

Fungi under the Microscope

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If someone totally unacquainted with mycology asks me "What are fungi?" I am reduced to reminding him of the few examples of this diverse group with which he may be familiar. "Mushrooms and toadstools, bracket fungi, puffballs, yeast, green and black moulds, wheat rust" I say, and he is satisfied. But the mycologist learns early that this catalogue is far from complete. Even the list of common names can be extended - smuts, mildews, ergot, cup fungi, coral fungi, jelly fungi, earth stars, stinkhorns, bird's-nest fungi - and most microfungi lack common names altogether. Almost 100,000 different species of fungi are already known, and hundreds of previously unobserved ones are described every year in scientific publications.

The fungi have been of considerable historical importance. For millennia, man has used the fermenting powers of yeast in the making of beer, wine and bread. The Romans were accustomed to using certain fungi as food, and were also quite familiar with wheat rust. Successive failures of the potato crop caused by epidemics of late blight fungus led to the Irish famine of the 1840's, and resulted in the emigration of a million people to the New World. In the 1870's, the introduction from the New World of the downy mildew fungus attacking grape vines almost ruined the French wine growing industry. If Professor Millardet had not invented the fungicidal Bordeaux mixture, the French might today be drinking beer - or even milk. It was the coffee rust fungus which forced Ceylon to switch from coffee growing to tea plantations. World-wide decay of timber and spoilage of stored food is caused by these ubiquitous organisms. On the positive side the fungi play a vital role in the decay of most forms of organic matter, performing essential steps in the carbon and nitrogen cycles. Of more immediate concern to man are the many valuable by-products of fungal fermentation including alcohol, antibiotics, organic acids and vitamins; and we must not forget the delicious edible chanterelles, truffles, morels and mushrooms.

Most fungi are microscopic objects, and even the largest must be studied under the microscope if their structure and development are to be understood, and a proper

identification made. Fungi are strange, secretive creatures, neither plant nor animal by nature. They may be saprobic, existing on dead organic matter, or parasitic; but in either case they cannot photosynthesize as green plants do, and they do not ingest their food as many animals do. Many fungi live in a silent nether world, craving only moisture and a source of carbon and nitrogen as they creep stealthily about their vital work of decay. Their assimilative organs are wefts of fine branched tubes called hyphae, ramifying invisibly through the substrate, and we may not become aware of their activities until they have exhausted their food supply and their characteristic fruiting structures appear. Fungi generally reproduce by means of spores - tiny packets of cytoplasm and nuclei which can be carried over long distances by wind, water, or animal vectors, remaining dormant until favourable conditions arise. Most classifications of the fungi reflect the ways in which sexual reproduction is achieved, then the often highly individual structures on or in which spores are produced, and finally the features of the spores themselves. By these criteria, we divide the fungi into three large natural groups, the Phycmycetes, Ascomycetes and Basidiomycetes.

The Phycmycetes comprise the lower fungi, a rather diverse group, many of which have motile reproductive cells at some stage in their life history, either living in water or needing free water for dispersal. The highest Phycmycetes, however, have become truly terrestrial, and lost their motile cells, their sexual processes now involving the production of zygospores. A zygospore of **Phycmyces** is shown in Fig. 1. Two specialized hyphae containing compatible nuclei touch, and nuclear fusion follows. In **Phycmyces** the two suspensor hyphae develop dichotomously branched, antlerlike outgrowths which may serve to protect the maturing zygospore from the browsing activities of tiny animals.

The second major group, the Ascomycetes, characteristically produce meiospores (spores formed after reduction division) inside tiny sacs called asci. These asci may be naked, as in the yeasts and the peach leaf curl fungus, or enclosed in a fruit body called an ascocarp, as in **Eurotium** (Fig. 2). Here

the asci are spherical and randomly arranged in what we believe to be their primitive condition, but in most Ascomycetes, such as *Sordaria* (Fig. 4) they are cylindrical and develop from a definite hymenial layer. The eight meiospores in each ascus of *Sordaria* are all derived from a single fusion nucleus, meiotic division preceding a final mitotic division. Two strains of *Sordaria fimicola* with different coloured ascospores were crossed to produce the ascocarp whose contents are shown in Fig. 4. The segregation of colour factors at first and second meiotic divisions is clearly shown. *Sordaria* and its relation, *Neurospora*, the red bread mould, have proved to be excellent tools for our explorations of fungal and biochemical genetics.

Although meiospores usually number eight in each ascus, in some groups there are many more, and in others, such as the subterranean but deliciously edible truffles, there may be only from one to four spores per ascus (Fig. 5). The powdery mildews are ascomycetes which cause foliage diseases of higher plants and are, in fact, obligate parasites. Their ascocarps often possess curiously branched appendages, such as that of *Microsphaera*, shown under phase contrast illumination in Fig. 3.

The third major group of fungi, the Basidiomycetes, produce their meiospores externally on structures called basidia. Following nuclear fusion the haploid condition is restored by meiosis, and in Fig. 8 the four products of meiotic division can be seen just prior to their migration into the four developing basidiospores. Normally these basidiospores are forcibly shot off when mature by a mechanism as yet only partially understood. In the higher Basidiomycetes, of which the mushrooms and toadstools (agarics) are the best known examples, the basidia are produced on thin vertically oriented plates of tissue called gills or lamellae. Fig. 7 shows a section through a lamella of *Coprinus*.

The wheat rust fungus is a specialized kind of obligately parasitic Basidiomycete with a very complex life history involving four kinds of spore and two different host plants, wheat

and barberry. The spores shown in Fig. 6 are called uredospores, and it is these which, produced in reddish masses on wheat during the summer, give the disease its name and by their rapid airborne dispersal permit its build-up to epidemic proportions. The germ pores at the equator of each uredospore allow its rapid germination if it lands on a susceptible host plant.

Most fungi reproduce asexually as well as sexually. Asexual reproduction is basically very simple, involving neither nuclear fusion nor reduction division, and in many Ascomycetes asexual spores known as conidia represent the main dispersal mechanism during the growing season, sexual reproduction occurring only in spring or autumn. A very large group of fungi are only known to reproduce asexually, and are therefore termed Fungi Imperfecti. A few have affinities with the Basidiomycetes, but most resemble conidial states of Ascomycetes. Thus the Fungi Imperfecti are not a particularly natural assemblage, but they are nevertheless a very important group, causing many plant and animal diseases, and producing antibiotics like Penicillin.

Finally I must mention the Lichens. These are composite organisms, intimate associations of an alga and fungus. Their fructifications, however, are typically those of the fungal component, usually an Ascomycete, and their taxonomy is essentially that of the fungus.

The foregoing text and the accompanying photomicrographs present only a brief glimpse of the fungi, but I hope they will stimulate someone's interest in this fascinating and infinitely varied group of organisms. Further reading is suggested below.

The photomicrographs were all taken on a ZEISS photomicroscope using 35 mm Kodachrome II daylight film with the appropriate Wratten colour correction filter.

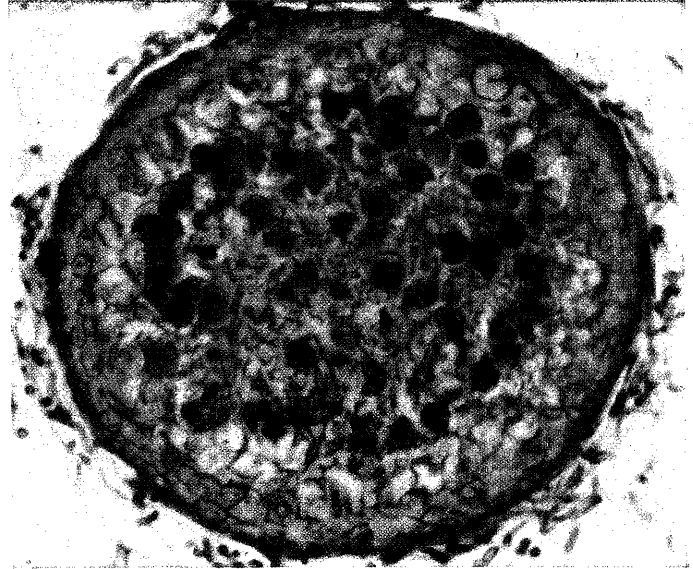
I have found that, with this combination, excellent colour photomicrographs can be obtained both under bright-field and phase-contrast illumination.

References

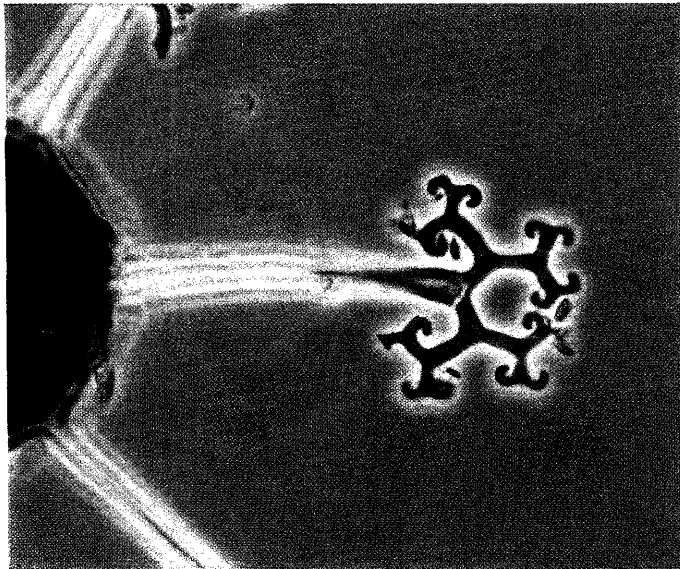
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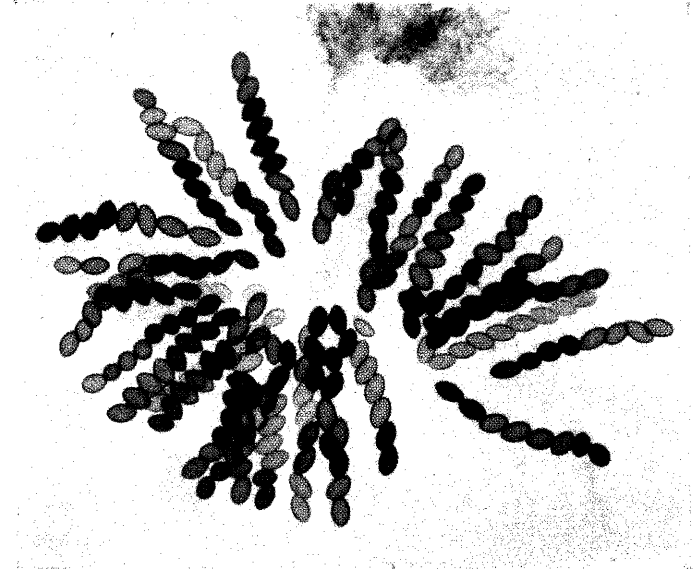
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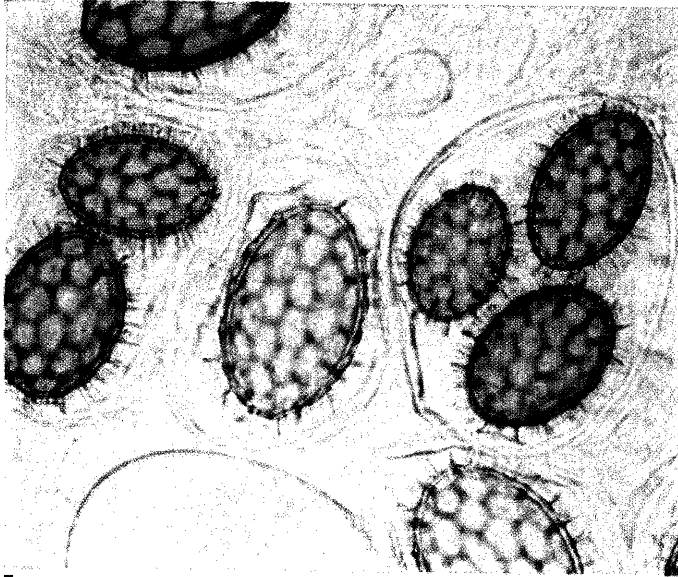
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Fig. 1: *Phycomyces*, whole mount of zygospore with dichotomously branched appendages growing from suspensor cells.

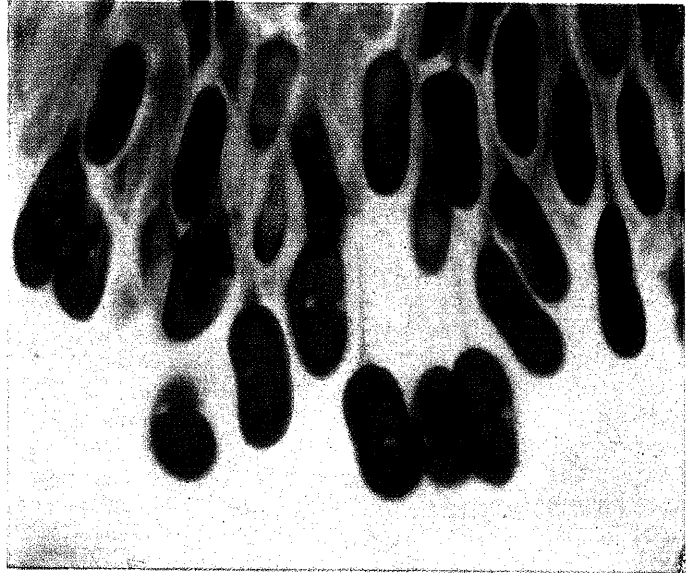
Fig. 2: *Eurotium* cleistothecium, vertical section, showing randomly arranged, spherical asci.

Fig. 3: *Microsphaera*, whole mounts of cleistothecium showing a characteristic dichotomously branched appendage under phase-contrast illumination.

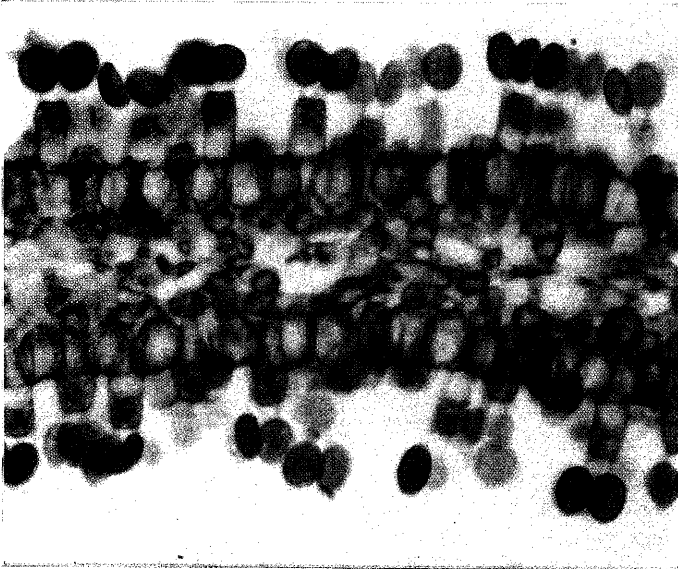
Fig. 4: *Sordaria fimicola*, perithecial squash, showing 8-spored asci, with segregation of ascospore colour factors at first and second meiotic divisions.



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Fig. 5: **Tuber** (truffle) asci containing one, two and three ascospores.

Fig 6: **Puccinia graminis tritici** (wheat rust) uredospores with equatorial germ pores.

Fig. 7: **Coprinus** (inky cap mushroom) section of a lamella with numerous basidia, each bearing four basidiospores.

Fig. 8: **Coprinus** basidia and basidiospores: note the four nuclei resulting from reduction division after nuclear fusion.