Ecology and phylogeny of black yeast-like fungi: diversity in unexplored habitats

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Published online: 6 March 2014
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The known biodiversity of black yeasts and their allies has exploded over the last decades. This even applies to medically significant genera such as *Exophiala* and *Cladophialophora*, where the number of accepted species has grown since the 1990s of the previous century from 9 to 44 and from 5 to 34, respectively. A first source of change no doubt is dissection of many supposed ubiquitous generalists into series of narrowly circumscribed molecular siblings, which often appear to be specialists with ecological preferences differing significantly between species. An early example of subdivision of classical species in black yeasts, using DNA homology techniques, concerned *Exophiala jeanselmei*. One of its siblings today is known to be a biofilm former in drinking water networks, while *E. jeanselmei* sensu stricto is thus far only known from subcutaneous infections in humans.

Multilocus sequencing-aided discovery of molecular siblings has now become standard in mycology. Even in well-studied groups, such as yeasts and *Aspergillus*, we witness a steady increase of the number of taxa. Upgrading populations to the level species is usually done because of absence of gene flow between lineages. But there is a limit to what can be subdivided: better gene sampling will not always reveal hidden species. In some, apparently over-classified groups the molecular approach has even led to a decrease of the number of species. For example, *Rhizopus microsporus* was shown to be a single species with 9 proven synonyms, and in dermatophytes several well-known clinical species appeared to be cultural variants of a single, prevalent taxon, *Trichophyton rubrum*. Understanding of sexual processes is needed for ultimate proof of conspecificity. Since fungal evolution is

driven by interaction with its environment, ecology is a second essential parameter in taxonomy.

Ecology also plays a role as a source of diversity at higher phylogenetic levels. In chaetothyrialean black yeasts closely related species may occupy very different habitats, while in most Capnodiales we witness gradational differences between environmental preferences of neighboring species. Black yeast-like fungi are unique in the fact that many species inhabit strange, extreme, poor, or toxic environments. Throughout history of mycology researchers have focused primarily on accessible and easily culturable species, but now it's time for the difficult fungi with odd behavior. Hostile environments like bare rock of the Antarctic or the Himalaya appear to be very rich in members of Capnodiales, many of which are as yet undescribed. Inspired by classical studies on Antarctic rocks, Wolfgang Krumbein and co-workers sampled marble buildings of cultural heritage in Mediterranean Europe where numerous species and genera of obligatorily rock-dwelling fungi were uncovered. Other hostile environments are toxic mines, creosoted oak wood, ant nests, or low-nutrient environments. Not only the number of fungi present in these environments appears to be overwhelming, but it also makes us aware of large distortions in our phylogenetic trees due to incomplete taxon sampling: with every new study supposedly ancestral species appear to be phylogenetically remote. An example is *Phaeococcus nigricans* which initially was thought to belong to a basal lineage of Chaetothyriales in the class Eurotiomycetes, but is now recognized as a member of Lichenostigmatales in the Arthoniomycetes.

The present special issue of Fungal Diversity contains elements of all problems discussed above. The diversity of the current *Exophiala jeanselmei* clade is described by Zeng et al. Feng et al. provide an overview of *Cyphellophora* and relatives as one of the clades of Chaetothyriales which recently was upgraded to family level. Vicente et al. demonstrate the

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significance of dissecting morphological species into molecular siblings, suggesting that routes of infection of traumatic infections in humans may be more complicated than anticipated. Attili-Angelis et al. sampled the unusual environment of ant-nests which are kept free of microorganisms by an abundance of toxic hydrocarbons by the ants, and encountered several new species of Chaetothyriales. Unexpected phylogenetic positions of black yeast-like organisms were revealed by Machouart et al. with

Ochroconis, which appears to belong to the family Symptoventuriaceae of Venturiales; the taxonomy of this enigmatic group was elucidated by Samerpitak et al. The stunning diversity of rock-inhabiting black fungi was described by Egidi et al. and Selbmann et al. with the introduction of several new genera and new species. The Tree Of Life certainly remains unstable for some time to come, due to sampling effects from hidden diversities in extreme habitats.