



British Mycological
Society promoting fungal science

journal homepage: www.elsevier.com/locate/fbr



Editorial

Complex fungi



Keywords:

Big data analysis
Fruiting bodies
Functional and morphological complexity
Fungal hyphae
Sexual and asexual differentiation
Simple and complex multicellularity

ABSTRACT

Filamentous fungi grow in form of multicellular tubular hyphae ('simple multicellularity'). When hyphae aggregate, more complex three-dimensional structures emerge. Differentiation of hyphal cells adds to morphological and functional complexity of aggregated fungal organs ('complex multicellularity') that serve such different biological purposes as sustenance, resilience, or sexual or asexual reproduction. The most complex structures in the fungal kingdom are the multicellular sexual fruiting bodies with distinct fungal tissues and multiple cell types. Between fungal taxa, fruiting bodies come in various morphological shapes, colors and sizes. So far, it is largely unclear what genetically determines such complex multicellularity in fungi and how and how often core functions of such multicellularity evolved. Research targets at to find out what is behind the complex multicellularity in fungal fruiting body development. Combined inputs of environmental signals to transcription of participating genes are coordinated in the nuclei by distinctive transcription factors. Comparative analyses of big data sets derived from sequenced genomes of different fungal species and from sequenced situational transcriptomes can extract what is common in developmental programs as potential core functions in multicellularity and also identify that what is specific in individual development.

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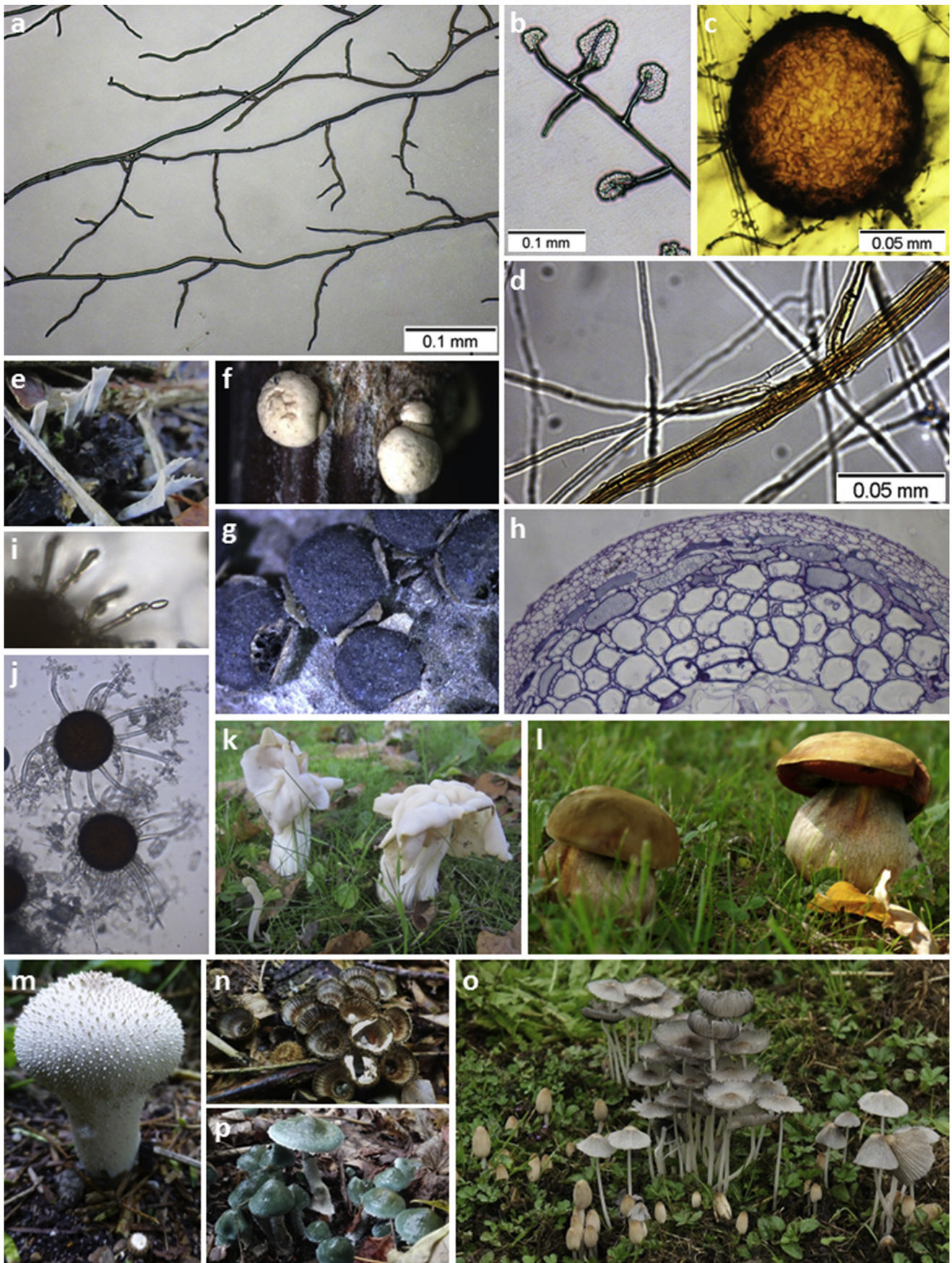
1. Introduction

Fungi can either grow single-celled or multicellular or some are also dimorphic and may switch between these fundamentally different types of cellular growth forms according to the environmental signals they receive (temperature, oxygen, CO₂, nutrients, specific chemicals; Gauthier 2015; Lin *et al.* 2015). Multicellular can refer to a hyphal filament as a chain of interconnected cells and to mycelia as larger hyphal networks or to more specific and complex morphological structures with distinct functions, such as hyphal strands, cords, mycelial fans, rhizomorphs, outer ectomycorrhizal mantles and Hartig nets, sclerotia, stromata, and sexual and asexual reproductive organs including most complex sporocarps (Fig. 1; de Mattos-Shiple *et al.* 2016). A single species, such as the necrotrophic plant-pathogenic molds *Botrytis cinerea* and *Sclerotinia sclerotiorum* (Amselem *et al.* 2011) and the ectomycorrhizal broad-leaf-tree-symbiont *Tuber melanosporum* (Kües and Martin 2011) from the Ascomycetes and the coprophilous model mushroom *Coprinopsis cinerea* (Kües 2000) and the wood-rotting forest

pathogen *Armillaria ostoyae* (Sipos *et al.* 2018) from the Basidiomycetes, may adopt various different of such complex multicellular morphologies in course of their sexual reproductive life cycles and in any subsidiary asexual reproductive pathways and as specific organs for own sustenance and duration. Sometimes, multicellularity of fungi is understood in a more restricted sense of complex multicellular development of differentiated three-dimensional (3D) structures such as the sexually reproductive fungal fruiting bodies present. However, as indicated already above and shown in the randomly selected examples given in Fig. 1, there are different levels and complexity in multicellularity and many types of morphological variation (Knoll 2011; Nagy *et al.* 2018).

2. Multicellularity provides distinct advantages

Multicellularity commonly involves differentiation and specialization and, therefore, targeted spatial and temporal decisions with which an organism can react on changing



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