al.* (2018).

Bartheletia paradoxa is a remarkable basidiomycete only known from fallen leaves of *Gingko biloba,* and referred to as a "living fossil" because of its association with this tree genus, which is known as a fossil from 270 million years ago, and its peculiar septal structure, basidia, and position at the basal branching of *Agaricomycotina* (Scheuer *et al.* 2008). Just what the position might be was unresolved in the original nucSSU DNA sequence analyses, but now a more comprehensive phylogenomic approach using a wide range of highly conserved genes by Mishra *et al.* (2018) has provided a greatly improved resolution. The new study used 67 highly conserved orthologous loci, which were used in a network analysis. Then, after removing poorly resolving genes, data based on 26 gave strong (but not maximum) support to this fungus being at the base of the *Agaricomycotina* and sister to all other members of the subphylum, and separate from the *Pucciniomycotina* and *Usilaginomycotina* which together form a sister group to the whole of the *Agaricomycotina*. The authors speculate that the lack of stronger support may be attributable to a rapid radiation related to the advent of basidian the last common ancestor. The new class and ordinal names *Bartheletiomycetes* and *Bartheletiales* are formally introduced here for this weird fungus.

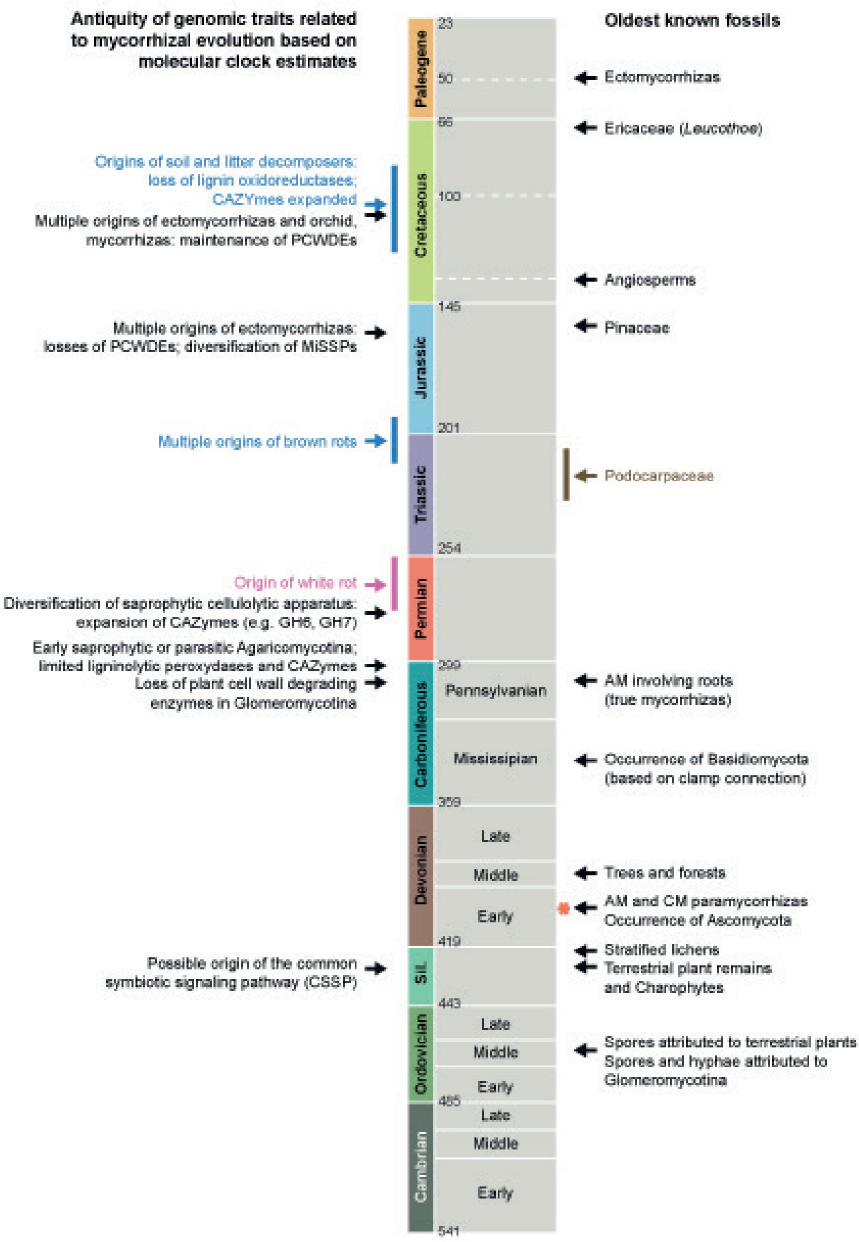
Mishra B, Choi Y-J, Thines M (2018) phylogenomics of *Bartheletia paradoxa* reveals its basal position in *Agaricomycotina* and that the early evolutionary history of basidiomycetes was rapid and probably not strictly bifurcating. *Mycological Progress* **17**: 333–341.

Scheuer C, Bauer R, Lutz M, Stabentheiner E, Mel'nik A, Grube M (2008) *Bartheletia paradoxa* is a living fossil on *Gingko biloba* leaf litter with a unique septal structure in the *Basidiomycota*. *Mycological Research* **112**: 1265–1279.

Mycorrhizal origins and functioning

The December 2018 issue of the *New Phytologist*, is a 399-page open-access special issue devoted to "Cross-scale integration of mycorrhizal function" (**81** (4): 937–1336; https://nph.onlinelibrary.wiley.com/toc/14698137/2018/220/4). There are 38 items in the issue including a mixture of review articles, research papers, commentaries, letters, and viewpoints. It is partly based on discussions stimulated by two international mycorrhizal conferences held in 2017 in Prague and Toulouse, supplemented by other contributions solicited by the eight co-editors of the issue, lead by Francis M. Martin. This is definitely a "must" not only for **all** mycorrhizal researchers, whether endo- or ecto-, but also for **all** interested in the evolution and functioning of symbiotic relationships from the palaeontological to the genomic levels.

Workers whose primary interest is mycorrhizal fungi will want to see the whole issue, and here I will draw attention to two contributions that I found especially fascinating. First is an insightful review of the history of mycorrhizal investigations and how that has helped shape current understandings by Paola Bonfante (2018). Paola eruditely and succinctly introduces the key players from Frank onwards, with glimpses of aspects of their lives and key insights they made, and notes on influential international meetings. Here also is a modestly presented synopsis of her own pioneering and elegant investigations first into the biochemistry and later the genetics of fungal-root interactions from colonization onwards. She stresses that much can be learnt from examining what has been done and what questions were asked in the past; something that not all researchers make the time to do in the pace of research in the 2000s when material not online is too frequently ignored. All mycologists and foresters who



Geological timescale with the oldest known fossils (right) *and antiquity of genomic traits* (left). Reproduced from Strullu-Derrien *et al.* (2018) which should be consulted for further explanation.

have a mycorrhizal slot in their teaching programmes will find this a fascinating overview with tid-bits to help make them even more captivating to students.

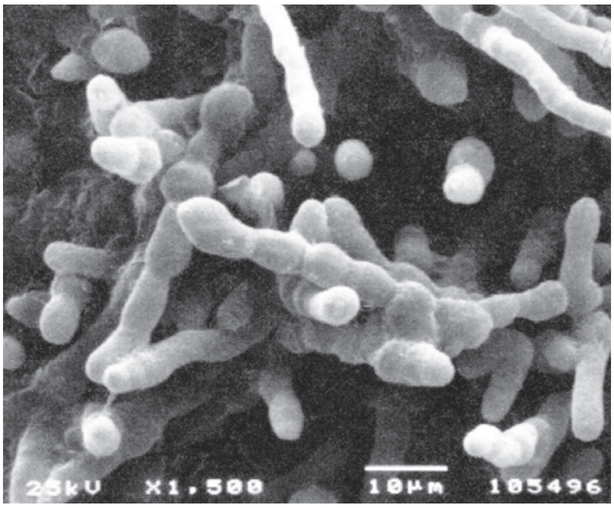
Second, is a review focussing on the evolution of mycorrhizal symbioses on the basis of both the fossil record and what has emerged from phylogenomic studies by Strullu-Derrien *et al.* (2018). These separate data sets are succinctly summarized in a figure (reproduced here) relating the fossils to the origin of genomic functional traits based on molecular clock estimates of age. Particular attention is given to the evolution of endomycorrhizas from the "paramycorrhizas" in aerial parts of the Devonian Rhynie Chert plants to tree roots by the late Carboniferous. A broad view is taken, including relationships to atmospheric carbon dioxide concentrations, pointing out that under elevated levels trees support larger hyphal networks and increased conversion of silicate minerals; issues that need to be considered in global warming scenarios. There are helpful boxes looking at atmospheric environmental contexts, the earliest terrestrial communities, and the fossil record and how it is linked to exceptional geological situations. Further, almost five pages of references are provided, making this an enormously important source work for all interested in relating the fossil record to extant mycorrhizas.

Bonfante P (2018) The future has roots in the past: the ideas and scientists that shaped mycorrhizal research. *New Phytologist* **220**: 982–995.

Strullu-Derrien C, Selosse M-A, Kenrick P, Martin FM (2018) The origin and evolution of mycorrhizal symbioses: from palaeomycology to phylogenomics. *New Phytologist* **220**: 1012–1030.

Gamma ray tolerance in an Antarctic black meristematic fungus

There has been much interest in the possible role of melanin pigments in conveying radiation resistance to fungi. Particular attention was drawn to this when it was found that melanin-containing fungi dominated in the most heavily contaminated sites in the inner parts of the damaged Chernobyl Nuclear Power Plant in Ukraine (Zhdanova *et al.* 2000). In nature, exposed rock surfaces can support a wide range of black conidial, often meristematic, fungi and that is especially so in Antarctica where radiation is especially high. One such fungus which occurs inside the upper layers of rocks in the driest and coldest ice-free areas of Antarctica is *Friedmanniomyces endolithicus*, a "cryptoendolithic" species. The fungus has been obtained in culture which makes experimentation possible. Pacelli *et al.* (2018) used an ex-epitype (as "epitype") culture to investigate the tolerance of this fungus to the effects of ionizing radiation (gamma rays) by monitoring survival and metabolic activity after exposure – and then modelling the survival dose response. Radiation doses of up to 400 Gy[1] were used. Exposure to 50 Gy resulted in the death of approximately 20 % of the cells as assessed by colony-forming-unit counts, 100 Gy to the death of around 40 %, but increases beyond that to 400 Gy did not give any statistically different percentages. Even at these enormous doses, the fungus still had a substantial proportion of cells with the ability to either resist the radiation effects or repair damage. Further, the XTT metabolic activity analyses showed the cells metabolic activity to increase with increasing radiation doses.



Scanning electron micrograph of *Friedmanniomyces endolithicus*. Reproduced from Onofri *et al.* (2007).

This level of resistance is much larger than that reported in other eukaryotes, for example in humans, the D_{50} values half the maximal inhibitory dose of ionising radiation required for 50 % inactivation of a tumor cell population, is just 4.5 Gy. Just how representative or exceptional *F. endolithicus* is amongst melanin producing fungi in general will have to await more studies on other melanized fungi, but the level of resistance to ionizing radiation demonstrated in this study is truly remarkable.

Onofri S, Zucconi L, Tosi S (2007) *Continental Antarctic Fungi*. Eching: IHW Verlag.

Pacelli C, Bryan RA, Onofri S, Selbmann L, Zucconi L, *et al.* (2000) Survival and redox activity of *Friedmanniomyces endolithicus*, an Antarctic endemic black meristematic fungus, after gamma rays exposure. *Fungal Biology* **122**: 1222–1227.

Zhdanova NN, Zakharchenko VA, Vember VV, Nakonechnaya LT (2000) Fungi from Chernobyl: mycobiota of the inner regions of the containment structures of the damaged nuclear reactor. *Mycological Research* **104**: 1421–1426.

[1]Gy is a measure of ionizing radiation dose; 1 Gy = is the absorption of one joule of radiation energy/kg of matter.

Ganoderma extract reduces effect of bee virus

There is worldwide concern over declines in bee populations, attributed to both the use of neonicotinoid pesticides on crops, parasitic mites (*Varroa destructor*), and associated RNA viral diseases. Most important amongst the latter are deformed wing virus (DWV) and Varroa destructor virus-1 (VDV1). Control has centred on eliminating the mites by spraying miticides in bee hives, but that has not been universally effective. As some polypore fungi in particular are reported as having anti-viral properties, and bees have been seen foraging amongst mycelium, Stamets *et al.* (2018) tested the effect of extracts of various polypore fungi on DWV and another virus attacking honey bees in the USA, Lake Sinai virus (LSV). Promising results were obtained from *Fomes* and *Ganoderma* mycelium extracts, so the authors scaled their studies up to field trials. Extracts were added to bees' water feeders at a concentration of just 1 %. The results were particularly striking in the case of *G. resinaceum* extracts, where a 79-fold reduction in DWV and a staggering 45 000-fold reduction in LSV was obtained compared with controls.

As the extract are just added to water feeders, the usage of such fungal extracts by beekeepers is a relatively routine process so can be implemented without recourse to precautionary procedures necessary when spraying miticides. The extent to which this will be taken up remains to be seen, but the supply of extract should not be a major problem in the case of the *Ganoderma* as mycelium was produced from liquid culture. Leaving basidiomes around hives to facilitate self-medication by the bees would perhaps also be beneficial.

Stamets PF, Naeger NL, Evans JD, Han JO, Hopkins BK, *et al.* (2018) Extracts of polypore mushroom mycelia reduce viruses in honey bees. *Nature Scientific Reports* **8**: 13936.

Bumble bee affected by Deformed Wing Virus (DWV). Photo: Jacqueline Hartwright.