DIVERSITY OF FORM, FUNCTION AND ADAPTATION IN FUNGI

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Contents

Summary

Fungi are usually composed of filaments, called hyphae, which constitute a fungus' functional and nutritional unit. A complex of hyphae forms a mycelium while unicellular forms of fungi are represented by yeasts. Afungal cell is eukariotic and thus

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includes nucleus and cytoplasmic organelles; it lacks plastids, such as starch-containing amyloplasts , storing chemical energy in glycogen, as is the case in animals. The mycelium grows radially, forming round colonies in a homogeneous medium; it produces extracellular enzymes able to digest all kinds of substances. The apical cells of hyphae absorb the soluble compounds obtained by degradation.

Fungi reproduce asexually and sexually. Asexual reproduction is quite common and mainly performed by production of conidia (i.e. spores produced externally commonly by specialized cells, called conidiogenous cells) or sporangiospores (i.e. spores produced within specialized cells, called sporangia). Sexual reproduction involves fusion of two haploid cells so that nuclei are in a common cytoplasm (plasmogamy); nuclear fusion (karyogamy) gives origin to a diploid cell; meiosis produces recombinant haploid nuclei. Sexual spores are zygospores in Zygomycota, ascospores in Ascomycota and basidiospores in Basidiomycota.

Fungal spores disseminate very easily: 10,000 spores per cubic meter of air are quite common. Several agents, such as wind, water, soil, insects, are involved in spore dissemination; or the fungus can have a self-dispersal mechanism. To a lesser extent, other animals and humans may be involved.

Fungi can live as saprobes, parasites or symbionts. Saprobic fungi feed on non-living organic material, other than that killed by the fungus itself. They are the major degraders of organic matter in natural environments, since they degrade the major polymeric structural components of plant, animal or microbial cells. Saprobic fungi can be specialized in the degradation and subsequently absorption, of a particular substrate.

Fungal parasites gain their nutritional requirements from another organism (host) with which they live in intimate association. A pathogen is a parasite that causes overt disease. Most of the parasitic fungi are nonobligate parasites as they can live either on living or on death host tissues, while obligate parasites can live only in intimate contact with living host tissues.

The most important fungal symbioses are mycorrhizas, lichens and endophytism which differ from each other in host type and in the depth of hyphal penetration into the host tissues.

Endophytes are of interest because of their possible employment as biocontrol agents against plant pathogens and pests.

True fungi appeared on Earth during the Silurian Period ca 400 millions of years before present (MYBP).

Fungi are more adapted than plants to terrestrial habitats as indicated by their ability to grow at high negative water potentials. They also show wide temperature requirements that range from –15 ^{o}C, in psychrophilic (cold-growing) species, to 60 ^{o}C for thermophiles (heat-growing).

Fungi are the main plant pathogens and cause about 70% of the major crop diseases,

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with an economic cost of billions of dollars a year.

Fungi, often moulds, are the most diffuse agents of food spoilage. They damage flavor and food consistency; some moulds growing on food are toxic to man and animals because of the mycotoxins they produce. Many fungi are important producers of drugs, mainly the antibiotics penicillin and cephalosporin and the immunosuppressant agents cyclosporins.

Fungi, including yeasts, are probably the most important organisms used in food processing. The production of bread, wine and beer is based on the metabolism of the yeast *Saccharomyces cerevisiae*; other fungi are used for cheese production or to obtain Soya sauce, Saké and Tempe.

Among a wide variety of edible wild mushrooms, a number are harvested for commercial purposes and a few are cultivated. Cultivated mushrooms can grow on agricultural wastes, transforming them into protein-rich animal feed ingredients with lower lignin content.

1. Introduction

Fungi are eukaryotic, heterotrophic organisms, with nutrition by absorption, mostly with filamentous structures, known as hyphae, surrounded by a cell wall. Fungi colonize almost all organic substrates and microhabitats, producing extracellular enzymes able to decompose any kind of substrate. Fungi can digest some extremely tough substances, such as keratin (hair, feathers, horn, skin), chitin (insect exoskeletons), cellulose (most plant debris) and lignin (wood). The uncommon ability of saprobic fungi to exploit cellulose and lignin gives them almost exclusive access to the enormous quantity of plant debris released on Earth and for this reason, fungi are the most important recyclers in the world. Besides their saprobic habits, fungi can live as symbionts (for instance in lichens or associated with plant roots in mycorrhizas). A very large number of fungal species are plant or animal pathogens, causing about 70% of major crop diseases. Fungi are terrestrial organism, adapted to dryness and are able to grow between about –15 and 60°C. Fungi can colonize any environment so that fungal spores are everywhere, sometimes reaching more than 10,000 spores per cubic meter of air. They produce enormous damages as pathogens of cultivated plants, can contaminate foods producing mycotoxins, or can be agents of mycoses of skin and internal organs in both, animals and humans. However, fungi can also produce antibiotics and immunosuppressants or they convert plant wastes into animal feed. Finally, in many culinary cultures, mushrooms, morels, truffles are regarded as most valued delicacies.

2. Diversity of form

To date about 56,000 fungal species have been described, taking into account only the species included in Phyla Chytridiomycota, Zygomycota, Ascomycota, and Basidiomycota, which represent the Phyla properly included in the Kingdom of Fungi. It has been estimated that on Earth there are from 1 to 1.5 million species of fungi. The diversity of form in fungi, ranging from unicellular yeasts to the North-American basidiomycete, *Armillaria bulbosa*, one of the largest and the oldest organisms, is

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outlined here.

2.1. Hyphae and mycelium

Mycelium is the vegetative thallus of a fungus, composed of radiating hyphae. The hypha is essentially a rigid-walled tube enclosing moving protoplasm (cytoplasm). It has an indeterminate length but the diameter is constant depending on the species and growth conditions. Hyphae grow only at their tips; while the tip is growing, the protoplasm moves continuously from the older regions of the hypha to supply the tips with materials for growth. Hyphae of most Chytridiomycota and Zygomycota are without cross-walls (septa, sing. septum) except where they occur as complete barriers to isolate old or reproductive regions. The aseptate fungi have many nuclei in a common cytoplasm, so these fungi are coenocytic. Ascomycota, Basidiomycota and mitosporic or conidial fungi have septa at fairly regular intervals with pores through which cytoplasm can migrate towards the growing tip. Septate hyphae do not consist of completely separate cells but of interconnected compartments. The septate fungi usually have several nuclei in the apical compartment but often one or two in compartments behind the apex. In general, septa can be of two types: simple septa with a large central pore are typical of Ascomycota and the related conidial fungi, whereas a dolipore septum with a narrow central pore and bracket-shaped membranous structures (parenthosomes) is typical of Basidiomycota. Cytoplasmic organelles and nuclei can pass through simple septa; conversely, dolipore septa allow cytoplasm continuity but preclude the passage of major organelles. Clamp connections ensure regular distribution of nuclei in dikaryotic (binucleate) hyphae of Basidiomycota. Such connections are structures of the binucleate hyphae of basidiomycetes, which allow pairing of different nuclei; a short and reversed cell outgrowth fuses with the preceding cell, thus providing a gateway for one of the nuclei produced during synchronous division of the binucleate cell. Septa develop as centripetal ingrowths from the hyphal wall with an inner region of chitin overlaid by proteins and glucans.

Hyphal branches arise by the development of new apices due to the synthesis of new protoplasm; they often originate immediately behind the septa. There is a relationship between cytoplasm volume, nuclear division and branching. When a critical volume has been synthesized, the nucleus divides and a septum is laid down at the point of nuclear division, originating two cells. The new apical cell grows on and repeats the whole process. The penultimate cell produces a new branch apex and its protoplasm flows into this one.

Hyphal compartments, i.e. fungal cells, contain different organelles such as nuclei, mitochondria, vacuoles, endoplasmic reticulum, Golgi bodies or dictyosomes, lipid bodies and vesicles.

Several differentiated hyphal structures serve specific functions. Stromata (sing. stroma) are compact mycelial structures on or in which fructifications are usually formed. Sclerotia (sing. sclerotium) are specialized hyphal bodies involved in long term survival in a dormant state, in soil. Three different layers can be distinguished: a thin outer rind, an interior cortex of thick-walled melanized cells, and a central medulla where nutrients are stored. Sclerotia can have different dimensions and are typical of several pathogenic

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fungi, namely *Corticium rolfsii*, *Sclerotinia sclerotiorum*, *Claviceps purpurea*, *Verticillum albo-atrum*, and *Rhizoctonia solani.*

Other hyphal structures are mycelial cords and rhizomorphs, which ensure nutrient transport through nutrient-free environments. These structures are common in wood-rotting and root-rotting fungi. Mycelial cords are also present in fungi forming ectomycorrhizal symbiosis with roots of higher plants, and at the base of larger mushrooms and toadstools to drive nutrients for fruiting body development. Rhizomorphs are typical of *Armillaria mellea*, a major root-rot pathogen, which spreads from tree to tree by growing as rhizomorphs through soil and spreading up to the trunks of diseased trees beneath the bark. Rhizomorphs have a thick-walled melanized outer cell layer and they resemble bootlaces. These structures can extend much more rapidly than the undifferentiated hyphae, but they need to be attached to a food base because their growth depends on nutrient translocation. Does this mean that " ... their growth depends on their ability to transport nutrients along the length of the rhizomorph.

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Biographical Sketches

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