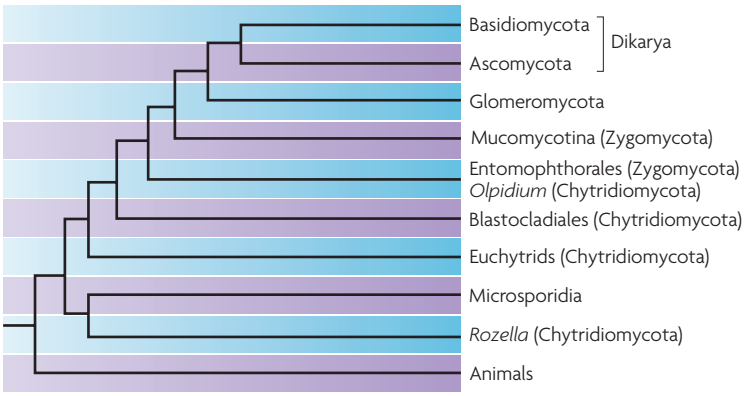
FUNGAL BIOLOGY

SEX and the parasitic fungi

Microsporidia are obligate, intracellular parasites of animals, which makes them difficult to culture in the laboratory. Originally thought to be an ancient lineage of eukaryotes owing to their lack of true mitochondria, they are now known to be related to fungi. Writing in *Current Biology*, Lee *et al.* argue that synteny between the sex-determining locus of zygomycetes and a region in the microsporidian genomes shows that microsporidia are true fungi and might undergo as-yet-unobserved sexual reproduction.

Microsporidia form a group of more than 1,200 species that are divided into ~150 genera. Selected genomes have been sequenced, but determining evolutionary relationships has been hampered by their small genome size (some have less than 2,000 genes). Owing to the specialized lifestyles of different microsporidia, the nucleotide sequences of genes changes rapidly, but gene order or synteny is often preserved because their reduced genomes and shortened intergenic spaces restrict the number of genome rearrangements that can occur without disrupting vital genes. Lee and co-workers have studied gene synteny in the microsporidia to unravel their evolutionary history.

Fungi can reproduce both sexually and asexually. In most fungi the different 'sexes' are determined by a mating-type locus (*MAT*) that contains dimorphic homeodomain genes. The zygomycete *Phycomyces blakesleeanus* has a different architecture for its sex-determining locus (*SEX*), which consists of a gene that encodes a high-mobility group (Hmg) domain protein that is flanked by genes for a triose phosphate transporter and an RNA helicase. The choice of one of two forms of the *HMG* gene (named *SEXP* and *SEXM*) sets the mating type of the fungus. The authors found that this arrangement is preserved in other zygomycetes and that a similar gene cluster is present in the microsporidia *Encephalitozoon cuniculi*, *Enterocytozoon bieneusi* and *Antonospora locustae*.



This highly simplified evolutionary tree shows the traditional phyla — Ascomycota, Basidiomycota, Glomeromycota, Zygomycota and Chytridiomycota. Also shown are the microsporidia and *Rozella* branches, which seem to be basal to all the other fungi. Image reproduced, with permission, from Bruns, T. Evolutionary biology: a kingdom revised. *Nature* **443**, 758–761 (2006).

The researchers went on to identify several other regions that were syntenic between microsporidia and zygomycetes, but failed to find a significant co-occurrence of gene order in other fungal groups, such as ascomycetes, basidiomycetes and a chytridiomycete. This suggests that the microsporidia are highly specialized fungi and are close cousins of the zygomycetes, rather than a sister group to the entire fungal kingdom that diverged early in its history, as previously suggested.

All the *HMG* genes sequenced from microsporidian *SEX* loci are more related to *SEXP* than to *SEXM*. Perhaps this locus has a function other than sex in microsporidia, which would account for this finding, but it is plausible that the microsporidial genes that have so far been sequenced were all from the same mating type. Alternatively, the presence of genes that encode sex proteins with tandem Hmg domains in *E. cuniculi* and *A. locustae* could indicate that these species are homothallic, and can supply both 'male' and 'female' cells when required. The presence of genes that encode protein homologues that have functions in meiosis in other fungi supports the suggestion that microsporidian sexual cycles remain to be discovered.

Whatever the sexual proclivities of microsporidia, their identification as true members of the fungal kingdom that are closely aligned with the Zygomycota will advance investigations into their specialist biology and inform approaches that will allow us to combat the diseases they cause.

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> “...microsporidia are true fungi and might undergo as-yet-unobserved sexual reproduction.”

ORIGINAL RESEARCH PAPER Lee, S. C. *et al.* Microsporidia evolved from ancestral sexual fungi. *Curr. Biol.* 30 Oct 2008 (doi:10.1016/j.cub.2008.09.030)