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Fungi

Organisms

Arthrinium Kunze 1817 : Fries

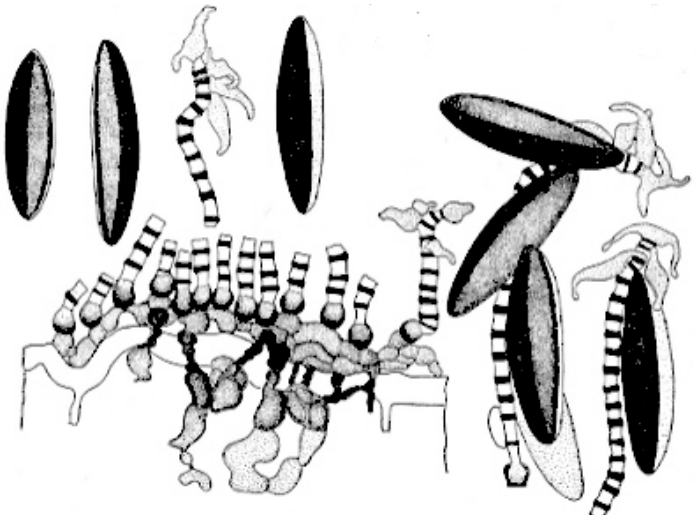
Classification - Hyphomycetes, anamorphs of ***Apiospora, Physalospora, Pseudoguignardia*** (***Apiosporaceae***, Ascomycetes). About 30 species.

Relevance - Found in spore traps. Potentially allergenic.

Identification - Characterized by (1) single, dry, darkly pigmented amerospores (lenticular, narrowly ellipsoidal and bicolored, angular, curved and with or without 2 horns), having (2) conspicuous germ slits, arising laterally from (3) basauxic conidiogenous hyphae, which develop from (4) phialide-like mother cells.

Ecology - Occur on grasses (plus rushes and sedges) and other plants. Cosmopolitan.

References - Ellis (1965) Mycol. Pap. 103: 1-33 (Monograph, Key).
Ellis (1971) Dematiaceous Hyphomycetes pp. 567-575 (Key)



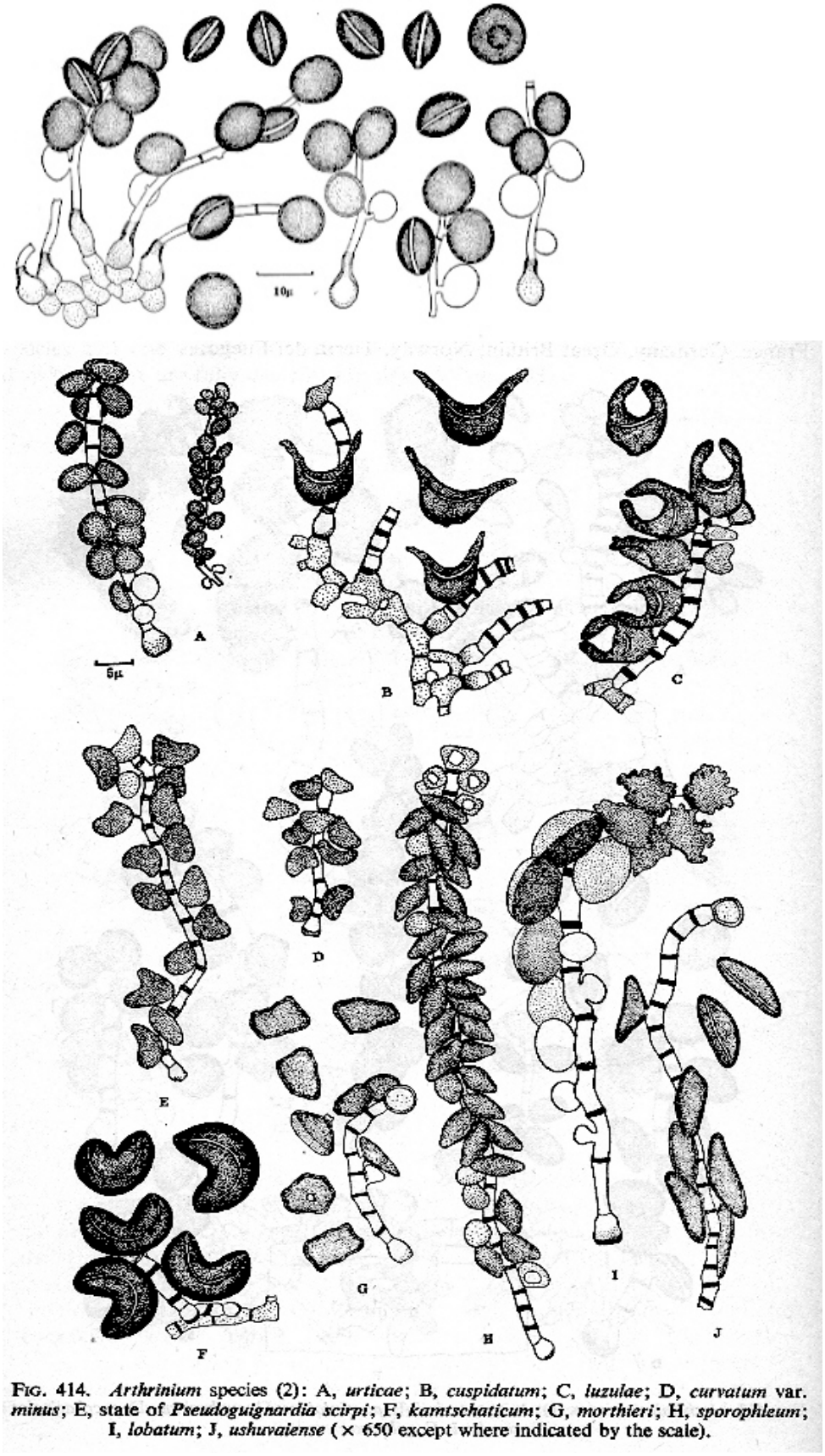


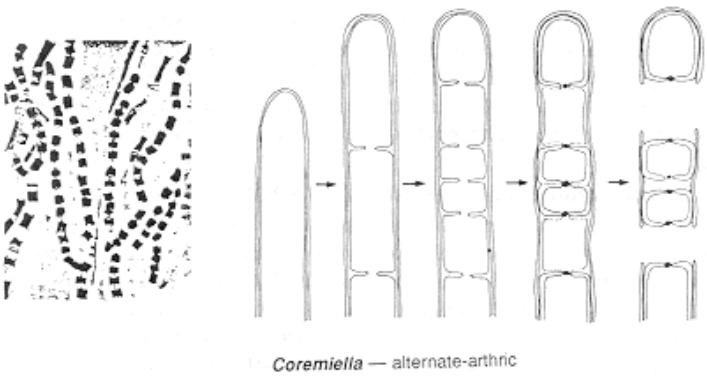
FIG. 414. *Arthrinium* species (2): A, *urticae*; B, *cuspidatum*; C, *luzulae*; D, *curvatum* var. *minus*; E, state of *Pseudoguignardia scirpi*; F, *kamtschaticum*; G, *morthieri*; H, *sporophleum*; I, *lobatum*; J, *ushuvaiense* (× 650 except where indicated by the scale).

Arthrospores

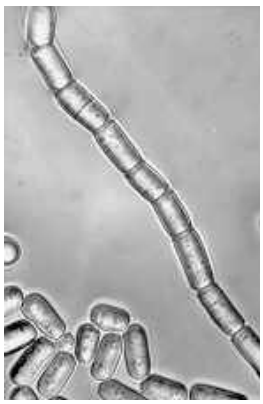
Arthrospores are essentially cells of a hypha which split up at the cross-walls (septa) and behave as individual, independent conidia (asexual spores, mitospores). They are produced by some hyphal yeasts (e.g. ***Geotrichum***), and by the anamorphs of many basidiomycetes. The hyphomycete genus ***Oidiodendron*** produces them by the fragmentation of the branches of an upright conidiophore.

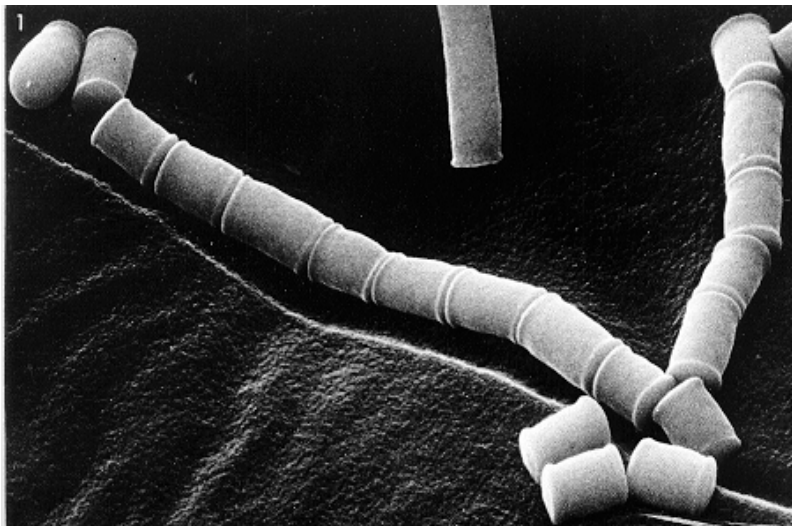
Identification - We can usually recognize arthrospores (I call them thallic-arthric conidia) by their short-cylindrical shape with more or less truncate ends.

References - Kendrick (2007) The Fifth Kingdom on CD-ROM. Chapter 4a.



Geotrichum Arthrospores - SEM





Ascospores

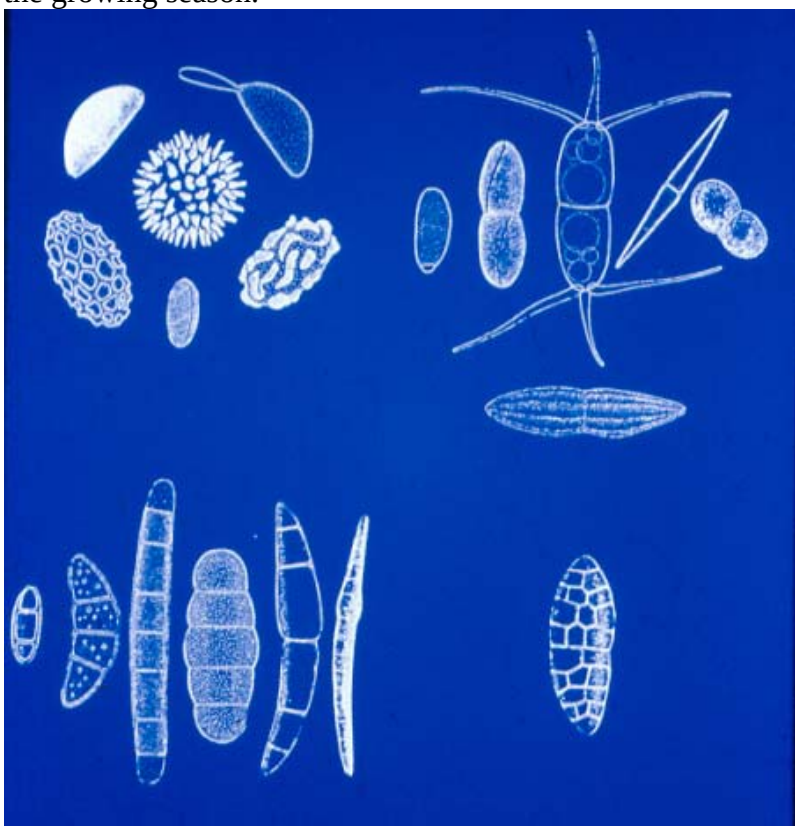
Classification - sexual spores of a very wide range of Ascomycetes**.** These meiospores are produced inside tubular, sac-like or globose cells (meiosporangia) called asci (singular, ascus q.v.). The usual number of ascospores in an ascus is 8, but it can range from 1 through 2, 4, 8, 16, 32, 64, 128, and exceptionally to 256, 512, 1024 to 2048. If ascospores are very long and thin, even if there are only 8 they sometimes break up into a large number of part-spores (as in

Cordyceps). They may be amerosporous (as in ***Chaetomium***), didymosporous, phragmosporous, scolecosporous or dictyosporous, but are almost never helicosporous (coiled) or staurosporous (with projecting arms), because such shapes would not fit or develop comfortably inside an ascus. They may be smooth-walled or variably ornamented, and pigmented or colorless.

Relevance - The fungi producing these spores occur on a very wide range of substrates, and the spores are in most cases propelled forcibly into the air a maturity, and are thus present in the air spora.

Identification - Ascospores almost always lack a dehiscence scar at the base, usually being rounded at both base and apex. They are sometimes shot out in groups of 8.

Ecology - Ascomycetes grow on a huge variety of substrates, living and dead. Ascomycetes with macrosopic ascomata tend to fruit in Spring, but microscopic forms sporulate throughout the growing season.



This illustration shows something of the range of size, shape and septation possible in ascospores. The one with appendages is an aquatic form - here the ascospores are not forcibly ejected.

Other kinds of appendage, often gelatinous, are found on ascospores of dung-inhabiting fungi, in which the spores must adhere to food plants in order to be ingested by the appropriate animal.

References - Breitenbach & Kraenzlin (1984) Fungi of Switzerland Vol. 1. Ascomycetes.

Dennis (1968) British Ascomycetes. 455 pp. + 40 color plates and 31 monochrome plates.

Aspergillus Micheli ex Link 1809 : Fr.

Classification - Hyphomycetes, often asexual states of ***Trichocomaceae*** (Ascomycetes) including ***Eurotium, Emericella, Edyuillia, Neosartorya, Fennellia, Warcupiella, Hemicarpenteles, Sclerocleista***. About 280 species. Many are anamorphic holomorphs (have no teleomorph).

Relevance - grows commonly on many indoor substrates, including paper, and is involved in food spoilage and contamination with serious mycotoxins, esp. aflatoxins, which are highly carcinogenic. Esp. common contaminant of peanuts, but also found in many other foods. Also causes a lung disease called Aspergillosis (especially common in wild birds), and sometimes causes lung tumours called Aspergillomas. If conidiophores are not seen, the conidia are usually lumped with the similar spores of ***Penicillium***.

Identification - Easily recognized by: (1) the swollen, vesiculate apex of the unbranched conidiophore, which (2) bears either a layer of phialides (conidiogenous cells), or an additional layer of supporting cells (metulae) below the phialides, (3) the amerosporous, often globose conidia, which are borne in parallel chains, (4) are often some shade of green or grey (occasionally yellow, brown or black), (5) and are dry and hydrophobic..

Ecology - many species prefer warmer temperatures, and the genus is more diverse in the tropics.

References - Raper and Fennell (1965) The genus ***Aspergillus***. Williams and Wilkins. Wang and Zabel (1990) Fungi from Utility Poles pp.186-191.

Aureobasidium Viala & Boyer 1891

Classification - Hyphomycetes 'Black yeasts', asexual states of ***Potebniamyces***, ***Dothidea***, ***Muellerites***, ***Discosphaerina*** (***Dothideaceae***, bitunicate ascomycetes). Three species. ***Aureobasidium pullulans*** is apparently a holomorphic anamorph (has no known teleomorph).

Relevance - Very common phylloplane fungus, in soil, on wood, on paint and many other substrates. Often seen on tape-lifts.

Identification - Not easy, since this fungus is very variable (as the illustration, from Wang and Zabel, shows). (1) Hyphae are brown, monilioid, often modified to (2) brown, thick-walled chlamydospores, but also producing (3) endogenous spores, and (4) slimy, yeast-like, amerosporous conidia. Compare with ***Hormonema***.

Ecology - very common in nature, especially on living leaves, but also on many substrates in houses.

References - Cooke (1962) Mycopath. Mycol. Appl. 17: 1-43.
Hermanides-Nijhof (1977) Stud. Mycol. 15: 141-177 (Monograph, Key).
Wang & Zabel (1990) Fungi from utility poles pp. 192-193 (Illus.)

Basidiospores - exogenous meiospores produced by Basidiomycetes on basidia: usually 4 per basidium. (These spores arise from a meiotic nuclear division that takes place inside a basidium; they are borne at the ends of narrow projections called sterigmata). Most basidiospores are unicellular (amerospores). They are actively shot away from the sterigmata into the air, and the shooting mechanism requires that they be borne asymmetrically. They usually have a small projection to one side near the base (the apiculus) which betrays their origin.
Basidiospores are produced on the gills (lamellae) of mushrooms, inside the tubes of boletes and bracket fungi, and on the smooth hymenia (fertile layers) of many resupinate fungi.

Bipolaris Shoemaker 1959

Classification - Hyphomycetes, asexual states of ***Cochliobolus*** (***Pleosporales***, bitunicate ascomycetes). About 75 species.

Relevance - Mostly subtropical and tropical, causing diseases of grasses, but sometimes occurring on wood. Spores become airborne. Several species are well documented human

pathogens, causing mycotic keratitis, subcutaneous phaeohyphomycosis, sinusitis, peritonitis in patients on continuous ambulatory peritoneal dialysis (CAPD), and cerebral and disseminated infections. Phaeohyphomycosis has been reported in both normal and immunosuppressed patients.

Identification - Recognized by (1) its single, upright, brown conidiophores which extend sympodially, sometimes becoming geniculate, producing (2) single, dry, brown, smooth-walled, ellipsoidal or fusiform, phragmoseptate, distoseptate conidia with rounded apex and truncate base. (3) Conidia and conidiophore have flat, dark dehiscence scars. Compare with ***Drechslera*** and ***Exserohilum***.
Diagnostic features: conidia fusiform-ellipsoidal, central cells not much darker and broader than end cells, basal scar not protuberant, germination bipolar.

Ecology - Basically plant parasites, mostly on grasses.

References - Luttrell (1963) Mycologia 55: 643-674.
Alcorn (1983) Mycotaxon 17: 1-86.
\Sivanesan (1987) Mycol. Pap. 158: 1-261 (Monograph, Key)

Botrytis Micheli ex Persoon 1794 : Fries

Classification - Hyphomycetes, asexual states of ***Botryotinia*** (***Sclerotiniaceae***, ***Helotiales***, inoperculate discomycetes, Ascomycetes). About 25 species.

Relevance - Occurs on a very large number of plants, esp. on senescent or dead flowers and fruits. Spores become airborne.

Identification - Recognizable by (1) the broad, pale brown, branched conidiophores, with branches ending in (2) swollen or vesicular conidiogenous cells which produce (3) blastic-synchronous, dry, smooth-walled, amerosporous conidia which are readily deciduous.

Ecology - Extremely common, cosmopolitan colonizers of dead flowers and over-ripe fruits (notably grapes - the famous ‘noble rot’) in Fall.

References - Hennebert & Groves (1963) Can. J. Bot. 41: 341-370.
Ellis (1971) Dematiaceous Hyphomycetes pp. 178-184 (Key).
Hennebert (1973) Persoonia 7: 183-204.
Coley-Smith et al. (Eds.) (1980) The Biology of ***Botrytis***. Academic Press. 318 pp.

Cercospora Fresenius 1863

Classification - Hyphomycetes, asexual states of ***Mycosphaerella***, ***Sphaerulina*** (***Mycosphaerellaceae***, ***Dothideales***, bitunicate ascomycetes)**.** About 660 species.

Relevance - Spores commonly recovered from air, esp. during the growing season.

Identification - The genus is easily recognized by: (1) its colorless phragmoseptate conidia which are very long (scolecospores), gradually tapering from base to apex, have (2) a wide, dark scar at the base, and are produced from (3) sympodially extending conidiogenous cells. Brown to almost colorless. Chupp's 1954 monograph employed a broad generic concept, and although as many as 50 segregate genera have since been proposed, the tendency now ids to accept a core of four - ***Cercospora, Passalora, Pseudocercospora*** and ***Stenella***. Many species are described each year, usually based on host differences.

Ecology - Causes leaf disease of many plants.

References - Chupp (1954) Monograph of the genus ***Cercospora*** 667 pp. Ithaca.
Deighton (1959) Mycol. Pap. 71: 1-23.
Ellis (1976) More Dematiaceous Hyphomycetes pp. 243-293 (Keys).

Chaetomium Kunze 1817

Classification - ***Chaetomiaceae, Sordariales*** (Ascomycetes): some species have anamorphs in ***Acremonium, Botryotrichum, Paecilomyces, Scopulariopsis, Trichocladium.*** No anamorph is known for the common cellulolytic species ***C. globosum.***

Relevance - grows commonly on indoor substrates containing cellulose, especially carpets and paper. Some species are thermophilic, some are toxigenic.

Identification - The genus is easily recognized by: (1) ascomata with profuse brown hyphal appendages which may be coiled, sinuous, or dichotomous, (2) brown, lemon-shaped or football-shaped ascospores which are freed at maturity when the asci break down.

Ecology - the ascomata appear on many cellulosic substrates in all parts of the world, but especially in warmer areas: on dung, straw, wet paper, cotton fibres, etc.

References - Ames (1961) A monograph of the ***Chaetomiaceae***. U.S Army R&D Series #2. 125 pp. (Key)
Von Arx et al. (1986) Beih. Nova Hedwigia 84 (Keys).

Cladosporium Link 1815 : Fries

Classification - Hyphomycetes - asexual states of ***Davidiella***, (***Pleosporales***, bitunicate ascomycetes) often identified as ***Mycosphaerella***. About 80 species.

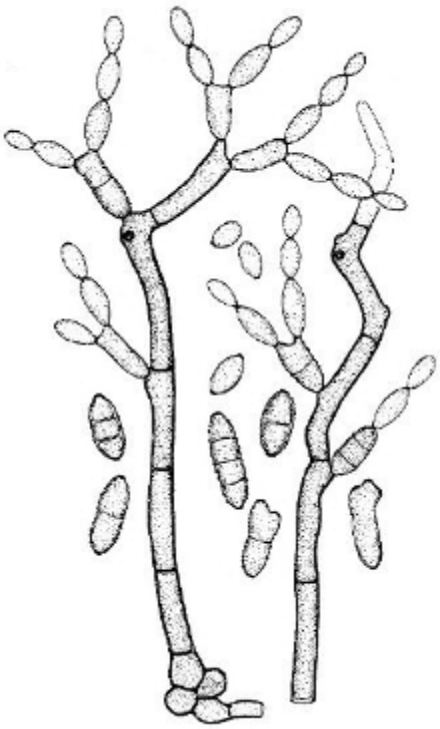
Relevance - The most common airborne fungus. Its conidia commonly make up 35%, and sometimes up to 90%, of all spores in the air. It grows on a wide range of organic substrates, and is commonly found inside buildings. It can cause skin lesions, keratitis, onychomycosis,

sinusitis and pulmonary infections.

Identification - easily identified on tape lifts and other non-viable analyses by conidia which are: (1) darkly (though variably) pigmented, (2) very variable in size, and anything from spherical to spindle-shaped, (3) mostly amerospores, but some didymospores and some up to several-celled phragmospores, (4) with distinct, usually darker, narrow basal and apical scars, (5) produced in sometimes branched acropetal chains (extending at the tip and easily disarticulating), (6) characteristically, some conidia are ramoconidia, with one scar at the base, and two (occasionally three) at the apex, showing where the chain of conidia branched.

Ecology - grows on dead leaves and stems of many plants, and on the surface of wood and paper indoors. Spore chains easily disarticulating and wind dispersed.

References - Ellis, M.B. (1971) Dematiaceous Hyphomycetes pp. 308-319 (Key).
Ellis, M.B. (1976) More Dematiaceous Hyphomycetes pp. 325-344 (Key).



Curvularia Boedijn 1933

Classification - Hyphomycetes, asexual states of ***Pleosporaceae*** (bitunicate ascomycetes) About 45 species.

Relevance - commonly isolated from air, commonly cause seed-borne diseases of plants, esp. cereals; may (rarely) cause phaeohyphomycosis, keratitis, allergic sinusitis, cerebral abscess, cerebritis, pneumonia, allergic bronchopulmonary disease, endocarditis, dialysis-associated peritonitis, and disseminated infections.

Identification - The genus is easily recognized by: (1) its conidia, which are usually slightly curved, brown, dry, single, phragmoseptate (3 or more septa), with wider and often darker central cells (conidia of some species look like croissants, or boomerangs, others are almost straight); (2) conidia often have dark scars at the base, and are produced (3) on brown, sympodially extending conidiogenous cells, often aggregated in stromata.

Ecology - grow on many plants, especially cereals, in all parts of the world, sometimes causing disease.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 452-459. (Key)
Ellis (1966) Mycol. Pap. 106: 1-57. (Revision, Key)
Sivanesan (1987) Mycol. Pap. 158: 1-261. (Revision, new spp.)

Drechslera Ito 1930

Classification - Hyphomycetes, asexual states of ***Pyrenophora*** (***Pleosporales***, bitunicate ascomycetes). About 30 species.

Relevance - Occur on leaves and seeds of grasses and other plants; spores become airborne.

Identification - Recognized by (1) its single, upright, brown conidiophores which extend sympodially, sometimes becoming geniculate, producing (2) single, dry, brown, smooth-walled, cylindrical or fusiform, phragmoseptate, distoseptate conidia with rounded apex and truncate base. (3) Conidia and conidiophore have dark dehiscence scars. (4) Conidia are usually straight, but occasionally curved. Compare with ***Bipolaris*** and ***Exserohilum***.

Ecology - Sporulate on soil and plants.

References - Ellis (1971) Dematiaceous Hyphomycetes pp.403-452 (Key)
Ellis (1976) More Dematiaceous Hyphomycetes pp. 396-404 (Key)
Alcorn (1983) Mycotaxon 17: 1-86.

Epicoccum Link 1815 : Fr.

Classification - Hyphomycetes, producing dark sporodochial conidiomata. No teleomorphs known. About 5 species described.

Relevance - grows commonly on stems and leaves of many plants.

Identification - The genus is easily recognized by: (1) its large, rounded, dry, rough-walled, dark, dictyoseptate, single conidia, which are produced in (2) small sporodochial conidiomata (many conidia of different ages develop in a clump). Note that (3) the internal septa are often

rather indistinct.

Ecology - grow on many substrates in all parts of the world: plants, soil, foodstuffs, and spores are isolated from air.

References - Schol-Schwarz (1959) Trans. Brit. Mycol. Soc. 42: 149-173.
Ellis (1971) Dematiaceous Hyphomycetes p. 72.

Exosporiella P. Karst. 1892

Classification - Hyphomycetes, anamorph of ***Anomolemma*** (***Dothideales***, bitunicate ascomycetes). One species.

Relevance - Not high. Found only occasionally.

Identification - Easily recognizable by its caudate pigmented phragmoconidia. These conidia arise from colorless percurrent conidiogenous cells, which occur in a palisade.

Ecology - Occur on fungi (***Corticium***).

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 148-149.

Exserohilum Leonard & Suggs 1974

Classification - Hyphomycetes, asexual states of ***Setosphaeria*** (***Pleosporales***, bitunicate ascomycetes). About 30 species.

Relevance - Occurs on leaves of grasses, spores become airborne. May be agents of phaeohyphomycosis - clinical manifestations include mycotic keratitis, subcutaneous phaeohyphomycosis, endocarditis, osteomyelitis and sinusitis in both normal and immunosuppressed patients.

Identification - Recognized by (1) its single, upright, brown conidiophores which extend sympodially, with scars, and sometimes becoming geniculate, producing (2) single, dry, brown, smooth-walled, cylindrical or fusiform, phragmoseptate, distoseptate conidia with rounded apex and (3) protuberant basal scar. Compare with ***Bipolaris*** and ***Drechslera.***
Diagnostic features: conidia with a **protuberant basal scar**, fusiform-cylindrical to obclavate, germination bipolar.

Ecology - Found commonly on plants and in soil.

References - Honda & Aragaki (1978) Mycologia 70: 547-555.
Alcorn (1986) Mycotaxon 17: 1-86
Sivanesan (1987) Mycol. Pap. 1-261 (Key).
McGinnis, M.R., M.G. Rinaldi and R.E. Winn. (1986) Emerging agents of Phaeohyphomycosis: pathogenic species of ***Bipolaris*** and ***Exserohilum***. J. Clin. Microbiol. 24:250-259.

Fusarium Link 1809 : Fr.

Classification - Hyphomycetes, asexual states of ***Nectriaceae*** (Ascomycetes) About 150 species.

Relevance - Very important mycotoxin producers (trichothecenes such as vomitoxin, zearalenone). These toxins contaminate many foods such as corn, and are dangerous to livestock.
Cause wilts of many plants. May also cause opportunistic infections of humans.

Identification - The genus is easily recognized by its curved, colorless, slimy phragmospores which often have a distinctly angled foot cell. Didymospores and amerospores may also be produced. The macroconidia just described may be accompanied by small, globose microconidia, and by chlamydospores or small sclerotia.

Ecology - A common soil fungus which causes important plant diseases (esp. wilts).

References - Booth (1971) The Genus ***Fusarium*** Commonw. Mycol. Inst. 236 pp.
Nelson et al. (1983) ***Fusarium*** species, an illustrated manual for identification. Penn. State Univ. Press 193 pp.
Chelkowski (Ed.) (1989) ***Fusarium***, mycotoxins, taxonomy and pathogenicity. Elsevier 492 pp.

Fusicladium Bonorden 1851

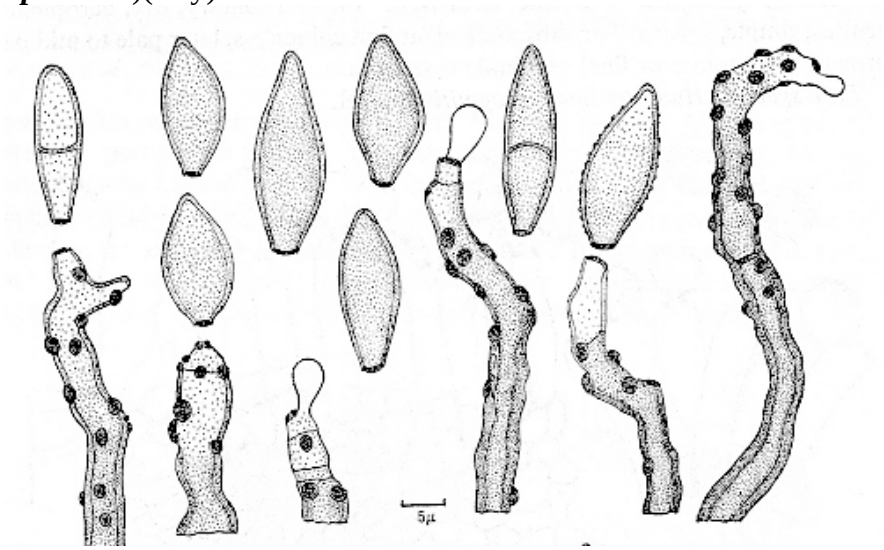
Classification - Hyphomycetes, anamorphs of ***Venturia*** (***Venturiaceae, Dothideales***, bitunicate ascomycetes). 56 species.

Relevance - The dry spores readily become airborne, and can be allergenic.

Identification - Recognized by its (1) dry, single, brown, smooth-walled or slightly roughened, amerosporous or didymosporous conidia (1- or 2-celled; non-septate or 1-septate), which are (2) flame-shaped, tapering to a narrow apex, and with a dark scar at the narrowly truncate base. These are produced from (3) a sympodially extending conidiogenous cell which becomes conspicuously cicatrized as a result of repeated conidiogenesis. The conidiophores are localized on (4) dark stromata developing on leaves or fruit. The genus ***Spilocaea*** also contains anamorphs of ***Venturia***, and differs only in its percurrent conidiogenesis.

Ecology - Occur on leaves, shoots, bud scales, flowers and fruit of pear trees, causing scab, and on Betula, Hevea, Malus, Populus, Prunus, Pyrus and others. Cosmopolitan

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 141-143, 271-273 (partly as ***Pollaccia, Spilocaea***).
Ellis (1976) More Dematiaceous Hyphomycetes pp. 109-114, 237-240 (partly as ***Pollaccia, Spilocaea***)(Key).



Graphium Corda 1837

Classification - Hyphomycetes, asexual states of ***Petriella***, ***Pseudoallescheria***, ***Kernia*** (***Microascales***, Ascomycetes). About 15 species.

Relevance - Found on wood, litter, hydrocarbon-contaminated soil and humans.

Identification - Has (1) determinate, darkly pigmented, synnematal conidiomata with (2) numerous apical, conspicuously percurrent conidiogenous cells producing (3) a mass of slimy, amerosporous conidia. Compare with ***Pesotum***, which contains synnematal asexual states of the ***Ophiostomatales*** (Ascomycetes) and has various kinds of conidiogenesis.

Ecology - Saprobic mold, grows on hydrocarbon-contaminated soils.

References - Booth (1964) Mycol. Pap. 94: 1-16.
Von Arx et al. (1988) Beih. Nova Hedwigia 94: 1-162 Seifert & Okada (1993) in Wingfield et al. (Eds.) ***Ceratocystis*** and ***Ophiostoma***. pp. 27-42.

Hormonema Lagerberg & Melin 1927

Classification - Hyphomycetes, 'black yeasts', asexual states of ***Sydowia***, ***Xenomeris***, ***Guignardia***, ***Dothiora***, ***Pringsheimia***, ***Potebniamyces*** (***Dothideales***, bitunicate ascomycetes). About ten species.

Relevance - Occurs on wood in dwellings; detected by tape lifts.

Identification - Has (1) dark, monilioid chains of chlamydospores, often becoming dictyoseptate with age, bearing (2) lateral percurrent conidiogenous cells, producing (3) slimy amerosporous yeast-like conidia. Differs from ***Aureobasidium*** in having only 1-2 conidiogenous loci per cell, with inconspicuous percurrent extensions and slimy heads of conidia.

Ecology - On many plants, wood, wood pulp,

References - Hermanides-Nijhof (1977) Stud. Mycol. 15: 141-177 (Revision, Key)
Wang & Zabel (1990) Fungi from utility poles pp.236-237 (Illus.).

Monodictys Hughes 1958

Classification - Hyphomycetes, some asexual states of ***Tubeufia, Ohleria, Ascotawania, Hymenoscyphus, Nereiospora*** **(*Tubeufiaceae, Pleosporales***, bitunicate ascomycetes) but almost certainly heterogeneous. About 40 species.

Relevance - Sporulating mainly on wood.

Identification - Produces single, brown, dictyoseptate conidia on poorly differentiated, sessile conidiogenous cells. Size and shape of conidia vary widely among species, some verging on being bulbils.

Ecology - Occurs on wood, litter, leaves, lichens, soil and dung.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 68-70 (Key)
Ellis (1971) Mycol. Pap. 125: 1-30.
Ellis (1976) More Dematiaceous Hyphomycetes pp. 41-44 (Key).
Sivanesan (1984) Bitunicate Ascomycetes (Teleomorphs)

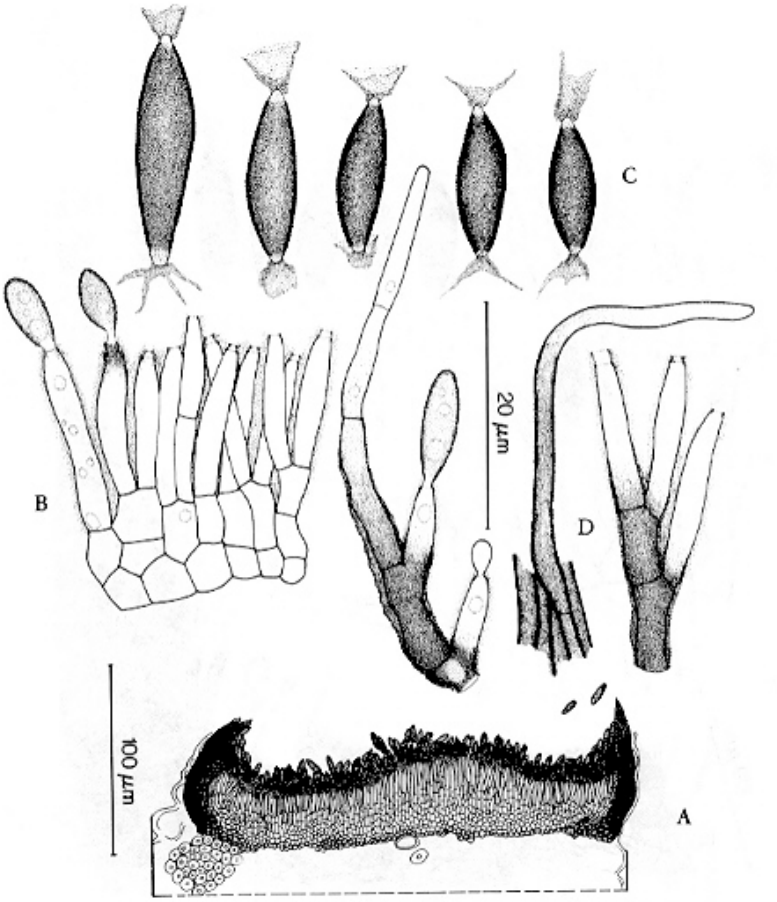
Myrothecium Tode 1790 : Fries

Classification - Hyphomycetes, anamorphs of ***Nectria*** (***Hypocreales***, Ascomycetes). About 30 species.

Identification - Characterized by (1) sporodochial or synnematal conidiomata producing (2) slimy, colorless or green, fusiform or bacilliform ameroconidia (with funnel-shaped mucoid appendage at one end or both ends, in some species) which arise from (3) phialides or percurrent conidiogenous cells on (4) penicillate conidiophores.

Ecology - Occurs on leaf litter, soil, fungi (esp. ***Russula***) and other substrates . Cosmopolitan.

References - Booth (1959) Mycol. Pap. 73: 1-115.
Ellis (1971) Dematiaceous Hyphomycetes pp. 552-556 (Key).
Tulloch (1972) Mycol. Pap. 130: 1-42 (Monograph).



Myxomycetes (slime molds)

Classification - These are actually members of Kingdom Protozoa (Phylum ***Myxostelida***), not fungi at all. However, their spores are common in the air. Since they are amerosporous, spherical, often darkly pigmented and ornamented, they are generally lumped in with spores of

smut fungi and the hyphomycete genus, ***Periconia***.

Relevance - Common in air, occasionally fruiting in water-damaged buildings, and spores possibly allergenic.

Identification - Difficult to differentiate from smut and ***Periconia*** spores, so usually lumperd with them. However, darkly pigmented spores belong to either ***Stemonitales*** or ***Physarales***. If some of the sporangium is recovered, the non-cellular, often ornamented capillitium (helical or spiny) may assist in identification.

Ecology - The somatic phase of slime molds is a visible plasmodium of naked, amoeboid, multinucleate protoplasm which lives in soil or rotting organic matter, ingesting bacteria and other small food particles. When it has accumulated enough food, or when triggered by climatic conditions (often in Fall), it may emerge and differentiate into variously configured sporangial fruiting bodies, the protoplasm having metamorphosed into spores, capillitium and supporting structures.

References - Frederick, L. (1990) Phylum plasmodial slime molds: class Myxomycota. pp. 467-483 (in) Handbook of Protoctista. (Eds.) L. Margulis, J.O. Corliss, M. Melkonian and D.J. Chapman. Jones and Bartlett, Boston.
Gray, W.D. and C.J. Alexopoulos (1968) Biology of the Myxomycetes. Ronald, New York.

Nigrospora Zimmerman 1902

Classification - Hyphomycetes, asexual states of ***Khuskia*** **(*Trichosphaeriales*, Ascomycetes)**
Four species.

Relevance - grows on many plants (***Musa, Oryza, Saccharum*****)** and in soil, and is often recorded from air.

Identification - The genus is easily recognized by: (1) its black, smooth-walled, almost spherical single, amerosporous conidia, which are borne on (2) paler, short, somewhat swollen, sessile conidiogenous cells.

Ecology - grow on many substrates in all parts of the world, but more particularly tropical.

References -
Ellis (1971) Dematiaceous Hyphomycetes pp. 319-320. (Key)
Wang & Zabel (1990) Fungi from Utility Poles pp. 256-257 (Illus.)

Oidium Link 1824

Classification - Hyphomycetes, asexual states of ***Erysiphales*** **(**powdery mildews**,** Ascomycetes**).**
About 440 species.

Relevance - obligately parasitic on leaves of a very large number of plants, commonly recorded from air later in the growing season.

Identification - The genus is easily recognized by: (1) its large, swollen, colorless, dry, thin-walled, amerosporous conidia, mostly truncate at base and apex, which develop (2) in basipetal gradually maturing chains arising from surfaces of living plants. Does not grow in axenic culture.

Ecology - sporulating on plants in dry summer weather and liberating numerous conidia into the atmosphere.

References -
Braun (1987) Monograph of the ***Erysiphales*** Beih. Nova Hedwigia 89: 10, 595-618.
Braun (1995) The powdery mildews (***Erysiphales***) of Europe. pp. 30, 221-228.
Belanger et al. (Eds.) (2002) The powdery mildews: a comprehensive treatise. APS Press, 292 pp.

Paecilomyces Bainier 1907

Classification - Hyphomycetes, asexual states of ***Byssochlamys, Talaromyces, Thermoascus, Chromocleista*** (***Trichocomaceae***, ***Eurotiales***, Ascomycetes)**.** About 45 species**.**

Relevance - grows on soil, fruit, wood, insects and many other substrates. Related to ***Penicillium***. May cause corneal ulcer, keratitis, and endophthalmitis following extended wear contact lens use or ocular surgery. ***Paecilomyces*** is among the emerging causative agents of opportunistic mycoses in immunocompromised humans.

Identification - The genus is recognized by: (1) its colorless conidiogenous cells (phialides) which have slightly swollen bases and long, tapered apices without collarettes, and are borne singly or in small verticils or clusters; from these arise (2) basipetal chains of small, dry, colorless, fusiform, amerosporous conidia.

Ecology - A very common mould on many substrates, soil, decaying plants, food products and insects. Conidia are often found in air.

References -
Brown & Smith (1957) Trans. Brit. Mycol. Soc. 40: 17-89. (Monograph)
Stolk & Samson (1974) Stud. Mycol. 6: 1-119. (Monograph)
Samson et al. (2000) Food- and Airborne Fungi 6th Edn. pp. 28-30, 170-173.

Penicillium Link 1809 : Fr.

Classification - Hyphomycetes, often asexual states of ***Trichocomaceae***, ***Eurotiales*** (Ascomycetes) including ***Eupenicillium, Talaromyces, Hamigera, Trichocoma, Dichlaena***.

About 250 species. Many are anamorphic holomorphs (have no teleomorph).

Relevance - grows commonly on many indoor substrates, and is involved in food spoilage and contamination with mycotoxins, esp. ochratoxins, patulin, PR toxin, and tremorgens such as penitrem. Can cause allergies, and may cause infections in immunocompromised individuals.

Identification - The genus is easily recognized by: (1) the 1-3- layered fan-shaped branching of metulae at the apex of the conidiophore, which (2) ultimately bear a layer of phialides (conidiogenous cells), (3) the small, amerosporous, often globose, sometimes rough-walled conidia, which are borne in parallel chains, (4) are often some shade of green, or blue-green, and (5) are dry and hydrophobic. Some species produce synnematal conidiomata. Species identification is difficult and best left to experts. If conidiophores are not seen, the conidia are usually lumped with the similar spores of ***Aspergillus***.

Ecology - this genus is more or less omnivorous and occurs on a wide range of organic substrates, in soil and (as spores) in the air.

References - Raper and Thom (1949) A manual of the Penicillia. Williams and Wilkins.
Pitt (1979) The genus ***Penicillium*** and its teleomorphic states ***Eupenicillium*** and ***Talaromyces***.
Wang and Zabel (1990) Fungi from Utility Poles pp. 268-275
Pitt (2000) A laboratory guide to common ***Penicillium*** species 3rd Edition, CSIRO, Australia. (Key)
Frisvad & Samson (2004) Stud. Mycol. 49: 1-174.

Periconia Tode 1791 : Fries

Classification - Hyphomycetes, asexual states of ***Lophiostoma***, ***Halosphaeria*** (***Lophiostomataceae***, bitunicate Ascomycetes)

Relevance - Spores commonly recovered from air.

Identification - This genus has (1) single brown conidiophores, apically branched and producing (2) sympodially extending conidiogenous cells giving rise to (3) brown, dry, amerosporous mostly globose (but in a few species ellipsoidal), usually rough-walled conidia arising in branched acropetal chains which mature basipetally (thus distal conidia in chains are larger than proximal). When these conidia are recovered from air, they are usually grouped with the very similar spores of smut fungi (***Ustilaginales***) and slime molds of orders ***Physarales*** or ***Stemonitales*** (***Myxostelida***).

Ecology - Saprobic on dead leaves, litter, bark and wood of many plants.

References - Mason & Ellis (1953) Mycol. Pap. 56: 1-127 (Monograph)
Ellis (1971) Dematiaceous Hyphomycetes pp. 344-353 (Key)
Ellis (1976) More Dematiaceous Hyphomycetes pp. 352-359 (Key)

Pesotum Crane & Schoknecht 1973

Classification - Hyphomycetes, asexual states of ***Ophiostoma*** (***Ophiostomatales***, Ascomycetes)

Relevance - common wood- and bark-inhabiting fungi, often present on worked wood.

Identification - Has (1) dark or pale, determinate, synnematous conidiomata, bearing (2) numerous apical conidiogenous cells which can be percurrent, sympodial or phialidic, producing (3) aggregated, slimy, colorless, amerosporous conidia.

Ecology - Often associated with bark beetles.

References - Crane & Schoknecht (1973) Am. J. Bot 60: 346-354.
De Hoog (1974) Stud. Mycol. 7: 1-84.
Mouton et al. (1993) Mycotaxon 46: 371-379.
Seifert & Okada (1993) in Wingfield et al. (Eds.) ***Ceratocystis*** and ***Ophiostoma***. pp. 27-42.

Pestalotiopsis Steyaert 1949

Classification - Coelomycetes, anamorphs of ***Broomella*** and ***Pestalosphaeria*** (***Xylariales***, unitunicate-inoperculate ascomycetes). Many species.

Relevance - Not high. Found occasionally.

Identification - Easily recognizable by its pigmented 3-4-septate phragmoconidia with colorless basal and apical cells, and one basal and two to several (often three) apical filiform appendages. These conidia arise from colorless percurrent conidiogenous cells, which occur in an acervular conidioma.

Ecology - Occur on leaves of many plants.

References - Nag Raj, T.R. (1993) Coelomycetous anamorphs with appendage-bearing conidia pp 618-671.

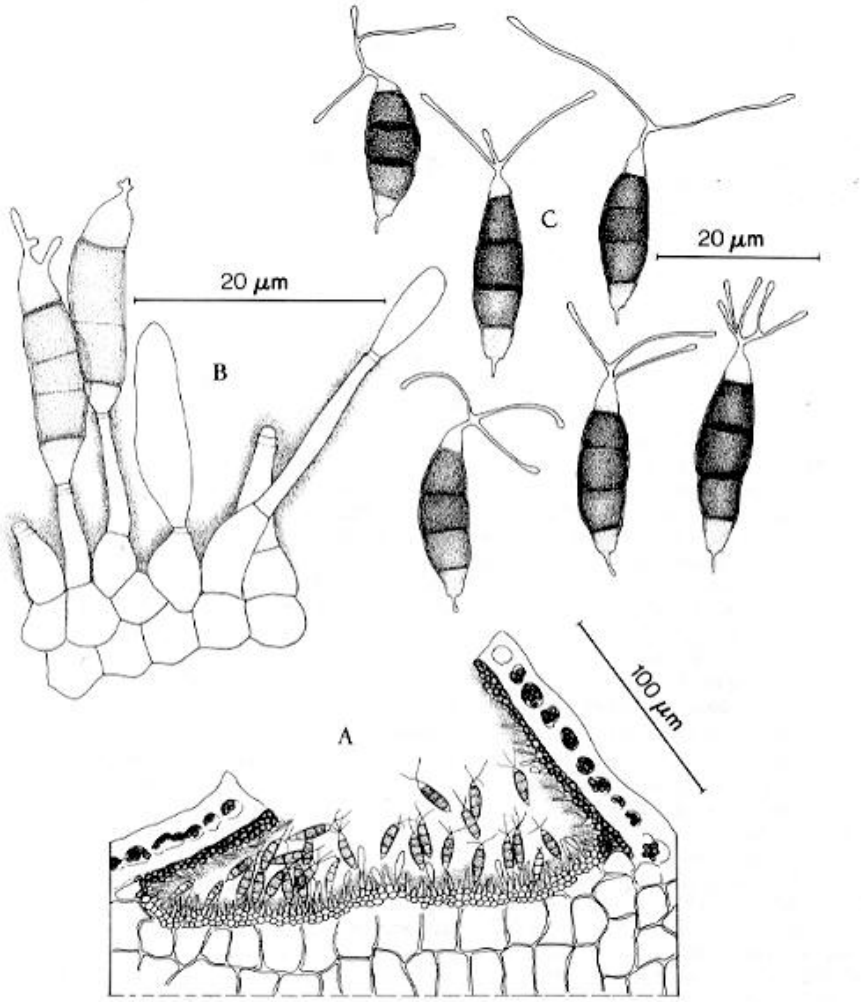


Figure 92.11. *Pestalotiopsis maculans* ex holotype in PR 155665. A. Vertical section of a conidioma. B. Conidiophores and conidiogenous cells with developing conidia. C. Mature conidia.

Phialophora Medlar 1915

Classification - Hyphomycetes, in the strict sense, asexual states of ***Capronia*** (***Herpotrichiellaceae, Chaetothyriales***, Ascomycetes) but since this is a simple and generalized anamorph, species are connected to other ascomycetes, such as ***Cercophora, Chaetosphaeria, Chlorociboria, Eosphaeria, Leptosphaeria, Mycocalicium, Phruensis, Podospora, Retrostium, Spathulospora, Tirisporella***, so the genus is polyphyletic. There are also many synanamorphs (too many to mention here). About 8 species, more to be described.

Relevance - Common on wood and wood pulp, soil, Man, other fungi. ***Phialophora*** species are among the causes of chromoblastomycosis and ***Phialophora verrucosa*** is the principal causative agent of chromoblastomycosis in tropical and subtropical areas, particularly Japan and South America.

Identification - The genus is relatively easy to recognize by (1) its phialides which are relatively short, often single and sessile, or in small clusters, with a slightly swollen venter and

(2) a clearly defined expanded apical collarette, from which (3) a basipetal series of slimy, amerosporous conidia are secreted.

Ecology - a soft-rot species isolated from many kinds of wood. Implicated in human disease (see above)

References - Cole & Kendrick (1973) Mycologia 65: 661-688 (Key).
Ellis (1976) More Dematiaceous Hyphomycetes pp. 452-455 (Key)
Wang & Zabel (1990) Fungi from utility poles pp. 284-305 (Illus.)
De Hoog, G. S., J. Guarro, J. Gene, and M. J. Figueras. (2000) Atlas of Clinical Fungi, 2nd ed, vol. 1. Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands.

Pithomyces Berkeley& Broome 1873

Classification - Hyphomycetes, asexual states of ***Leptosphaerulina*** (***Pleosporaceae***, bitunicate Ascomycetes. About 35 species.

Relevance - grows saprobically on many plants, soil and paper. ***Pithomyces chartarum*** growing on dead grasses produces the mycotoxin sporidesmin, which triggers facial eczema in sheep (esp. in New Zealand). Conidia often recovered from air.

Identification - The genus is easily recognized by: (1) its large, dark, single, dry, usually rough-walled, phragmoseptate or dictyoseptate conidia, produced from (2) short, undifferentiated or reduced conidiogenous cells.

Ecology - Especially common on dead parts of forage grasses in wet weather.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 43-46 (Key)
Ellis (1976) More Dematiaceous Hyphomycetes pp. 30-32 (Key)

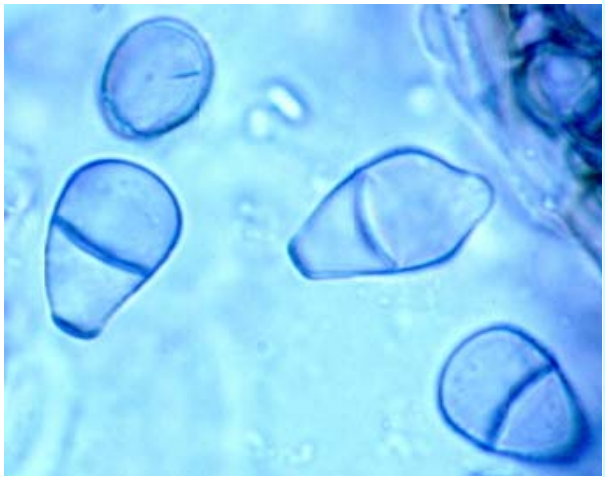
Polythrincium Kunze 1817 : Fries

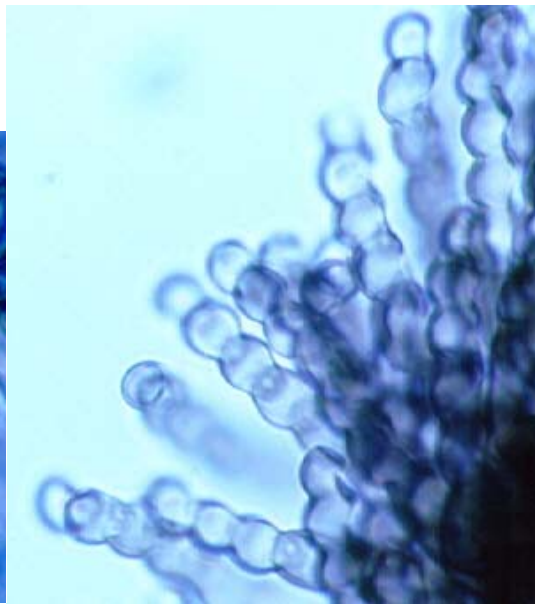
Classification - Hyphomycetes, anamorph of ***Mycosphaerella*** (***Dothideales***, bitunicate ascomycetes). One species.

Relevance - The dry conidia readily become airborne..

Identification - Easily recognizable by its (1) dry, single, pigmented, rather wedge-shaped, didymosporous conidia with a truncate base and a rather rounded apex. These conidia arise from (2) an unusual conidiogenous cell which extends sympodially, but produces conidia only along one side, leaving large flat scars after they secede.

Ecology - Occur on leaves of clover (***Trifolium***), causing a leaf spot disease.
References - Ellis (1971) Dematiaceous Hyphomycetes pp. 284-285.





Pyricularia Saccardo 1880

Classification - Hyphomycetes, asexual states of ***Magnaporthe, Massarine, Ceratosphaeria*** (***Magnaporthaceae*** and ***Leptosphaeriaceae***, ***Pleosporales***, bitunicate ascomycetes)
About 40 species.

Relevance - On grasses and other plants, often causing disease. Spores become airborne.

Identification - Recognized by (1) its single, upright, sympodially extending, denticulate conidiophores giving rise to (2) single, obclavate or pyriform, brown phragmosporous conidia with denticulate basal scars.

Ecology - ***Pyricularia oryzae*** is the fungus causing rice blast disease, and other species attack many other grasses.

References - Ellis (1971) Mycol. Pap. 125: 1-30.
Ellis (1971) Dematiaceous Hyphomycetes pp. 218-219.
Ellis (1976) More Dematiaceous Hyphomycetes pp. 186-188.

RUSTS - diseases affecting a very wide range of plants, and caused by obligately parasitic basidiomycetous 'rust fungi' (most are order *Pucciniales*, subphylum *Pucciniomycotina*, but the so-called 'white rust' of cabbage family plants is caused by an oomycete). Many rust fungi produce a series of different kinds of spores during their life cycle, and move between two different host plants. For example, the black stem rust of wheat, caused by *Puccinia graminis tritici*, produces (1) urediniospores (summer spores, which often erupt through the wheat

epidermis and give it a rusty red appearance - hence the name rust diseases), then (2) teliospores (dark colored overwintering spores, also developing on wheat), (3) basidiospores arising from the teliospores on the ground in Spring, (4) spermatia (sometimes called pycnospores) non-motile male gametes developing on barberry, and (5) aeciospores (transfer spores which must move from one host to the other, also formed on barberry, but able to infect only wheat).

Scopulariopsis Bainier 1907

Classification - Hyphomycetes, asexual states of ***Microascus, Kernia, Petriella*** (***Microascaceae***, Ascomycetes). About 25 species.

Relevance - Spores frequently recovered from air. It is weakly keratinolytic, and is implicated in nail infections (onychomycosis), and may cause invasive and sometime fatal infections in immunocompromised patients.

Identification - The genus is easily recognized by: (1) branched or penicillate conidiophores; (2) the conidiogenous cells minutely extending percurrently during conidiation, producing (3) small, rough-walled, lightly pigmented, dry, amerosporous conidia with truncate bases (4) in basipetal chains. Different species may be brown or colorless. The conidia are rather similar to those of ***Aspergillus*** and ***Penicillium***, but have truncate bases and rounded apices.

Ecology - Grows on soil, dung, debris, human nails and many other substrates.

References - Morton & Smith (1963) Mycol. Pap. 86: 1-96 (Monograph).
Hennebert (1968) Trans. Brit. Mycol. Soc. 51: 749-762. (Revision)
Ellis (1971) Dematiaceous Hyphomycetes pp. 326-328.

Smut fungi

Classification - various species of genera such as ***Ustilago***, ***Tilletia***, ***Entyloma*** (***Ustilaginales*** (subphylum ***Ustilaginomycotina***)

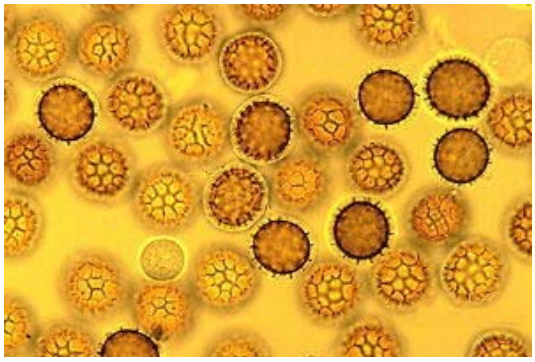
Relevance - obligate parasites of living plants, replacing storage organs or other organs in which food energy is concentrated - seeds, anthers, bulbs - with fungal spore masses. Spores may be very numerous in air at harvest time. May be allergenic.

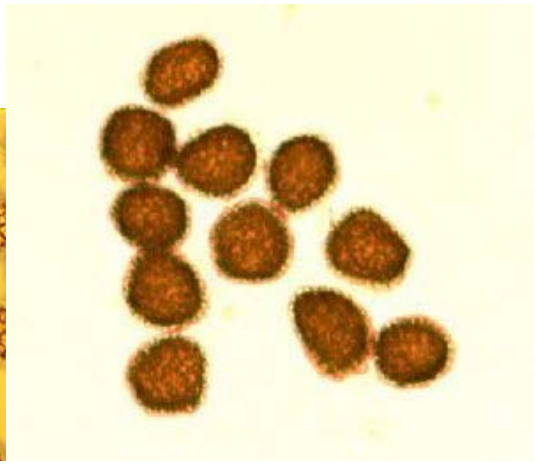
Identification - Many smut spores are amerosporous, spherical, brown, and have surface ornamentation, so are lumped with the very similar spores of plasmodial slime molds and the hyphomycete genus **Periconia**..

Ecology - obligate plant parasites, spores released in Fall and common in air.

References - Vanky (2002) The smut fungi of the world - a survey.
Vanky (2002) Illustrated genera of smut fungi. 2nd edn.

spores of ***Tilletia controversa*** spores of smut on ***Carex***





Spegazzinia Saccardo 1880

Classification - Hyphomycetes, anamorphs with no known teleomorphs. About 8 species.

Relevance - Occurs on plants and soil in warmer climates. Often seen on spore trap samples.

Identification - Characterized by (1) small, brown, single, dry, dictyosporous, cruciately septate conidia, usually with 4 cells (one species with 8-9 cells), smooth-walled when young, and constricted at the septa, but developing projecting spines or blunt protuberances on all cells at maturity; (2) conidia arising singly at the apex of unbranched, hyphoid conidiogenous cells developing by basauxic growth from sessile, phialide-like mother cells.

Ecology - Found on ***Ananas, Oryza, Pennisetum, Phragmites, Saccharum, Sorghum, Theobroma, Triticum***, and ***Zea***, in many tropical countries and U.S.A.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 565-567 (Key).
Ellis (1976) More Dematiaceous Hyphomycetes pp. 474-477 (Key)

Stachybotrys Corda 1837

Classification - Hyphomycetes, asexual states of ***Melanopsamma*** (***Hypocreales***, Ascomycetes)**.**
About 35 species. Molecular data supports placing ***Memnoniella*** in synonymy.

Relevance - Occurs on damp paper and cardboard (cellulolytic). Very common on soaked drywall. Some strains of ***S. chartarum*** produce satratoxins and are in some quarters regarded as a serious threat to health.

Identification - This fungus is grey-black throughout (as opposed to the dark browns of many other pigmented molds). It is characterized by (1) short, upright, repeatedly branching,

conidiophore stipes which bear (2) small, digitate, terminal clusters of rather clavate phialides, which produce (3) dark, slimy, rough-walled, oblong, amerosporous conidia with rounded ends, that (4) accumulate in small heads that do not readily become airborne until after the fungus has dried out completely.

Ecology - Cosmopolitan on plant debris, but most commonly seen on damp cellulosic substrates indoors

References -
Jong & Davis (1976) Mycotaxon 3: 409-485.
Ellis (1971) Dematiaceous Hyphomycetes pp. 540-546 (Key, partly as ***Memnoniella*)**.
Samson et al. (2000) Food- and Air-Borne Fungi 6th Edn, 162-163, 258-259 (Key, partly as ***Memnoniella*)**.

Stemphylium Wallroth 1833

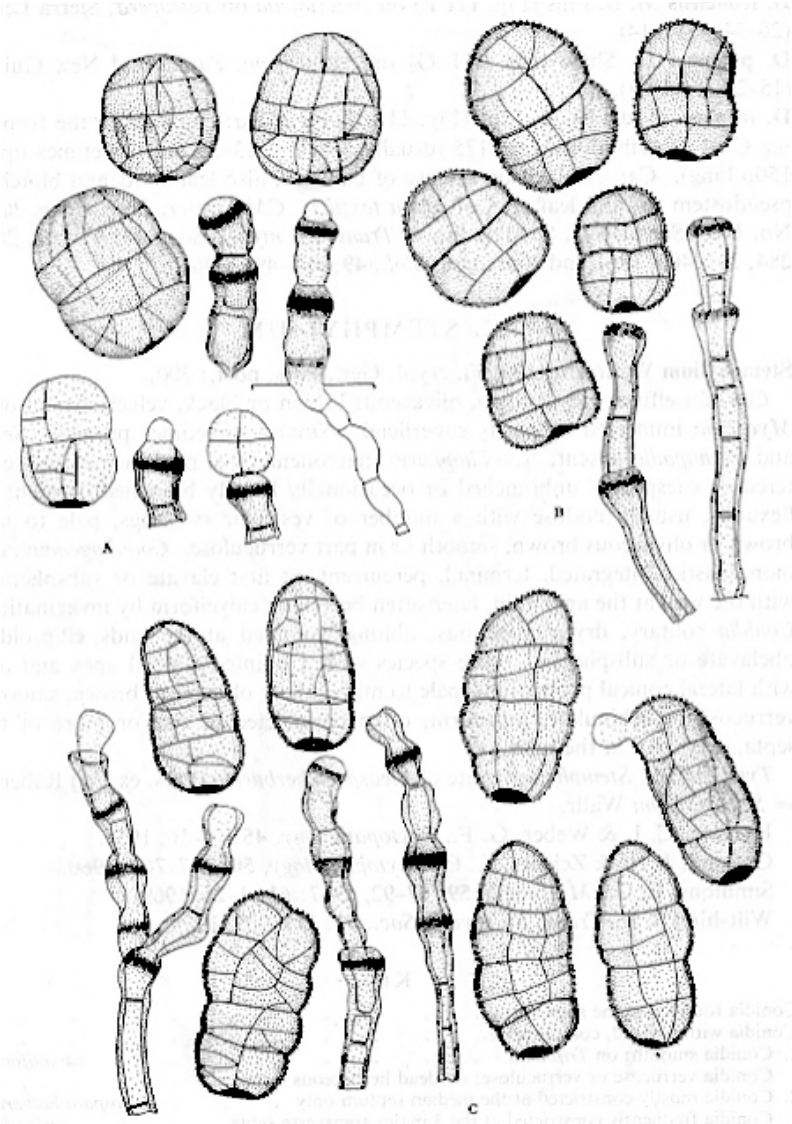
Classification - Hyphomycetes, anamorphs (asexual stages) of ***Pleospora*** (***Pleosporales,*** bitunicate ascomycetes). About 40 species.

Relevance - Found in spore traps. Potentially allergenic.

Identification - Characterized by (1) dark, dictyoseptate conidia, with rounded apices and squat bases, arising singly from (2) dark, thickened scars at the somewhat swollen apices of (3) unbranched conidiophores which often (4) extend percurrently and exhibit several intercalary nodes or swellings. The conidia are sometimes slightly constricted at the median septa.

Ecology - Occurs on leaves, litter, wood and other substrates.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 165-168 (Key).



Torula Persoon 1796 : Fries

Classification - Hyphomycetes, no known teleomorph. Probably ascomycetous.
About 6 species.

Relevance - Found in spore traps. Potentially allergenic.

Identification - Characterized by (1) darkly pigmented, straight, phragmosporous conidia, which are (2) more or less sharply constricted at each septum so that cells look monilioid, with (3) a basal cell darker and often collapsing to become cupulate, (4) conidia arising in branching, acropetal (apically extending) chains.

Ecology - Occurs on litter, soil and dung. Cosmopolitan.

References - Ellis (1971) Dematiaceous Hyphomycetes pp. 336-339 (Key).

Vasan Rao & De Hoog (1975) 8: 199-206 (Revision, Key).

Ulocladium Preuss 1851

Classification - Hyphomycetes, some are asexual states of ***Lasiobotrys***, and possibly other bitunicate ascomycetes. Some appear to be anamorphic holomorphs (have no teleomorph).There are about 15 species, and 19 binomials in the literature.

Relevance - One of the most common black molds found growing on wood and paper indoors. May cause phaeohyphomycosis and particularly subcutaneous infections in humans.

Identification - easily identified on tape lifts and other non-viable analyses by conidia which are
(1) large, (2) darkly pigmented, (3) multicellular (dictyoseptate/muriformly septate), (4) rounded and not beaked, (5) usually produced singly (though sometimes in short chains), (6) brown conidiogenous hyphae extend sympodially, often taking on a geniculate (zig-zag) appearance (see illustration).

Ecology - occurs naturally on soil, plant debris and other substrates.

References - Ellis, M.B. (1976) More Dematiaceous Hyphomycetes pp. 427-433. Key.
Simmons, E. (1967) Mycologia 59: 67-92. Key.

Zygomycetes - traditionally a Class of true fungi belonging to Phylum ***Zygomycota***. Now called Subphylum ***Mucoromycotina*** with several orders, particularly ***Mucorales*** ***Endogonales*** and ***Mortierellales***. They are fast-growing, terrestrial, largely saprobic fungi with no motile cells, and hyphae which are in most cases non-septate; they produce zygosporangia by fusion of usually similar gametangia; and also develop asexual sporangia (mitosporangia) containing one to many non-motile spores, and borne on simple to complex sporangiophores. Zygosporangia and mitosporangia are illustrated under those headings.

Zygophiala Mason 1945

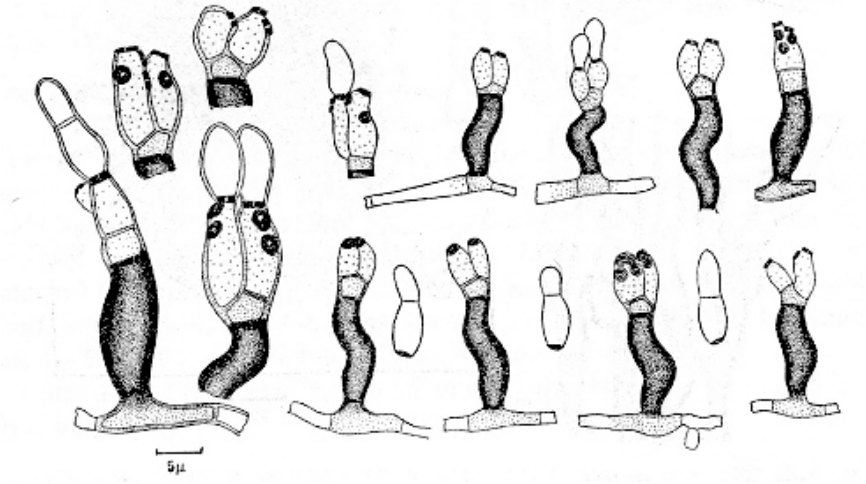
Classification - Hyphomycetes, no teleomorph known.

Relevance - Recorded in spore traps.

Identification - Recognizable by (1) the twin, dry (?), ***parallel***, colorless, didymosporous conidia with truncate bases and dark dehiscence scars. (2) The conidia are often constricted at the (colorless) septum. The rest of the fungus is rarely seen, but (3) the conidiophore is short, dark, unicellular and somewhat sinuous, with (4) two much paler, parallel, apical conidiogenous cells which extend sympodially, and acquire dark, flat, dehiscence scars during conidiogenesis.

Ecology - Occur on leaves and fruits of ***Musa***, causing 'flyspeck' disease.

References - Ellis (1971) Dematiaceous Hyphomycetes p. 292.



Structures and Other Terms

Asci (singular: ascus)

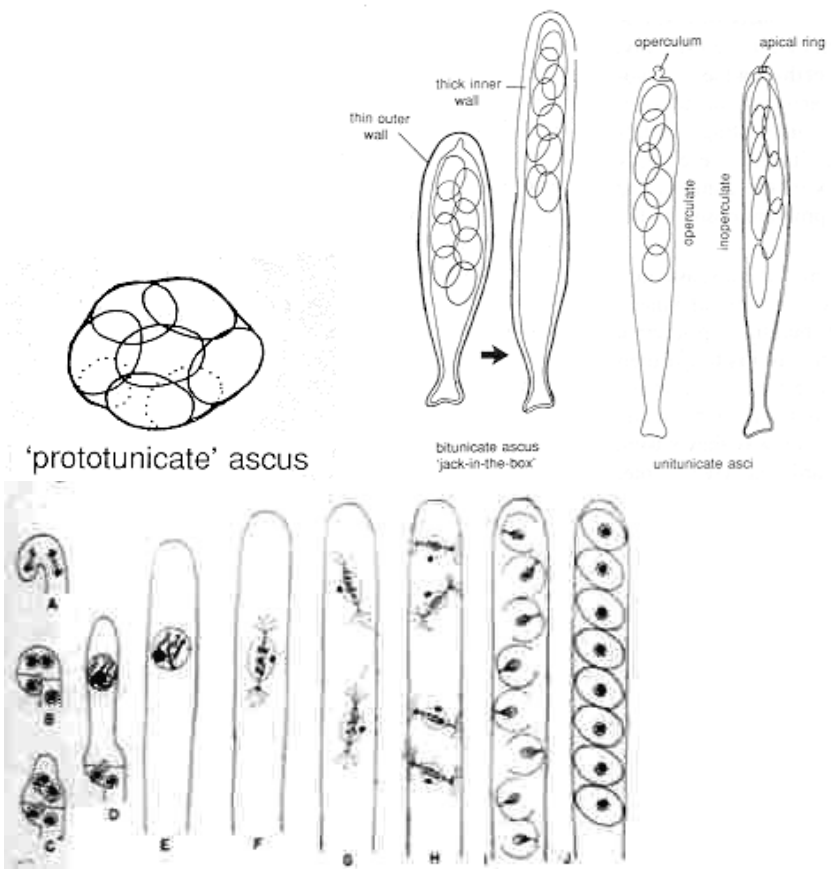
Asci are the meiosporangia (sexually derived sporangia) of a large group of fungi called ascomycetes. Inside the young ascus, two sexually compatible nuclei fuse, then undergo reduction division, usually followed by a normal mitotic division to produce 8 haploid nuclei. Each of these nuclei gathers cytoplasm around itself and secretes an outer wall, thus forming a spore. The spores are still inside the ascus, and are usually released when the tip of the ascus bursts open under hydrostatic pressure and squirts the ascospores out into the air to a distance of anything from a few millimetres up to a phenomenal 50 cm.
Asci are produced in very large numbers on or in ascomata (q.v.). Cup fungi, which have extensive exposed hymenia (fertile layers) on the surface of open ascomata, may discharge the contents of thousands of asci in a single visible puff, while other ascomycetes with closed ascomata usually discharge one or a few asci at a time.

Relevance - Following their expulsion from the asci, ascospores become a component of the air spora.

Identification - Most asci are narrow and cylindrical, as befits their function as spore guns. Some are broader and more sac-like, and others, which develop inside closed ascomata, are

globose. Some, like those of ***Chaetomium***, break down or dissolve at maturity, releasing their spores but not shooting them. Many such spores are dispersed by water or invertebrates.

References - Kendrick (2007) The Fifth Kingdom on CD-ROM

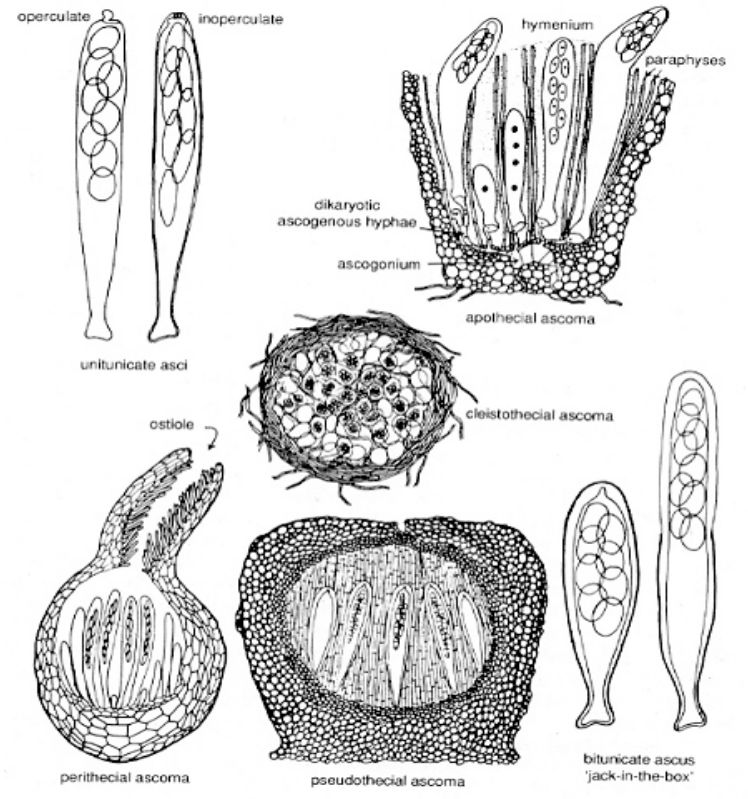


Ascomata

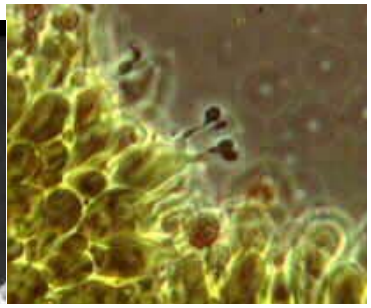
Ascomata are the complex structures on or in which asci (q.v.) are produced. They are developed by most ascomycetes, and come in four main kinds, shown in the drawings.

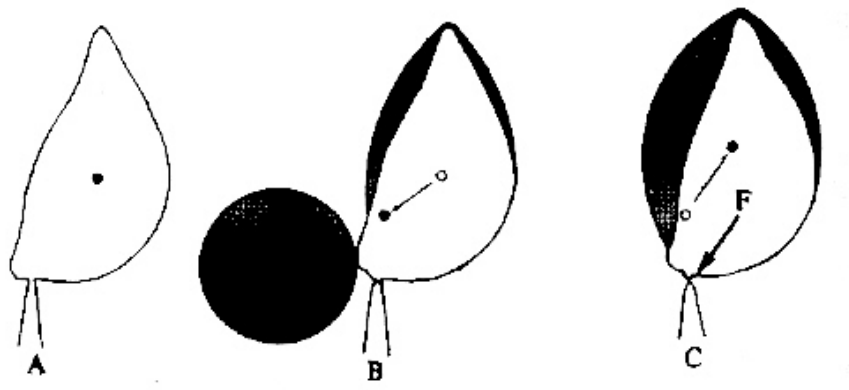
Identification - Ascomata can be open and flat, saucer-shaped or cupshaped (apothecia), or can be flask- or bottle-shaped with a neck or narrow opening at the top (perithecia), or globose with no opening (cleistothecia), or can be extended structures that contain many individual spore-producing cavities (compound ascomata). Those which contain bitunicate asci are called pseudothecia.

References - Kendrick (2007) The Fifth Kingdom on CD-ROM. Chapters 4a, 4b.



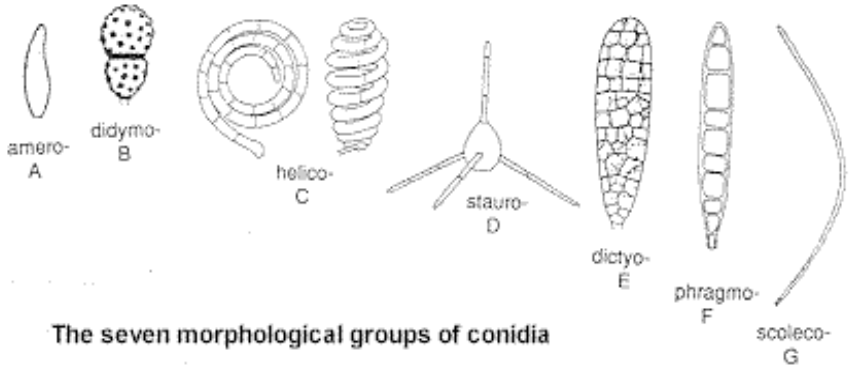
Basidium (plural: basidia) - the meiosporangium of the phylum ***Basidiomycota***; within which karyogamy (nuclear fusion) and meiosis (reduction division) take place, after which exogenous meiospores (usually 4, sometimes more, occasionally 2) are produced on special projections called sterigmata. In most cases basidiospores are shot away at maturity. Most basidiospores are therefore ballistospores. The shooting mechanism involves the development of the spores asymmetrically at the tips of the sterigmata, and the secretion and coalescence of a water droplet, as you can see in the pictures below. Basidia are found in very large numbers on the gills of mushrooms, lining the tubes of boletes and bracket fungi, covering the spines of tooth fungi and the flat hymenia of resupinate (spread out) wood-inhabiting fungi.





Cleistothecium (or Cleistothecial ascoma) - a walled ascoma, which is closed at maturity (has no ostiole); the unitunicate but frequently evanescent or prototunicate asci are often spherical and are not arranged in a hymenium; this kind of ascoma is characteristic of ***Eurotiales*** (e.g. teleomorphs of ***Penicillium*** and ***Aspergillus***). Atypically, ascospores in this group are not forcibly expelled.

Conidia (singular = Conidium) - non-motile fungal mitospores (asexual spores) ***not*** formed inside a sporangium; typical of anamorphs of both Ascomycetes and Basidiomycetes. Conidia are produced by hyphomycetes and coelomycetes, in many different ways, both singly and in chains.



The seven morphological groups of conidia

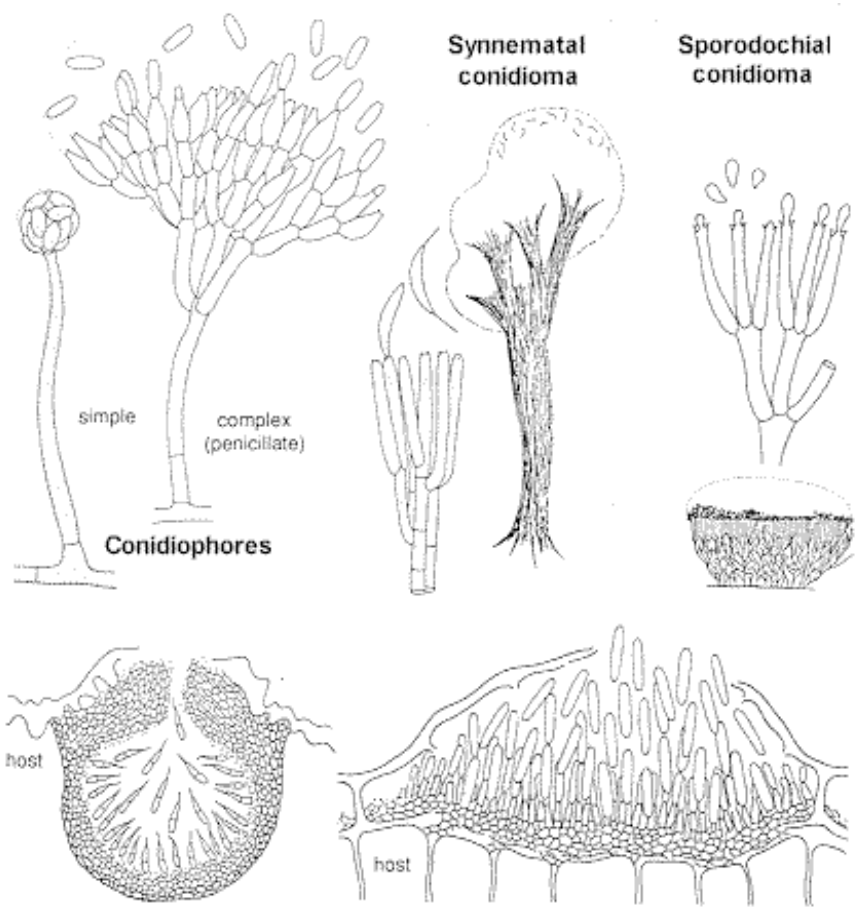
Conidiogenous cells - modified or specialized hyphal cells that produce conidia. They are a very varied lot.

Some produce an apparently endless series of conidia from an open end, without changing in size or shape (phialidic, think ***Penicillium*** and ***Aspergillus***); some gradually become longer as they produce conidia, acquiring lateral scars as they do so (sympodial, think ***Ulocladium***); some gradually become longer by growing on through the opening left by each conidium before producing the next (percurrent or annellidic, think ***Spilocaea***); some are themselves conidia which give rise to the next conidium in an apically extending chain (think ***Cladosporium***, ***Alternaria***).

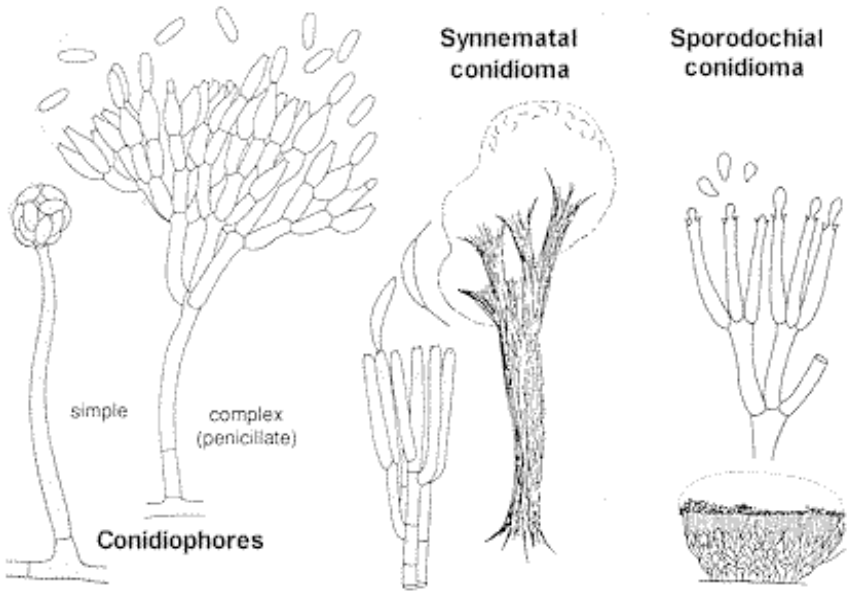
Some arise on conidiophores or conidiomata, developing in clusters or whorls at the top

of tall stalks; some arise singly from somatic hyphae, some are integrated into a hypha (not physically differentiated - we call these intercalary). But they all produce, or turn into, conidia.

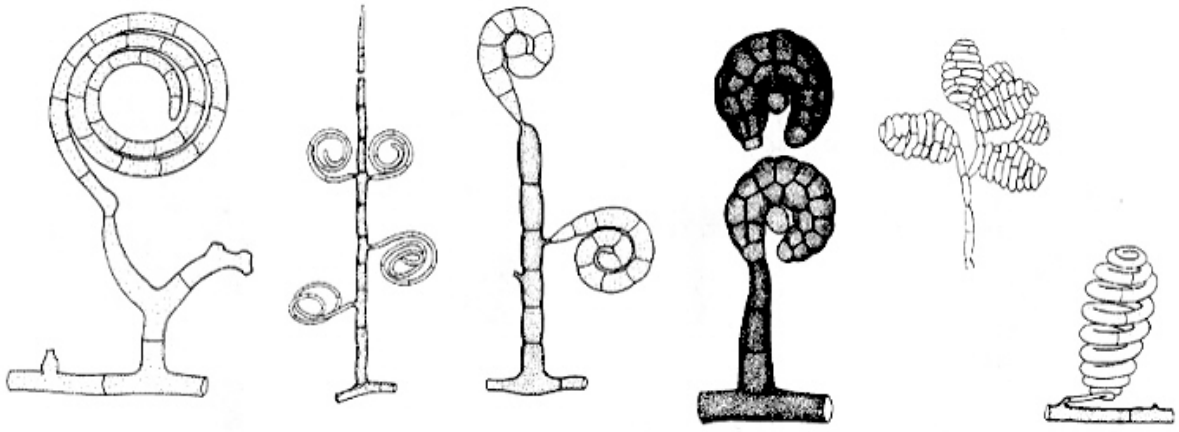
Conidioma (plural = Conidiomata) - any multihyphal structure producing conidia, .e.g, synnematal, sporodochial, acervular, or pycnidial conidiomata.. (Compare with conidiophore).



Conidiophore - a specialized hypha, unbranched or branched, on which conidia are formed.(see also conidioma).



Helicospore - a spore which curves through more than 180 degrees, and often through several complete gyres, coiling in two or three dimensions.



Hyphal fragments

Classification - The vast majority of fungi grow as a system of apically extending, branching tubes called hyphae, which may be pigmented or colorless, and which vary from about 2-12 microns in width (most are 4-6 microns wide). The walls of hyphae are made largely of chitin, and in most fungi there are septa or cross-walls at intervals, dividing the hyphae up into compartments which are connected by narrow pores that run through the septa. The cytoplasm and nuclei of the fungus live inside the more or less impermeable hyphae, protected from such things as drying out, solar radiation, and various toxic elements in the outside environment. Hyphae, which grow only at the tip, are the building units from which mushrooms and fungal colonies are made up, and spores are really no more than specially modified bits of hyphae. So it is not surprising that spore traps, bulk samples and tape lifts often reveal broken lengths of hyphae. Unfortunately, hyphae do not usually exhibit the special characteristics we learn to

recognize in spores or fruiting bodies, and so cannot usually be identified.

Relevance - Hyphae have the same allergens on their surface as are found on spores, so they can trigger allergies.

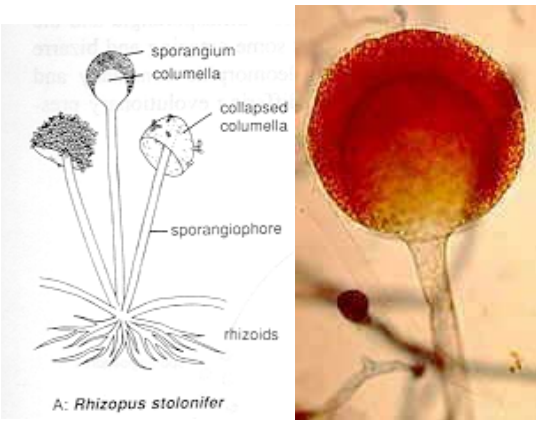
Identification - Reliable only to Kingdom, though it can be specified whether they are pigmented or colorless; thin-walled or thick-walled (relative terms); wide or narrow (relative terms); septate or non-septate (many Zygomycetes have non-septate hyphae); with clamp connections at the septa (which denotes a dikaryotic basidiomycete) or lacking clamps; smooth-walled or with surface ornamentations; with cells of equal width throughout or with cells wider in the middle, or with cells monilioid (swollen or subglobose). Not tgo be confused with the non-cellular, solid, often ornamented capillitium threads of Myxomycetes.

Ecology - hyphae are the architectural modules of fungi, and are found everywhere - in the air, on the surface and in the interior or leaves, on and in wood and soil.

References - Kendrick (2007) The Fifth Kingdom on CD-ROM Version 5.1. Mycologue Publications (www.mycolog.com).

Perithecium (or Perithecial ascoma) - a walled ascoma usually having an ostiole (an opening in the top) through which spores can be expelled at maturity; the asci are arranged in parallel or in a clump, in a hymenium (fertile layer); this kind of ascoma is characteristic of many ascomycetes with unitunicate-inoperculate asci (e.g. ***Podospora***, ***Sordaria***, ***Xylaria***, ***Nectria***). Perithecia may be single, or aggregated in a compound fructification.

Sporangia (singular: sporangium) - a specialized cell ***within which*** a spore or spores are developed. (Zygomycetes such as ***Mucor*** and ***Rhizopus*** produce mitosporangia - see below; Ascomycetes produce meiosporangia called asci, q.v.)



Spore Dispersal- Fungi essentially exist in two phases - hyphae and spores. Fungi spend most of their time in the hyphal mode, hyphae being narrow branching tubes (about 5 microns wide on average) which grow at the tip and explore their immediate environment gathering food. They eventually produce spores when they have accumulated enough energy to do so. Spores are modified, microscopic bits of hyphae, and after they have been released, their job is to disperse the fungus over long distances, and thus to find new sources of food.

Clearly, the easiest way to achieve this is to put spores into the air, and many fungi have evolved elaborate structures, such as mushrooms and cup fungi, to do just that. These structures make millions of spores and insert them into the atmosphere by means of delicate and ingenious spore shooting mechanisms. Mushrooms and bracket fungi produce spores on tiny cells called basidia, which cover their gills and line their pores. Each basidium makes four tiny spores at the tip of tiny projections and gently flips them into the air between the gills or inside the pores. They fall slowly under gravity into the open air, and are then carried away on the breeze. Cup fungi produce rows of eight spores in tiny tubes called asci that cover the inside of the cup, and each tube shoots its spores into the air when they are mature.

The spores made by basidia and asci are mostly very small (often only 5-10 microns) and can float in the air for a long time. They are joined there by what we call conidia, which are the spores produced by the asexual stages of many fungi. These stages have some familiar names, such as ***Penicillium*** and ***Aspergillus***. The spores of these asexual fungi are produced by specialized cells, but are *not* forcibly shot into the air. Yet they are very small and dust-like, and so can and do become airborne very easily with any kind of physical disturbance. The illustration (from 'Spore Liberation' by C.T. Ingold [1965, Oxford University Press]) shows a range of fungal spores, the very large one being of a lichen. Most of those shown are extremely small.

The air is full of spores - conidia, ascospores and basidiospores - something between 200 and 2,000,000 per cubic metre (though usually between 1,000 and 10,000 per cubic metre). Spores gradually fall toward the ground under the influence of gravity. Since they are tiny, they don't fall very fast. In fact, their rate of fall varies from more than 2 cm/sec for large spores to 0.05 cm/sec for very small ones. A slow rate of fall means that the potential distance over which spores can be carried by air currents may be very large - up to thousands of km. in windy weather, which can easily negate the influence of gravity. Rain will have the effect of causing large numbers of spores to be precipitated, and the air spora is often temporarily depleted after rainfall. This deposition of spores by rain is not a bad thing for the fungi, because spores need moisture in order to germinate, and there is certainly no point in their germinating while in mid-air. The whole point of casting millions of spores onto the wind is to saturate the environment with spores, so that when a new food substrate becomes available, the spores will be there to colonize and exploit it.

While rain washes many spores out of the air, wetting of substrates is often a prerequisite for the development and liberation of spores, and the wetting of substrates bearing ripe fungal fruit bodies may also lead to spore discharge, as in ***Venturia***, the apple scab fungus, which liberates abundant ascospores for up to three hours after a light rainfall of only 0.2 mm. The wood-inhabiting polypore ***Ganoderma*** is unusual in that it can continue to release basidiospores during long periods of drought. Raindrops striking leaves often release conidia of ***Cladosporium***, ***Alternaria*** and ***Oidium***, among others, which are replaced by the damp-air types like ascospores, while prolonged rain, as already mentioned, removes most spores from the air.

There is another category of spores that are not normally dispersed through the air. For example, the conidia of ***Stachybotrys*** are produced in tiny drops of slime and do not initially

become airborne. It is clear that these slimy spores are adapted for dispersal by a different route. Many slimy spores are adapted for dispersal by invertebrates such as mites or insects, others travel in flowing water. It is interesting that a number of fungi that are clearly adapted for non-aerial dispersal are nevertheless of importance in aerobiology. ***Acremonium***, ***Ophiostoma***, ***Chaetomium***, ***Chloridium***, ***Fusarium***, ***Geotrichum***, ***Myrothecium***, ***Pestalotiopsis***, ***Phialophora***, ***Stachybotrys***, ***Verticillium*** and many yeasts produce slimy spores. These may be dispersed by arthropods, or they may eventually dry out and become airborne as a result of physical disturbance.

Climate makes a difference. The air in warmer climates tends to carry a greater diversity of fungi than in cooler zones. Conidia are the most common spores in desert regions, and in continental warm summer humid zones, and in steppes and savannas.

I have mentioned the changes brought about by rain, but there are also a number of patterns of spore release that tie in to the time of day. Five patterns have been recognized. (1) Post-dawn, 7- 10 am. This is characteristic of fungi with spore release mechanisms that depend on rapidly changing humidity, such as ***Nigrospora***. Other post-dawn taxa are ***Cercospora***, ***Cordana***, ***Epicoccum***, ***Polythrincium***, ***Zygophiala*** and ***Zygosporium***. (2) Midday, 10 am to 4 pm, which involves species with spores released by increased temperature, wind speed and turbulence, such as species of ***Alternaria***, ***Aureobasidium***, ***Botrytis***, ***Cladosporium***, ***Curvularia***, ***Helminthosporium***, ***Oidium***, ***Penicillium***, ***Periconia***, ***Pithomyces***, ***Spegazzinia***, ***Stemphylium***, *Tetraploa* and *Torula*.(3) Double-peak, 8-10 am and 2-6 pm, which includes some species of ***Alternaria***, ***Cladosporium***, ***Curvularia***, ***Epicoccum***, ***Helminthosporium***, ***Periconia***, ***Pithomyces*** and ***Tetraploa***. (4) Post-dusk, 8-10 pm, ***Spegazzinia*** and ***Ustilaginoidea***. This pattern may involve increasing humidity. (5) Night, 2-4 am, characteristic of many ascospores and basidiospores, which often need high humidity, and a few conidia such as those of ***Fusarium*** and ***Pyricularia***.

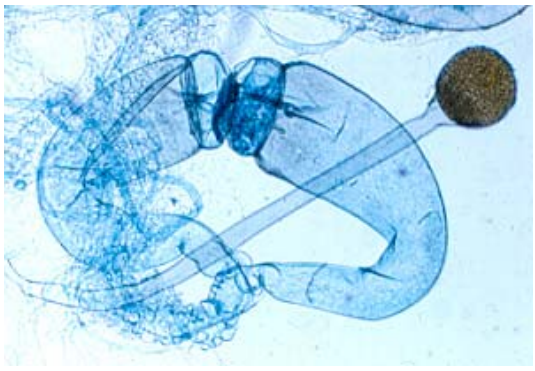
Many airborne spores are not viable - this applies to about 20% of ***Alternaria*** spores, 70-80% of ***Cladosporium*** spores. This is also true of many ascospores and basidiospores. But dead spores retain their surface chemistry, and so may still be allergenic.

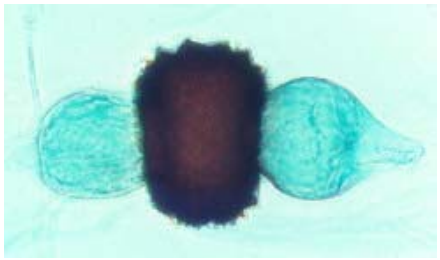
Spores often arise in indoor environments but are also carried in on air currents through open window and doors. Generally the spore concentrations outdoors are higher than those observed indoors. Homes with central air-conditioning and closed windows generally have indoor spore levels that are 25 to 33% of outdoor levels. Spore concentrations indoors that are higher than those found outdoors could indicate growth in the home. In a study by Lee et al. total spores had a median indoor concentration of 405 spores/m^3 and a median outdoor concentration of 1,182 spores/m^3. Another study by Levetin et al.focusing on schools showed indoor total spore concentrations from 288 spores/m^3 to 9,999 spores/m^3.

Reference –Lee T., S. (2006). Indoor Air. 16:37-47.
Levetin E. (1995). Aerobiologia. 11:27-34.

Zygosporangia - the meiosporangia of Zygomycetes. These are often thick-walled, sometimes ornamented, long-term survival structures They are formed by the fusion of two gametangia. The first picture below shows a young zygosporangium with a stalked

mitosporangium (the dark ball at the top contains the mitospores). The lower photo shows a mature zygosporangium with attached gametangial remains. The drawings show how a zygosporangium develops.





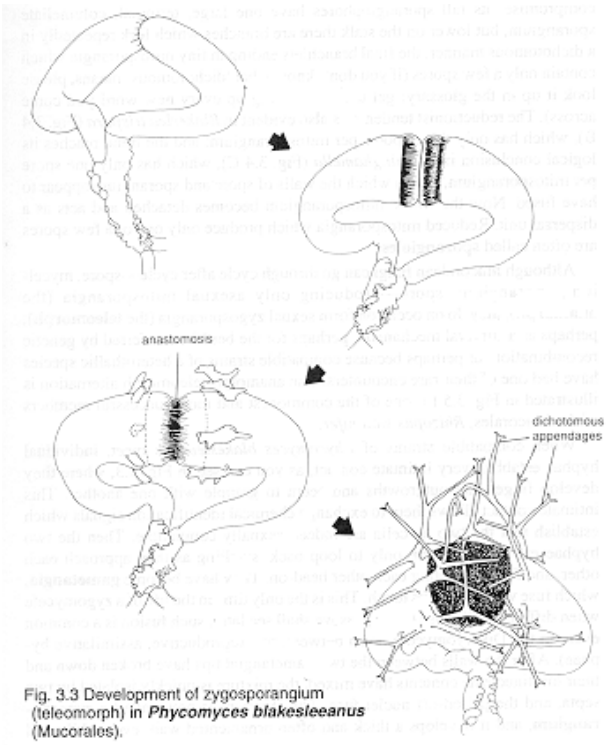


Fig. 3.3 Development of zygosporangium (teleomorph) in ***Phycomyces blakesleeanus*** (Mucorales).

Diseases and Allergies

Allergic Asthma- is a condition of the respiratory system which can be caused by many different allergens including exposure to fungi. Asthma is a type I hypersensitivity response to foreign antigen which cause the release of inflammatory mediators that cause multiple symptoms such as wheezing, coughing, gasping, and chest tightness. The symptoms can range for mild to sever persistent asthma that my require hospitalization. There are over 250 agents that have been shown to produce asthma so determining the cause of a individual response is sometimes difficult.

Reference – Macher (1999). Bioaerosols. American Conference of Government Industrial Hygienist. (25)3-5.

Allergic bronchopulmonary aspergillosis (ABPA) – is a condition characterized by the colonization of the bronchial tree. ABPA is most often caused by colonization of ***Aspergillus fumigatus*** but can also be caused by other ***Aspergillus*** species. It most often occurs in the immune compromised but can also affect the healthy.

Reference - Hung, Miller, and Dillon (2005) Field Guide for the Determination of Biological Contaminants in Environmental Samples:3-21.

Allergic Rhinitis – Is a common health problem experienced by millions of people in the United States. It is the most common health condition associated with exposure to fungal allergens and sensitization to those allergens. It is estimated that 10-30% of adults and 40% of children in the United States experience allergic rhinitis to some degree. The condition is due to an inflammatory reaction in the nasal mucosa which is often caused by exposure to airborne fungal spores and hyphae. Two of the most common symptoms are sneezing and nasal congestion. Although the condition can be caused by exposure to airborne fungal spores and hyphae there are several other biological causative agents such as pet dander, cockroach particles, rodents, pollens, and dust mites that can trigger an allergic reaction.

Reference - Dykewicz and Fineman (1998) Ann. Allergy Asthma Immunol. 81(5 Pt 2):463-468.
Hung, Miller, and Dillon (2005) Field Guide for the Determination of Biological Contaminants in Environmental Samples:3-21.

Aspergilloma – a localized non-invasive fungal ball found in the lung tissue. They can occur in immune compromised individuals as well as people with no obvious health problems but they generally occur in people with preexisting lung disorders.

Allergic Bronchopulmonary Aspergillosis (ABPA) – Is an allergic response to exposure to ***Aspergillus*** (typically inhaled spores) which cause inflamation of the lungs and causes asthma like symptoms.

Chronic Necrotizing Pulmonary Aspergillosis (CNPA) – is a semi-invasive fungal infection caused by species of ***Aspergillus***. The condition affects the lung tissue but usually only occurs in immune compromised individuals and the elderly.

Reference - Denning (2001) Clin. Microbiol. Infect. 7(2):25-31.
Hung, Miller, and Dillon (2005) Field Guide for the Determination of Biological Contaminants in Environmental Samples:3-21.

Hypersensitivity Allergic Response - Hypersensitivity allergic responses are caused by the normal immune system. They require the host to be pre-sensitized to the antigen and are generally broken into four main categories Type I-IV.

Type I - responses are IgE-dependent responses and are generally seen immediately after exposure to the allergen. IgE adheres to mast cells and basophiles and upon later exposure to the same antigen activates the cells causing a release in products such as histamine. This

release of products causes many of the symptoms commonly associated with an allergic reaction. Some common fungal induced type 1 reactions are allergic asthma and rhinitis

Type II – Is antibody dependent with the antigens binding to cells thus causing the cells to be recognized as not self by the immune system and are attacked.

Type III – This reaction occurs when antigens and antibodies are roughly equal in number and thus cross link to form large immune complexes. These large complexes can not be cleared and are deposited on vessel walls causing a inflammatory response.

Type IV – Or cell mediated immunity does not rely on specific antibodies but rather the activation of T-lymphocytes and other immune system cells. It is sometimes called delayed type hypersensitivity because the reaction takes two to three days to develop. An example of a condition caused by fungi that elicits a Type IV reaction is Hypersensitivity Pneumonitis.

Reference – Macher (1999). Bioaerosols. American Conference of Government Industrial Hygienist. (25)3-5.
American College of Occupational and Environmental Medicine (2002). Adverse Human Health Effects Associated with Molds in the Indoor Environment
http://www.acoem.org/guidelines.aspx?id=850

Type of Hypersensitivity Reaction	Name	Immunological Response	Time to onset	Diseases
I	Anaphylaxis	Mast cells/basophils, IgE	Minutes	Hay fever, asthma, eczema
II	Cytotoxic	Complement	Hours-Days	Transfusion reactions
III	Immune-Complex	IgG, antigen-antibody complexes	Hours-Days	Hypersensitivity pneumonitis, allergic alveolitis
IV	Cell Mediated	T lymphocytes	Days	Allergic contact dermatitis

Hypersensitivity Pneumonitis – is a broad term that is often used to characterize several granulomatous lung disease caused by the inhalation of and sensitization to biological agents (such as fungal spores) and low molecular weight chemicals. The diseases characterized under HP are often named after occupations where workers come into contact with the causative agents such as farmer's lung and mushroom workers lung. Mushroom workers lung has been linked to airborne ***Aspergillus fumigatus*** spores that are released during the composting process. Hypersensitivity Pneumonitis can occur in healthy individuals but generally only a

small number of those exposed develop the condition. Identification of the causative agent can often be problematic as there are multiple opportunities for exposure in everyday life.

Reference - Girard, Isreal-Assayag, and Cormier (2004) Curr. Opin. Allergy Clin. Immunol. 4(2):93-98.
Hung, Miller, and Dillon (2005) Field Guide for the Determination of Biological Contaminants in Environmental Samples:3-21.
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Brandt, (2006). Mold Prevention Strategies and Possible Health Effects in the Aftermath of Hurricanes and Major Floods. Center For Disease Control
http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5508a1.htm

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The Institute of Inspection, Cleaning, and Restoration Certification http://www.iicrc.org/

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