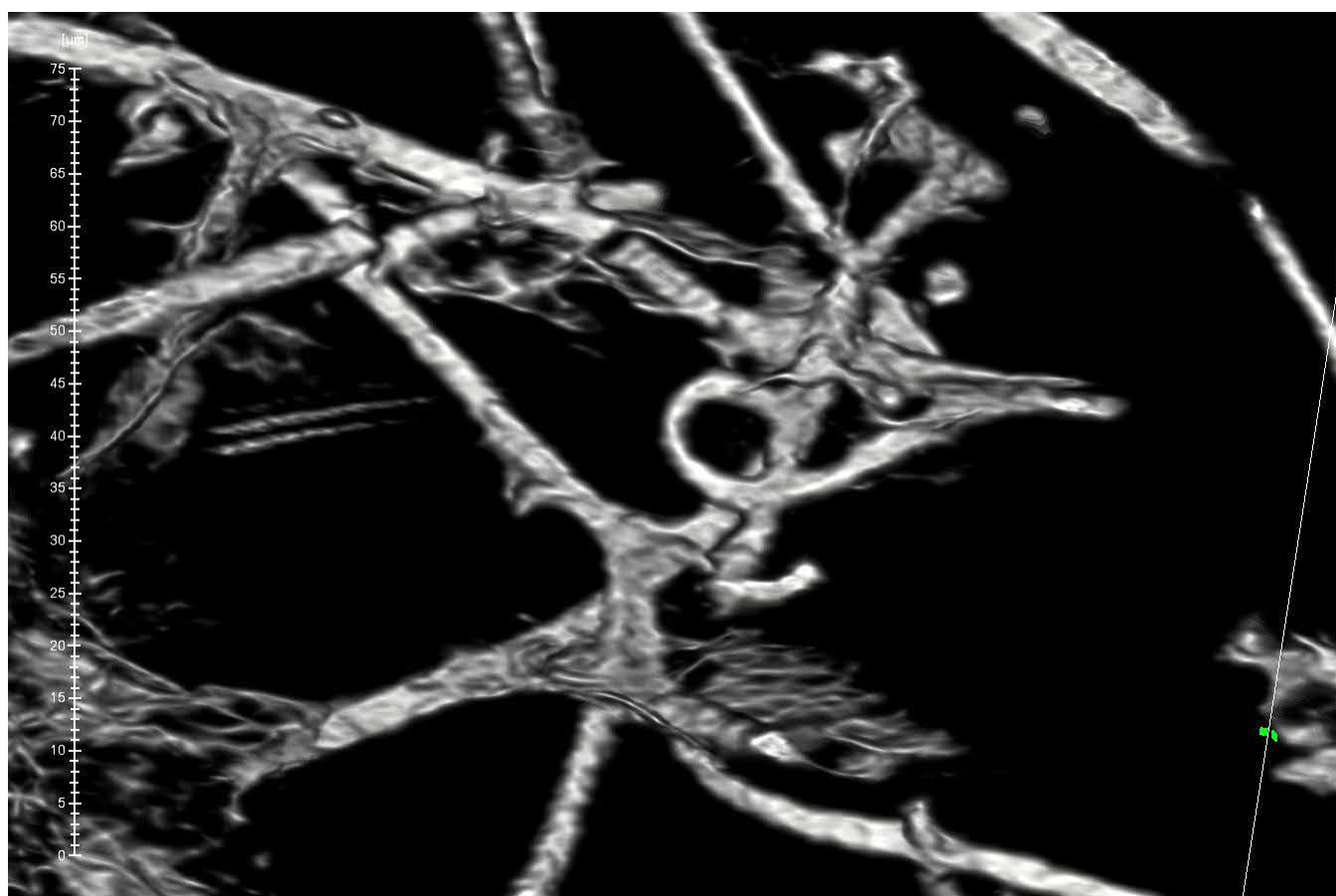


Mycelial-like 2.4 billion-year-old fossils



Vesicle (to left) with boom-like aggregations of filaments (upper left), and branched and anastomosing filaments (centre and right) as revealed by SRXTM surface/volume renderings. Photo courtesy: Stefan Bengtson.

Most fossils from the Pre-Cambrian that were claimed to perhaps be fungal have proved to be artefacts or otherwise dubious (Hawksworth 2015, Taylor *et al.* 2015). Some more convincing remains of mycelium-like structures have, however, now been reported from a 2.4 billion-year-old basalt from the Palaeoproterozoic of the Pre-Cambrian in South Africa (Bengtson *et al.* 2017). The basalts were submarine and have vesicles often connected by veins evident in thin sections, and the detailed structures have been elucidated by tomographic microscopy (SRXTM) surface/volume renderings. Networks of hyphal-like threads are visualized, some

with anastomoses, branches, and loops; measurements are given as 2–12 µm wide. No definite spore-like structures were discovered, but it is speculated that some bulbous protrusions of 5–10 µm diam might actually be spores. It cannot be categorically asserted or denied that these structures are fungal, but there can be little doubt that they are mycelium-like. No reference is made to septa, but none are evident in the photographs. The jury is likely to remain out for some time as to the nature of these remains, and the possibility that they could represent extinct lineages has to be borne in mind. Nevertheless, the presence of some early fungi or fungal

ancestor was to be expected in Cambrian or Pre-Cambrian rocks if it is assumed that the principal fungal phyla had all become well-separated by the Devonian.

Bengtson S, Rasmussen B, Ivarsson M, Muhling J, Broman C, *et al.* (2017) Fungus-like mycelia fossils in 2.4-billion-year-old vesicular basalt. *Nature Ecology and Evolution* 1: 0141.

Hawksworth DL (2015) Lichenization: the origins of a fungal life-style. In: *Recent Advances in Lichenology* (Upreti DK, Divakar PK, Shukla V, Najpai R, eds) 1: 1–10. Springer.

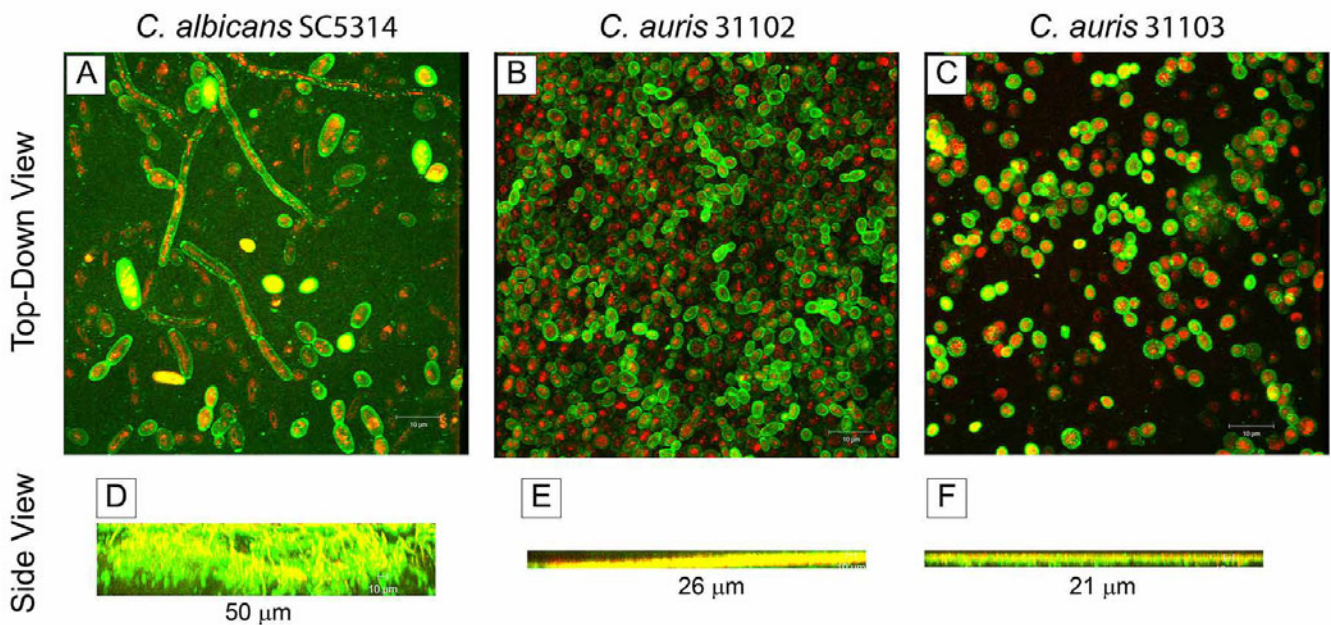
Taylor TN, Krings M, Taylor EL (2015) *Fossil Fungi*. Amsterdam: Elsevier Academic Press.

Secrets of the antibiotic resistant *Candida auris* revealed

There is particular concern amongst medical mycologists of the threat to human health posed by a species of *Candida* resistant to whole classes of antifungals and that

has been found in hospitals. This yeast, *C. auris*, was first described from the ear of a woman in Japan as recently as 2009, but has now been involved in invasive infections in

nine countries with over 30 patients being involved in some hospital outbreaks. There is a particular problem in that it can form drug resistant biofilms on, for example, catheters.



Biofilms formed by *Candida albicans* and *C. auris* strains as revealed by confocal scanning laser micrography, top down 3D (A-C) and side (D-F) views. Adapted from Larkin *et al.* (2017). Photos courtesy Mahmoud Ghannoum.

A major investigation into the biology, virulence, and drug resistance of this species has now been published by Mahmoud Ghannoum's research group at the Center for Medical Mycology, Case Western Reserve University and University Hospitals Cleveland Medical Center in Cleveland, Ohio (Larkin *et al.* 2017). Working with 16 strains from a wide range of countries, they tested the efficacy of 11 drugs belonging to different antifungal classes. Most were ineffective although there were some differences between strains. The drugs used, however, included a novel 1,3- β -D-

glucan synthase inhibitor (SCY-078) which is orally administered and completely inhibited growth of both this species and *C. albicans*. The drug operated by interrupting cell division, which was demonstrated by scanning electron microscopy, and also reduced the thickness of biofilms formed compared with controls. The group also explored what virulence determinants were expressed in connection with the resistance shown to fluconazole and amphotericin. Growth on different media was similar to that of *C. albicans*, except that no chlamydo spores were formed.

Further evaluation of SCY-078 for the routine treatment of *C. auris* infections appears to be warranted.

Larkin E, Hager C, Chandra J, Mukherjee PK, Retuerto M, *et al.* (2017) The emerging pathogen *Candida auris*: growth phenotype, virulence factors, activity of antifungals, and effect of SCY-078, a novel glucan synthesis inhibitor, on growth morphology and biofilm production. *Antimicrobial Agents and Chemotherapy* 61 (5): e02396-16.

Cantharellus species concepts in Europe clarified



Cantharellus cibarius. Photo: Gabriel Moreno.



Cantharellus pallens. Photo: Gabriel Moreno.

While the chanterelles are amongst some of the most recognizable and sought-after mushrooms in Europe and North America, agreement on species recognition has often been hard to achieve. An amazing 30 names have been applied to the European species, and the application of some has been far from clear in the absence of

modern molecular systematic approach incorporating sequences from type material. Olariaga *et al.* (2017) have carefully typified and/or epitypified the names proposed and carried out a new analysis using sequences from ITS2, nr DNA LSU, *RPB2*, and *TEF-I* genes. A set of 117 specimens was then used for DNA extractions, and a subset of

53 of these representative of the whole range of phylogenetic diversity in Europe was then studied in more detail. Just eight species could be supported in a well-structured combined tree, one of which was newly described (*Cantharellus roseofagetorum*). In contrast, several rather recently recognized species were relegated to synonymy (e.g. *C. henrici*, *C. lourizanianus*).

Meticulous morphological studies were carried out and selected ones mapped onto the phylogenetic tree. The result was not a set of taxa that could not be recognized by field mycologists, as has been the result of studies on some other mushroom genera, but the discovery of a series of characters that could be used to separate the species without recourse to DNA sequencing.

The colour of the pileus when young, and the colour of the young hymenium were found to be particularly informative, and when supplemented by the coating, staining, and spore shape characteristics enabled a traditional dichotomous key to be provided. When re-circumscribed in the manner proposed here, there were also some clear geographical differences, such as the predominance of *C. cibarius* in northern Europe and of *C. pallens* in

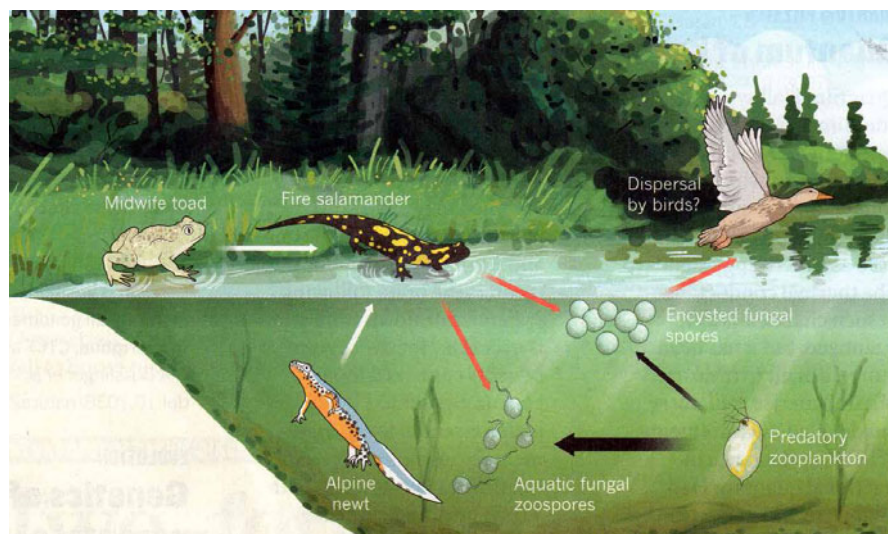
southern Europe. Further, some species were ectomycorrhizal only with deciduous trees (e.g. *C. friesii*) and others primarily with evergreen mediterranean oaks (e.g. *C. alborufescens*) or conifers (e.g. *C. cibarius*).

Detailed descriptions and colour photographs of the accepted species are provided, along with drawings of the basidiospores. It is a pleasure to see such a work clearly prepared with field mycologists

and mycophagists in mind, and all who wish to identify these fungi, whether for commercial, gastronomic, or scientific purposes, will find this paper invaluable.

Olariaga I, Moreno G, Manjón JL, Salcedo I, Hofstetter V, Rodríguez D, Buyck B (2017) *Cantharellus* (*Cantharellales*, *Basidiomycota*) revisited in Europe through a multigene phylogeny. *Fungal Diversity* 83: 263–292.

Reservoirs of *Batrachochytrium salamandrivorans* infection



Reservoirs and sources of infection of salamanders (*Salamandra salamandra*) by *Batrachochytrium salamandrivorans*. Reproduced from Fisher (2017).

In addition to the devastation caused in frogs worldwide by *Batrachochytrium dendrobatidis*, an additional species pathogenic to salamanders, *B. salamandrivorans*, was described in 2013 (see *IMA Fungus* 4 (2): (48)–(49), December 2013). This fungus is now known to have entered Europe from Asia around 2010, and is exceptionally virulent being able to kill more than 96 % of salamanders that are infected. Stegen *et al.*

(2017) critically monitored infections in salamanders in a forest in Belgium, just 57 km from the initial outbreak site in Europe. Infections were first noted in this site in 2014, and within two years under 1 % had escaped infection and were still able to travel around the forest.

In order to understand the epidemiology of this disease, Stegen *et al.* carried out a series of infection trials and also endeavoured to find reservoirs

from which the fungus could attack. They discovered that survival of the fungus outside salamander bodies was aided by the formation of encysted zoospores, something not seen in *B. dendrobatidis*. These spores float and are quickly picked up by not only salamanders, but also toads and waterfowl, the waterfowl being capable of spreading the disease over wide areas. DNA analysis of soils also showed that the zoospores could persist there. In addition, motile zoospores in the water are able to be carried to salamanders by newts which were also adversely affected by the disease.

As noted by Fisher (2017), the combination of multiple reservoirs and an ability to persist in the environment leads to a highly infected ecosystem. It is difficult to see how such infections can be combated in the wild, and there may be a need for what he terms ‘amphibian arks’ to safeguard vulnerable species.

Fisher MC (2017) In peril from a perfect pathogen. *Nature* 544: 300–301.

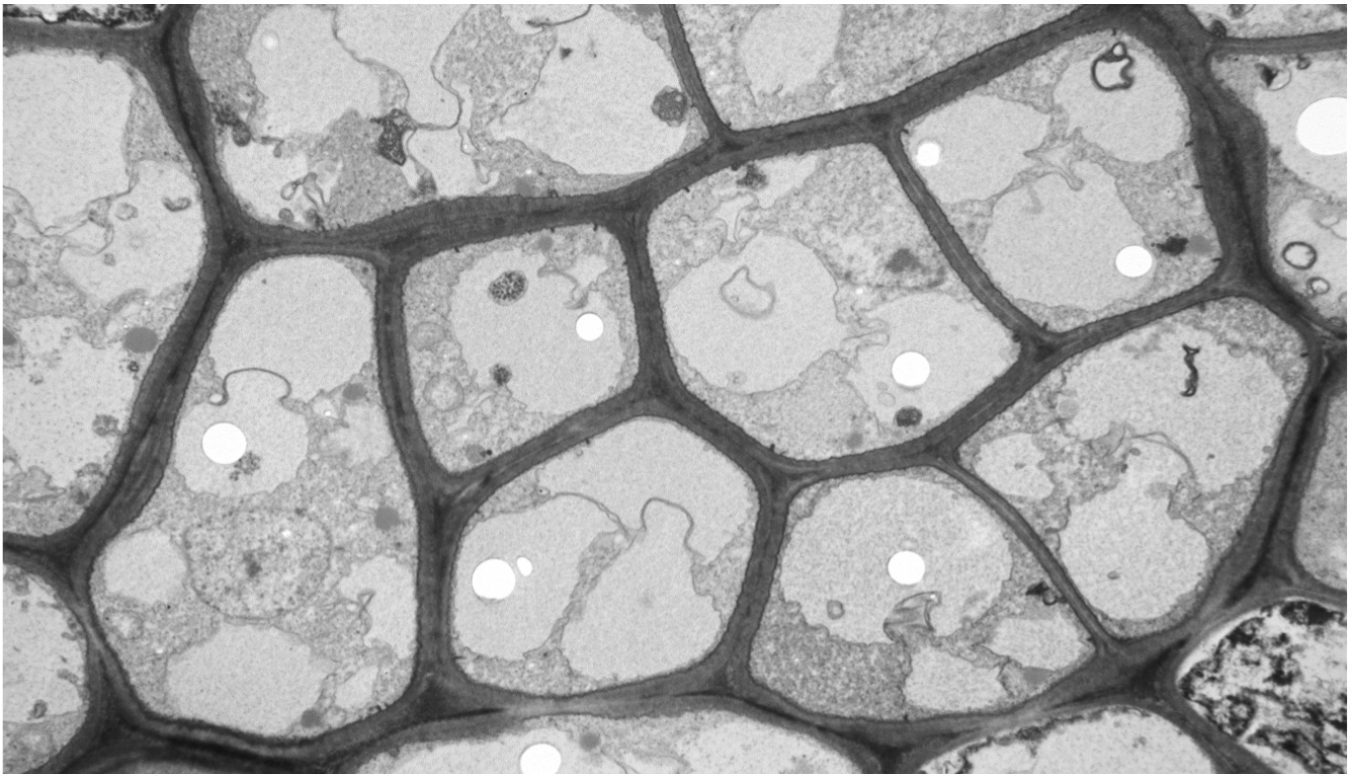
Stegen C, Pasmans F, Schmidt BR, Rouffaer LO, Van Praet S, *et al.* (2017) Drivers of salamander extirpation mediated by *Batrachochytrium salamandrivorans*. *Nature* 544: 353–356.

Tissue types in lichen cortices

Elegant microscopic methods can facilitate the elucidation of how tissues develop in complex fungal structures. Many groups of foliose lichens have well-developed cellular upper cortices, but the extent to which these parallel the cellular tissues found in plants has been uncertain. For example, are terms such as parenchyma appropriate? A true

parenchyma in plants has cells subdivided from adjacent cells by cross walls adjoining older cross walls. Sanders & Rios (2017) used transmission electron microscopy (TEM) to determine just what was the case in the cortices of three foliose lichens from different families, *Endocarpon pusillum* (*Verrucariaceae*), *Leptogium cyanescens*

(*Collembataceae*), and *Sticta canariensis* (*Lobariaceae*). They paid particular attention to the wall layers and found that the newer wall layers were not continuous with the older ones, the older ones tended to have amorphous electron-dense deposited in them and the newer layers increasingly well-delineated. Septal pores connecting adjacent



Upper cortex of *Sticta canariensis*, chloromorph, paradermal section in TEM. Photo: W. B. Sanders and A. de los Rios.

cells did, however, persist.

The resultant tissue in these cases is considered comparable to true parenchyma in the unrestricted orientation of the cross walls separating the cells, and the relationship of the cells to their neighbours. The authors do, however, recognize that earlier stages in the ontogeny of the tissues involve the coalescence of filamentous hyphae and subdivision into cell-like compartments, often termed a pseudoparenchyma, in which the filamentous origins are evident in

microscopic preparations. The cells in the lichen cortices studied are relatively thin-walled and rounded with no indication of a hyphal origin and so are interpreted as a parenchyma rather than a pseudoparenchyma. The lichen parenchyma is consequently homologous with plant parenchyma cells, and apomorphic (i.e. a derived character state) rather than plesiomorphic (i.e. an ancestral character state).

This study shows the care that is needed to unequivocally categorize the tissue types

in fungi from a developmental standpoint. It also suggests prudence in applying terms that have an implied ontogenetic meaning, and so the pragmatism of using the “tissue types” system (i.e. *textura globosa*, *textura intricata*, etc) describing what is seen with the light microscope with no implied ontogenetic overtones.

Sanders WB, de los Rios A (2017) Parenchymatous cell division characterizes the fungal cortex of some common foliose lichens. *American Journal of Botany* 104: 207–217.

Oldest fossil agaric discovered

Fungi which are composed primarily of soft tissues, such as most agaric mushrooms, could be expected to only rarely be preserved in the fossil record, and that proves to be the case. An exception is where they become encased in resin, and so survive as inclusions in amber, as with the 35–55 Myr-old *Gerontomyces lepidotus* reported on last year (see *IMA Fungus* 7 (2): (66), December 2016). Now a much older agaric has been discovered not in amber but in laminated limestones from Brazil from the Lower Cretaceous dating from 113–120 Mya.

This new mushroom is rather small, with a cap of just 10 mm diam borne on a stipe of 24 mm. It is named as

Gondwanagaricites magnificus, and is clearly a member of *Agaricales* as gills are evident, but a family placement is not suggested in the absence of basidiospores, which were not revealed even by scanning electron microscopy.

This is not just a curiosity, however, as this fossil provides a new and earlier calibration point for *Agaricales* for use in molecular clock phylogenies.

Heads SW, Miller AN, Crane JL, Thomas MJ, Ruffatto DM, *et al.* (2017) The oldest fossil mushroom. *PLoS One* 12 (6): e0178327.

Gondwanagaricites magnificus (holotype). Photo courtesy: Danielle Ruffatto.

