UNIVERSITY OF ALBERTA

HOLOMORPH STUDIES OF THE MICROASCACEAE

by

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For Linda

"O know sweet love, I always write of you
So all my best is dressing old words new
For as the sun is daily new and old
So is my love still telling what is told"
(W. Shakespeare, 1609)

ABSTRACT

Morphological, molecular and physiological characters were used to reevaluate the Microascaceae (Microascales, Ascomycota) to include sexually (teleomorphic) and asexually reproducing (anamorphic) species. Analysis of sequences from small subunit (18S) rDNA allowed integration of anamorphic taxa into the phylogenetic framework of the Microascaceae and provided support for monophyly of the family. Life histories were investigated by growing the organisms in axenic culture and revealed that many species exhibited a suite of spore-forming stages that comprised the holomorph. Connections between sexual and asexual states were made through mating trials. The discovery of the teleomorph of the common mold, *Scopulariopsis brevicaulis* was significant because it connected the type species of the anamorphic genus *Scopulariopsis* with the Microascaceae. Mating trials among isolates of four species in the *'Scopulariopsis brevicaulis* Series' demonstrated heterothallism and confirmed connections to teleomorphs in the genus *Microascus.* Single ascospore isolates demonstrated homothallism in *Microascus nidicola.* A reevaluation of definitive characters showed that the genus *Pithoascus* was synonymous with *Microascus.* The genus *Cephalotrichum* was redescribed for synnematous anamorphs of the Microascaceae with annellidic conidiogenesis and conidia in dry chains, and included synonymy of *Doratomyces, Stysanus* and *Trichurus.* Similarity of banding patterns from RFLP analysis of the ITS region of rDNA provided support for conspecificity among pleomorphic isolates of *Pseudallescheria boydii.* Tolerance to the antifungal compound benomyl was consistent

among 55 taxa of Microascaceae, and provided a simple test to separate microascaceous species from morphologically similar species in other pyrenomycete orders.

The Microascaceae were emended to include the teleomorphic genera *Microascus*, *Petriella*, *Pseudallescheria*, *Kernia* and *Lophotrichus*, and anamorphs in the genera *Scopulariopsis*, *Cephalotrichum*, *Echinobotryum*, *Wardomyces*, *Wardomycopsis*, *Graphium* and *Scedosporium*. Two teleomorphs were described, *Microascus brevicaulis* and *M. soppii*, and six new combinations were proposed, *Microascus stoveri*, *Cephalotrichum columnaris*, *C. cylindricum*, *C. dendrocephalum*, *C. putredinus*, and *C. spiralis*. Thirty three taxa of Microascaceae were reported from Alberta.

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CHAPTER 1

INTRODUCTION

The Microascaceae are a diverse family of saprobic fungi (Microascales, Ascomycota) found primarily on cellulosic and protein-rich substrata (soil, plant litter, wood, dung, animal remains), and having a world-wide distribution in tropical, temperate and polar regions. They are prevalent in human environments and important as agents of biodeterioration, indoor contamination and opportunistic infection, but their occurrence and habitat in nature are not well understood.

In the Microascaceae, fruiting bodies of the sexual or teleomorph stage are small (50-300 μm diam.), black perithecia or cleistothecia, containing single-celled, smooth, orange to red brown ascospores (meiospores). Other definitive features of the family include ovoid, evanescent asci irregularly disposed throughout the central cavity and dextrinoid immature ascospores. Many species have asexual states (anamorphs) which produce conidia (mitospores) from annellidic conidiogenous cells. These anamorphs are similar to other conidial fungi for which no teleomorph is known (placed with other molds in the form-class Hyphomycetes under the broad category of Fungi Imperfecti). Some species have more than one type of asexual reproductive structure (synanamorph). The entire suite of spore-forming stages, produced throughout the life history of each species, constitutes the holomorph (Hennebert and Weresub 1977).

The genus *Microascus* was established by Zukal in 1885, but the Microascaceae were not united at the family level until 1951 (Luttrell 1951; Malloch 1970). Connections between the anamorphic genus *Scopulariopsis* and teleomorphic states of *Microascus* were first recognized when several spore producing states formed in pure culture (Emmons and Dodge 1931; Barron et al. 1961b; Morton and Smith 1963). Recognition of pleomorphism (the production of different states by a single species) has allowed for an understanding of the holomorph species concept in the Microascaceae. Additional evidence of a connection between *Scopulariopsis* and *Microascus* was provided by some anamorphic taxa that formed sterile, perithecium-like structures (Morton and Smith 1963). Links between other strictly anamorphic genera and the Microascaceae were proposed primarily based on annellidic conidiogenesis. Pioneering work done by Hughes in 1953 elucidated differences in development, maturation, and detachment of conidia. Conidiogenesis is still of primary importance in classification and allows for phylogenetic inferences among the hyphomycetes (e.g., Campbell and Smith 1982; Valmaseda et al. 1987; Mouton et al. 1993).

Currently six genera comprising 45 species are placed in the Microascaceae, and an additional eight anamorphic genera containing about 50 species show sufficient morphological similarity to infer relationship to the family. Teleomorphic genera currently assigned to the Microascaceae include *Microascus*, *Kernia*, *Petriella*, *Pseudallescheria*, *Pithoascus*, and *Lophotrichus* (Barr 1990; Eriksson and Hawksworth 1998), distinguished

primarily by ascomata type (i.e., perithecium or cleistothecium) and ascospore morphology (size, shape and coloration). Affiliated anamorphic taxa include *Scopulariopsis*, *Cephalotrichum* (=*Doratomyces*), *Trichurus*, *Wardomyces*, *Wardomycopsis*, *Echinobotryum*, *Scedosporium*, and *Graphium* (e.g., Carmichael et al. 1980; Barr 1990). Current distinction among anamorphic genera is based on conidiophore structure (i.e., simple conidiophores versus compound structures formed by aggregations of conidiophores into synnemata) or conidium morphology and development (i.e., conidia in dry chains, slimy masses, or solitary). Monographs, where available, are dated (Barron et al. 1961a, b; Hennebert 1962, 1968; Morton and Smith 1963; Seth 1970; Malloch and Cain 1971), and a family-level revision, including both teleomorphic and anamorphic taxa, has not been done. New species are regularly described (e.g., Gams 1995; Sage et al. 1995; Rajendran 1997), and a reevaluation is required to clarify concepts of species and genera, relationships among taxa, and nomenclature of synanamorphs (Gams 1982).

Recent phylogenetic analyses using molecular data (e.g., Berbee and Taylor 1992; Hausner et al. 1993b; Spatafora and Blackwell 1994; Issakainen et al. 1997; Lee and Hanlin 1999) have supported the Microascaceae as a distinct group, but are based on few taxa. Two families, the Microascaceae and Ophiostomataceae, were classified together in the Microascales (e.g., Luttrell 1951; Barr 1990), but the relationship among taxa assigned to these families has been questioned based on morphological, developmental and physiological differences. The Ophiostomataceae, as traditionally delimited, were shown to be polyphyletic. *Ophiostoma* and *Ceratocystis* were separated primarily on the basis of anamorph conidiogenesis (*Sporothrix* and *Pesotum* anamorphs in *Ophiostoma* versus *Chalara* anamorph in *Ceratocystis*). Also, cycloheximide tolerance in *Ophiostoma* versus sensitivity in *Ceratocystis* provided a simple diagnostic test to separate these taxa (Harrington 1981). Recent molecular data have supported placement of the Ceratocystidaceae (formerly included within the Ophiostomataceae sensu lato) in the Microascales, while the Ophiostomataceae *sensu stricto* occupies an isolated phylogenetic position as the sole member of the Ophiostomatales (Hausner et al. 1993a, b; Spatafora and Blackwell 1994; Cassar and Blackwell 1996). Preliminary screening for benomyl tolerance demonstrated a uniform tolerance in the Microascaceae and sensitivity in the Ophiostomataceae (Summerbell 1993), suggesting another potential physiological test to indicate relationship among these morphologically similar taxa. Teleomorphs and anamorphs of some taxa in the Microascales and Ophiostomatales possess long necked, black perithecia, deliquescent asci, ascospores extruded in sticky masses, synnematous anamorphs with sticky conidia, and annellidic conidiogenesis. Morphological similarities are interpreted as convergent evolution for insect dispersal (Arx et al. 1984; Spatafora and Blackwell 1994).

Only two anamorphic microascaceous taxa (*Scedosporium* and *Graphium*) have been included in a molecular analysis (LeClerc et al. 1994; Issakainen et al. 1997; Okada et al. 1998). In other groups of ascomycetes, DNA sequence analysis has allowed integration of anamorphic taxa into a phylogenetic framework established using teleomorph characters (e.g., Bowman and Taylor 1993; LeClerc et al. 1994; Pan et al. 1994; Glenn et al. 1996; Messner et al. 1996; Hambleton et al. 1998).

Research Rationale and Objectives

The primary objective of this study was to test the hypothesis that the Microascaceae are a monophyletic group. Of particular interest was the placement of asexual stages with unproved affinities within the phylogenetic framework of the family, inferred through comparative morphology of cultures and type material. Physiological data (e.g., benomyl tolerance, cycloheximide resistance) and ribosomal DNA sequences provided independent characters for assessment of phylogeny. Although the Microascaceae require reevaluation at different taxonomic levels, ranging from order and family to genera and species, the goal was to circumscribe the family, and delimitation of genera and species which appeared to represent untenable assemblages was emphasized.

The detailed objectives of this project address specific problems in the understanding of the systematics and biodiversity of the family. These correspond closely to subsequent chapters in this dissertation.

Holomorph Studies.— In order to assess relationships between the sexual members of the family and asexual taxa with suspected affinities, detailed investigations into the life histories of selected species were undertaken. Connections between anamorphic and teleomorphic taxa were examined in Chapters 2, 3 and 4. Attempts were made to induce ascoma development in selected anamorphic taxa for which no teleomorphic state was known through use of various specialized media or substrata, extended growth periods, and mating trials. Close examination of life histories has broadened our understanding of inter- and intra-specific variation and has led to the discovery of sexual states for fungi previously assumed to be strictly asexual (Chapter 2).

The mating system in the Microascaceae was largely unknown, although some species of *Microascus* were known to be homothallic. Investigations into the mating system of species in the '*Scopulariopsis brevicaulis* Series' were undertaken to determine whether heterothallism occurs in this family. The results of mating trials link described asexual species with the appropriate sexual ones (Chapter 3). In other cases, mating trials produced sexual states which were previously unknown to science (Chapter 4) or which were 'lost species', not seen since their original description nearly a century ago (Chapter 3). By determining different mating systems (homothallic and heterothallic) and examining the holomorph, taxa exhibiting similar teleomorphic features could be differentiated (Chapter 4).

Pleomorphism expressed by species of Microascaceae presents a significant barrier to identification (Chapters 3 and 5). Recognition of the various and diverse sporulating sexual and asexual states of the holomorph is imperative. Two approaches were used to circumscribe morphological variation within a holomorph species. In chapter 3, mating trials revealed that a large number of described anamorphic taxa in the '*Scopulariopsis brevicaulis* Series' were conspecific. Many of these taxa had morphologically distinctive features and were accepted by various authorities as valid species, but produced fertile ascomata when mated. In chapter 5, isolates of *Pseudallescheria boydii* from a unique

habitat produced one or more different sporulating states in culture, including two synanamorphs and a teleomorph. The strains were suspected to be conspecific based on morphological evidence provided by an understanding of the species holomorph characters and this assumption was supported by common RFLP banding patterns and physiological similarities.

Taxonomic revision.— Monographic reassessment of genera and species of Microascaceae concentrated on genera or groups of species which were particularly problematic (Chapters 3, 4 and 6). In some cases, anamorphic taxa were linked to their sexual stages through holomorph studies and new insights were provided into boundaries separating teleomorphic taxa (Chapters 3 and 4). In other groups, anamorphic taxa were delimited and their disposition in appropriate form-genera using morphological characters of conidia, conidiophores, and conidiogenesis (including observation with SEM) was reevaluated (Chapter 6). Most species in the form-genera allied to the Microascaceae represent a morphologically uniform group, but several species differ and are phylogenetically unrelated, and belong in other anamorphic genera (see Chapters 6 and 7). Appendix 1 provides a bibliographic list of accepted taxa and specimens examined in this study.

Molecular systematics.— In order to test the monophyly of the family and to place the genera in a phylogenetic outline, the type species of each teleomorph and anamorph genus of the Microascaceae was analyzed (Chapter 7). DNA amplification by polymerase chain reaction (PCR) from living cultures allowed for sequence analysis of the nuclear encoded small subunit (18S) rDNA. This region was chosen since it has been found to contain phylogenetically informative sites in other closely related taxa (e.g., Spatafora and Blackwell 1994; Cassar and Blackwell 1996) and allowed comparisons of other sequences in GenBank. It was important to reexamine the morphology of the strains used in previous studies in order to confirm their identity before relying upon the GenBank sequences to interpret phylogenetic relatedness. The approximately 1000 base pair region sequenced was analyzed with PAUP 4.0b2 (Swofford 1998). Support for the inferred clades was estimated by calculating bootstrap confidence levels (Felsenstein 1985).

Biodiversity.— Many species of Microascaceae are common molds in the human environment in Alberta, growing in indoor environments and agricultural areas, but their occurrence in nature is unknown. A survey was undertaken in Alberta to determine occurrence of species on various substrata and to compare the species seen in boreal regions with that seen in disturbed habitats (Chapter 8). Specialized techniques and selective isolation media were developed to aid in the isolation of these fungi. Although work is needed for the Microascaceae in the areas of ecological interactions, habitat preference, and diversity, much of this was beyond the scope of the current project. Emphasis was placed on isolation of Microascaceae from various substrata in boreal and montane forests in Alberta to test the hypothesis that species prevalent in the human environment (e.g., *Scopulariopsis brevicaulis*) are also common in nature.

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CHAPTER 2

MICROASCUS BREVICAULIS SP. NOV., THE TELEOMORPH OF *SCOPULARIOPSIS BREVICAULIS*, SUPPORTS PLACEMENT OF *SCOPULARIOPSIS* WITH THE MICROASCACEAE[1]

Introduction

Scopulariopsis brevicaulis (Sacc.) Bainier, described by Saccardo (1881) as *Penicillium brevicaule* Sacc., is an ubiquitous, saprobic mold found worldwide in soil, plant and animal matter, and air (Domsch et al. 1980). It has proteolytic and cellulolytic abilities, and is an occasional agent of superficial human infection. Although the connection between *Scopulariopsis* and *Microascus* (Microascaceae, Microascales) has been established for some species (e.g., Sopp 1912 as *Acaulium*; Emmons and Dodge 1931; Barron et al. 1961; Morton and Smith 1963), a sexual state for the type species of *Scopulariopsis*, *S. brevicaulis*, has never been reported. Morton and Smith (1963) reported the presence of black 'sclerotia', which resembled perithecia but lacked ascospores, in two strains of *S. brevicaulis*. Many other *Scopulariopsis* species remain unconnected to sexual states.

An isolate of *Scopulariopsis brevicaulis* producing perithecia was recovered by air sampling in a honeybee (*Apis mellifera*) overwintering facility, along with many strictly anamorphic isolates (Sigler et al. 1996). Since the initial discovery in 1994, two other ascocarpic isolates have been recovered from indoor and outside air. A thorough re-examination of 65 strains of *S. brevicaulis* deposited in the University of Alberta Microfungus Collection and 25 unaccessioned isolates revealed two additional sexually reproducing isolates from Alberta.

The small, black, ostiolate ascomata and reniform, pale orange ascospores place the teleomorph of *S. brevicaulis* in the genus *Microascus*, and it is here described as a new species. A discussion of its relationship to other *Microascus* species is provided.

Materials and Methods

Ninety isolates of *Scopulariopsis brevicaulis* were examined for propensity to produce a sexual stage by growing them on oatmeal salts agar (OAT; Weitzman and Silva-Hutner 1967) and monitoring them for 25 wk. Five teleomorphic and six anamorphic isolates selected from diverse substrata and geographic origins (see *Specimens examined*), were compared to determine if there were differences between ascocarpic and nonascocarpic isolates. Colony diam and morphologies of the selected isolates were

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[1] A version of this chapter has been published as:
Abbott, S.P., L. Sigler, and R.S. Currah. 1998. *Microascus brevicaulis* sp. nov., the teleomorph of *Scopulariopsis brevicaulis*, supports placement of *Scopulariopsis* with the Microascaceae. Mycologia 90: 297-302.

examined on potato dextrose agar (PDA; Difco Laboratories, Detroit, MI) and pablum cereal agar (CER; Sigler 1992), and thermotolerance was assessed on PDA at 37 C. Tolerance to fungal inhibitors was determined by measuring colony diameters on mycosel agar containing cycloheximide at 400 µg/mL (MYC; Becton Dickinson Microbiology Systems, Cockeysville, MD) and on PDA supplemented with 2 µg/mL benomyl at 25 C after 7 and 14 d. For these tests, a sterile needle was inserted into a suspension of conidia prepared for each strain in semisolid detergent agar (Pitt 1973) and then stab inoculated into the center of 100 mm diam petri dishes containing one of the described media. Conidial morphology was observed in CER slide-culture preparations, and all mounts were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992). Selected specimens were either air dried or fixed in 2% osmium tetroxide vapor and critical-point dried for examination with a Hitachi S-2500 scanning electron microscope (SEM).

Holotype herbarium material and ex-type culture of the type strain, and living and dried material of the other strains are maintained in the University of Alberta Microfungus Collection and Herbarium (UAMH). Isotype herbarium material is deposited in the Herbarium, Royal Botanic Gardens, Kew (K).

Results

Microascus brevicaulis S.P. Abbott, sp. nov. FIGS. 2.1-2.7

Ascomycota, Microascales, Microascaceae

Status anamorphosis: *Scopulariopsis brevicaulis* (Saccardo) Bainier. 1907. Bulletin Societé Mycologique de France 23: 99.

Peritheciis 80-150 x 70-130 µm, globosis vel subglobosis, ostiolatis, papillatis, nigris; peridiis textura angularis; ascis octosporis, globosis vel subglobosis, deliquescentibus; ascosporis 5-6 x 3.5-4.5 µm, reniformis, laevis, subhyalinis vel aurantiis en masse; conidiophora annellata; conidiis 6-9 x 5.5-9 µm, subglobosis, verrucosis, pallido-brunneis. Holotypus. UAMH 7770.

Perithecia 80-150 x 70-130 µm, globose to subglobose, with a papillate to short-necked (up to 20 µm) ostiolar region, black; peridium of *textura angularis*, cells 5-9 µm diam; appendages lacking. *Asci* 8-10 µm diam, subglobose to slightly irregular, octosporous, deliquescent at a very early stage and infrequently observed. ***Ascospores*** 5-6 x 3.5-4.5 µm, broadly reniform (plano-convex to concavo-convex) in face view and flattened, 2.5-3 µm in end view, orange in mass, appearing subhyaline in transmitted light, smooth, de Bary bubbles and guttules lacking, germ pore not evident by light or scanning microscopy. ***Conidia*** 6-9 x 5.5-9 µm, globose to subglobose, with a truncate base, base may be slightly protruding (lightbulb-shaped), pale brown, occasionally smooth or only finely ornamented but the majority of spores verrucose with coarse irregular warts at maturity, produced in dry chains from simple or branched annellidic conidiogenous apparatus; annellides 10-25 x 3-5 µm, elongate ampulliform, hyaline.

Specimens examined. *Microascus brevicaulis.* HOLOTYPE. CANADA: ALBERTA: Scandia. dried colony on OAT at 25 wk ex indoor air of honeybee (*Apis mellifera*) overwintering facility, 11 Mar. 1994, *S.P. Abbott OHS 428*, (UAMH 7770). ISOTYPE. (K). PARATYPES. CANADA: ALBERTA: Calgary. indoor air from basement of home, 10 Jan. 1995, *S.P. Abbott SA-M26* (UAMH 7880); Barrhead. outside air, 20 Mar. 1996, *S.P. Abbott SA-M76*, (UAMH 8627); Alberta Game Farm east of Edmonton. straw of birdhouse roosts, 8 Nov. 1961, *J.W. Carmichael 16-12-a*, (UAMH 1197); Lethbridge. dead housefly larvae, 1974, *R.G. Bell*, (UAMH 3753).

Scopulariopsis brevicaulis. AUSTRALIA: QUEENSLAND: Innisfail. atmosphere, cleared site, 1985, *J. Upsher*, obtained from Australian National Collection of Biodeterioration Microfungi as AMRL 1675, (UAMH 8702). CANADA: ALBERTA: north of Mariana Lake. burnt wood of black spruce (*Picea mariana*), 16 Aug. 1996, *S.P. Abbott SA-M137*, (UAMH 8628). KOREA: Chuncheon. Meju, Korean fermented soybeans, *J.D. Lee A-1-2*, obtained from Japan Collection of Microorganisms as JCM 2619, (UAMH 8497). UNITED KINGDOM: Manchester. 1930, obtained from International Mycological Institute as IMI 61424, (UAMH 8785). VENEZUELA: Caracas. Sep. 1955, *C.B. Pinto 43-3*, obtained from United States Department of Agriculture as NRRL A-6185, (UAMH 943). ZAIRE: Mount Hawa. silk worm chrysalis, 1952, *R.L. Steyaert*, obtained from International Mycological Institute as IMI 49528, (UAMH 644).

Cultural properties. Macroscopic and microscopic morphological characters, as well as colony diameters under various conditions (medium, temperature, antifungal compounds) were comparable among the eleven strains and no distinction between ascocarpic and nonascocarpic strains was discerned (Table 2.1). Colonies were light sandy tan or avellaneous brown, typically with a white, entire margin, shallowly convex, fasciculate to velutinous, occasionally with a floccose mycelial overlay. Colonies on CER (Fig. 2.1) were more distinctly fasciculate, and the color was more pronounced than on PDA. Colony diam were greater, and there was less between-isolate variation among strains on CER than on PDA in 14 d at 25 C. All isolates grew more slowly at 37 C, with colony diam 33-86% of those at 25 C. All isolates were tolerant to benomyl at 2 μg/mL, with growth rates comparable to those on unamended media. Selected strains showed no inhibition when grown on PDA amended with 10 μg/mL benomyl (data not shown). On medium containing 400 μg/mL cycloheximide, isolates grew slowly but demonstrated good sporulation. Conidial size varied over a narrow range (extremes 5.5-7.5 vs. 6.5-9 μm diam) among strains.

Ascomata were produced on several media but were most abundant on OAT in 6 - 25 wk. They occurred on the agar surface and submerged in the upper 5 mm but their presence was obscured by the confluent conidial stage. Ascospores typically remained within perithecia for prolonged periods, but were eventually exuded in a droplet from the ostiole after 6-11 months as the medium dried. Unlike many other species of *Microascus*, no prominent cirrus was produced. Perithecia were produced less abundantly on MYC, CER, phytone yeast extract agar, Takashio agar (Takashio 1972), and corn meal agar. Cultures of UAMH 7770 grown for one year on 2% malt extract agar, soil extract agar,

potato dextrose agar, Sabouraud dextrose agar or on pieces of sterile wood (aspen and pine) placed on tap water agar failed to produce fertile ascomata.

Discussion

Considering the long history, widespread distribution, and frequent isolation of *Scopulariopsis brevicaulis*, the discovery of five sexually reproducing isolates is remarkable. There are several possible explanations for the teleomorph being hitherto unknown. (i) Ascomata are produced only after considerable time (6-25 wk). Because the colonies grow rapidly and conidia are produced abundantly within a week, isolates frequently are not retained long enough for ascoma production. (ii) Ascomata are obscured by heavy mycelial and conidial growth (Fig. 2.1), and their inconspicuousness is complicated by small size (70-130 µm diam)(Figs. 2.5, 2.7), lack of prominent cirrus, and production at the agar surface or submerged in the medium. Even when ascomata were nearly confluent they were difficult to see, and were often first noticed submerged in the agar against the side of the petri dish. (iii) Sporulating strains produced ascomata on a number of media, but ascomata were reduced, delayed or lacking on malt extract agar, potato dextrose agar and Sabouraud dextrose agar, routinely used for fungal isolation.

None of the other 85 strains of *Scopulariopsis brevicaulis* produced ascomata under any condition. These were from diverse sources from across North America, South America, Europe, Asia, Africa and Australia. All teleomorphic strains have been isolated from Alberta. It is possible that there is a geographic restriction of a potentially sexually reproducing population, as is known for *Hypomyces cervinigenus* Rogerson & Simms which has a widespread anamorph, *Mycogone cervina* Ditmar (Rogerson and Simms 1971). However, many other strains from Alberta exhibit typical anamorphic states only, including isolates recovered at the same sites as ascocarpic ones. Also, the two isolates reported to produce 'sclerotia' or abortive perithecia (Morton and Smith 1963) were from the U.K. These two isolates (UAMH 8785, 8786) were studied here but have not produced any ascomatal structures; however, each has been maintained in culture collections for about 70 years.

Examination of herbarium material consisting of dried colonies and permanent mounts of UAMH 1197 revealed the presence of primarily immature perithecia of which a small proportion produced a limited number of ascospores. When the isolate was regrown from a lyophilized ampoule (prepared 1962) and from an agar slant frozen at -20 C (prepared 1971), cultures were very slow (6 mo) to produce a few ascomata. Subsequent subculture from ascoma-producing areas of the colonies enhanced perithecium production and fertility. In contrast, UAMH 3753 recovered from a lyophilized ampoule (prepared 1975) produced abundant perithecia within 6 wk, although maturity required additional time. Particular attention was paid to preserve the three recent isolates of *M. brevicaulis* (UAMH 7770, 7880, 8627) from colonies with mature perithecia, and all have demonstrated the ability to produce fertile ascomata upon recovery from storage.

A variety of species of Microascaceae, including *Scopulariopsis brevicaulis*, have demonstrated tolerance to benomyl (Valmaseda et al. 1987; Summerbell 1993). Our results confirm the uniformity of tolerance among isolates. Tolerance to cycloheximide is also common in the family, but there is much greater variation between species and among individual strains (Abbott, unpublished data), as was shown for this species (Table 2.1).

Close relationship of *Microascus brevicaulis* to *M. manginii* (Loub.) Curzi, the teleomorph of *Scopulariopsis candida* Vuillemin, is suggested by similarities in ascomata, ascospores and conidial states. In both species, ascomata are small (up to 150 μm diam) and papillate. Ascospores are broadly reniform, 4-5 x 2.5-4 μm in *M. manginii* and 5-6 x 3.5-4.5 μm in *M. brevicaulis*. Conidia are similar in shape, but easily distinguished by surface texture (smooth in *S. candida* and ornamented in *S. brevicaulis*) and coloration (white to cream colonies with hyaline conidia in *S. candida* and sandy/tan brown colonies with distinctly pigmented conidia in *S. brevicaulis*). Similarities in conidia and conidiophores were noted by Morton and Smith (1963) who included both species within the 'brevicaulis series' of *Scopulariopsis*. Morton and Smith (1963) rarely observed perithecium-like bodies in both *S. candida* and *S. brevicaulis*. The propensity of *S. candida* to produce non-fertile perithecia was frequently observed in our isolates (e.g., UAMH 3568, 4065, 4367, 7882, 8683), but not in the 90 strains of *S. brevicaulis*.

Two other species of *Microascus* with conidial states similar to *M. brevicaulis* were described by Sopp (1912), as *Acaulium nigrum* Sopp and *A. flavum* Sopp. Although *Acaulium* Sopp is considered a synonym of *Scopulariopsis* by most authors (e.g., Barron et al. 1961; Morton and Smith 1963), Sopp described perithecia in three species. No type material or cultures exist of Sopp's specimens (fide Morton and Smith 1963), but the original descriptions and illustrations are sufficient to distinguish them from our new species. *Acaulium nigrum* was transferred to *Microascus* by Curzi (1931), as *M. niger* (Sopp) Curzi. Although no perithecia have been observed since the original description, *M. niger* was tentatively accepted by Barron et al. (1961) and regarded as the teleomorph of *Scopulariopsis asperula* (Sacc.) S. Hughes by Morton and Smith (1963). The anamorph is distinguished from *M. brevicaulis* in its darker, fuscous-brown colonies and conidia, and the ascospores, in the original description, are larger (7 x 5 μm). Morton and Smith treated *A. flavum* as a species of *Scopulariopsis* since their material failed to produce a sexual stage. This species differs from *M. brevicaulis* by paler, buff colonies and conidia (Morton and Smith 1963), and larger (6-7 μm) ascospores (Sopp 1912). Both of Sopp's species were isolated from insect larvae, as was one strain of *M. brevicaulis* (UAMH 3753).

Recent molecular phylogenetic studies (Berbee and Taylor 1992; Hausner et al. 1993; Spatafora and Blackwell 1994; Cassar and Blackwell 1996) have supported the Microascaceae as monophyletic, but the analyses have included few representatives of only teleomorphic taxa. Although the connection between *Microascus* and *Scopulariopsis* has been recognized by many authors, the discovery of a teleomorph for the type species of *Scopulariopsis* allows this anamorph genus to be placed among the Microascaceae. Anamorphic form-genera are primarily artificial taxonomic entities based on structural

similarity serving as a practical means of identifying and naming asexual fungi (Gams 1995), but many authors (e.g., Seifert 1993) have favored a phylogenetic approach for the classification of anamorphic taxa. Form-genera are not strictly monophyletic units, especially when combined in a phylogenetic framework with teleomorphic taxa, but I support the view that unrelated and morphologically divergent taxa should be excluded where practicable (Seifert 1993; Gams 1995). In this case, the form-genus *Scopulariopsis* can be restricted to anamorphs of the Microascaceae. Many morphologically distinct species with different affinities have already been transferred to other form-genera including *Sagenomella*, *Basipetospora*, *Polypaecilum*, and *Gliomastix*. Although some authors (e.g., Taylor 1995) have taken an extreme position and advocated the abandonment of anamorphic names when phylogenetic position can be clearly established, form genera continue to serve a useful purpose in routine identification, especially in a case such as this where the *Microascus* teleomorph is rarely seen.

Table 2.1. Comparison of conidium size and colony diameter in 5 ascocarpic and 6 non-ascocarpic strains.

Ascocarps	Conidium diameter (μm)	Colony diam at 14 d (mm)				
		PDA at 25 C	PDA + benomyl at 25 C	PDA at 37 C	CER at 25 C	MYC at 25°C
+	5.5-9	46-57	43-54	17-32	75-78	30-41
–	5.5-9	38-75	37-75	15-42	72-80	17-38

Figures 2.1-2.7. ***Microascus brevicaulis.***

Fig. 2.1. Colony on CER 14 d at 25 C showing confluent growth of anamorph (UAMH 7880), bar = 15 mm.

Fig. 2.2. Conidiophore and young, smooth to slightly roughened conidia (UAMH 1197), bar = 10 µm.

Fig. 2.3. Mature, coarsely ornamented conidia (UAMH 943), bar = 5 µm.

Fig. 2.4. Ascospores (black arrow) and conidia (white arrow) (UAMH 7770, TYPE), bar = 5 µm.

Fig. 2.5. Perithecium (UAMH 7770, TYPE), bar = 25 µm.

Fig. 2.6. Smooth ascospores and ornamented conidia showing slightly protruding and truncate base, SEM (UAMH 7770, TYPE), bar = 1.5 µm.

Fig. 2.7. Perithecium, note ostiole (arrow) and peridium of *textura angularis*, SEM (UAMH 7770, TYPE), bar = 20 µm.


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CHAPTER 3

HETEROTHALLISM IN THE MICROASCACEAE DEMONSTRATED BY THREE SPECIES IN THE *SCOPULARIOPSIS BREVICAULIS* SERIES

Introduction

Sexual reproduction, which allows for genetic variation, is accomplished by two different strategies in ascomycetous fungi. Homothallic fungi are self-fertile, while heterothallic species are self-sterile and require a compatible partner for reproduction to occur. Homothallism is most common, but both mating strategies occur among various groups of ascomycetes. Yun et al. (1999) demonstrated that homothallism is a derived state and that heterothallism is ancestral in the ascomycetes. The fertile ascomata produced abundantly in axenic culture by many species of the Microascaceae suggests they are homothallic, although the mating behavior has been examined for only a few species of *Microascus* (e.g., Barron et al. 1961). The mating system is unknown for *Kernia*, *Lophotrichus*, *Petriella* and *Pseudallescheria*. Emmons and Dodge (1931) showed that 20 single ascospore isolates of *Microascus trigonosporus* Emmons & Dodge all developed fertile perithecia. Many species of *Microascus*, including *M. trigonosporus*, are known to produce *Scopulariopsis* anamorphs, but the relationships of strictly anamorphic *Scopulariopsis* species has been only sparingly investigated (e.g., Abbott et al. 1998).

Morton and Smith (1963) defined the '*Scopulariopsis brevicaulis* Series' to include species with large, subglobose, smooth or ornamented, white to brown conidia, produced from highly branched conidiophores, and with annellides which were broad at the apex (3 µm) and ampuliform but not abruptly swollen at the base. Included here were *S. brevicaulis* (Sacc.) Bainier (the type species of the genus), *S. asperula* (Sacc.) S. Hughes, *S. flava* (Sopp) Morton & G. Smith, *S. candida* Vuillemin, *S. koningii* (Oudemans) Vuillemin, and *S. fusca* Castellani.

Some of these *Scopulariopsis* species produce sclerotium-like structures that resemble perithecia but lack ascospores (Morton and Smith 1963; Abbott et al. 1998) suggesting at least some genetic ability to produce a teleomorphic stage. One such sexual state was found for *S. brevicaulis*, described as *Microascus brevicaulis* S.P. Abbott (Abbott et al. 1998). Many isolates of *Scopulariopsis candida* produce these structures (Abbott et al. 1998), and this asexual species has been connected to the teleomorph *Microascus manginii* (Loub.) Curzi based on conidial similarity (Morton and Smith 1963). Morton and Smith tentatively accepted a connection between *S. asperula* and *M. niger* (Sopp) Curzi, but recommended that the teleomorph described by Sopp (1912, as *Acaulium nigrum* Sopp) be disregarded since there was no extant type material and the species had not been seen since the original description.

The *Scopulariopsis brevicaulis* Series presented an excellent opportunity to

evaluate the holomorphic life history and mating behavior of some additional species in the Microascaceae. Several observations suggested the possibility of heterothallism in this group: 1) only five teleomorphic strains were known for *S. brevicaulis* (Abbott et al. 1998), a very common mold, making it unlikely that *Microascus brevicaulis* could be homothallic; 2) the common recovery of infertile isolates assignable to *S. candida* compared with the infrequent isolation of *M. manginii*; and 3) the report of a sexual stage connected with an asexual state resembling *S. asperula* (Sopp 1912).

To address this question, mating trials among strains of species in the '*S. brevicaulis* Series' were performed. In addition to the species discussed above, two others, *S. koningii* and *S. fusca*, have never been connected to sexual states. These show considerable similarity to *S. brevicaulis* and *S. asperula* respectively, and were included in mating trials to evaluate their taxonomic status. No mating tests were done with *S. flava* since very few isolates are known (see Morton and Smith 1963). The results of mating tests are presented along with a reappraisal of accepted names in the '*Scopulariopsis brevicaulis* Series', including their connection to species of *Microascus*.

Materials and Methods

Morphology.— Living cultures and herbarium material of wild type strains, single ascospore isolates, and mated pairs are maintained in the University of Alberta Microfungus Collection and Herbarium (UAMH). Colonial features were recorded and colony diameters were measured on oatmeal salts agar (OAT; Weitzman and Silva Hutner 1967) and potato dextrose agar (PDA; Difco Laboratories, Detroit, MI) at 25 C after 7, 14, 21 and 28 days. Colors were determined using the color standards of Kornerup and Wanscher (1978). Microscopic mounts were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992) and ascospores were observed in squash-mount preparations. The slide culture technique was employed using cereal agar (Sigler 1992), to allow observation of conidial stages. Selected specimens were fixed in 2% osmium tetroxide vapor and critical-point dried for examination with a Hitachi S-2500 scanning electron microscope (SEM).

Scopulariopsis brevicaulis.— Nine single ascospore isolates of *Microascus brevicaulis* were obtained from UAMH 8627 (ex-paratype culture) by removing one perithecium and washing the surface repeatedly with sterile water to remove adhering conidia. The ascoma was then placed in 10 ml of sterile water and crushed to suspend the ascospores. Approximately 1 ml of the suspension was spread across 10 PDA plates. These were incubated at 22 C for three to seven days to allow germination. Colonies were observed under the microscope to ensure that they resulted from germination of single ascospores. Hyphal-tip transfers were placed on OAT to obtain pure cultures. Crosses between the 9 single ascospore isolates were made in all combinations (including self crosses) by suspending conidia in 1.5 ml of sterile water and pipeting one drop of suspension onto the centre of an OAT plate. A drop of suspension from a second strain was then added allowing conidia to mix. Plates were incubated at 22 C, examined after 7 weeks and periodically for 14 months. Plates were checked macroscopically for development of

submerged ascomata around the edge of the plate and with a dissecting microscope after removing sections of superficial conidial growth to find ascomata along the agar surface in the centre of the plate. Microscopic mounts were made to monitor for ascospore production. Two single ascospore isolates that yielded a fertile cross were arbitrarily designated as plus (UAMH 9090) and minus (UAMH 9092) mating types. These were mated with the six wild type strains of *S. brevicaulis* examined in Abbott et al. (1998) and three stains received as *S. koningii* or *S. flava*. Conidia of each strain were suspended in semisolid detergent agar (SSD; Pitt 1973). The strains were paired by streaking the suspension of each strain onto one half of an OAT plate, allowing for a central zone of contact as the isolates grew. Crosses were incubated at 22 C and monitored after 6 weeks and checked periodically thereafter for 12 months for development of ascomata along the central contact zone.

Scopulariopsis candida.— Nine wild type strains of *S. candida* were crossed in all possible combinations, using SSD on OAT as described above. Plates were held for 19 months to determine teleomorph fertility. Strains were chosen to represent the broad range of variation seen among the 35 strains examined at UAMH (see Appendix 1). These included strains that routinely exhibited sterile ascomatal structures as well as those that demonstrated only conidia. Representative plus and minus mating type strains were selected (UAMH 3568, 9004) and back crossed to the type culture of *Microascus manginii*, which produced only the anamorph in culture when received from the Centraalbureau voor Schimmelcultures (CBS 170.27; =UAMH 9135). The perithecia and ascospores produced in all positive pairings were compared with those produced by eight isolates of *Microascus manginii* housed at UAMH.

Scopulariopsis asperula.— Nine strains which represented type, authentic, and recent isolates of *S. asperula, S. fusca, S. roseola, S. arnoldii* and *S. bestae*, were crossed in all combinations as was done for *S. candida* above. These were selected from among 25 strains (see Appendix 1) with a similar gross morphology, and which included the extremes of morphological variation seen among this group of isolates. Representative teleomorph-producing crosses were accessioned into the UAMH in order to maintain sexually reproducing strains (UAMH 9489, 9490, 9491).

Crosses between species.— To test for fertility between species, plus and minus mating type strains determined in each experiment above were crossed. Pairings were done as above between *S. brevicaulis* (UAMH 9090, 9092), *S. candida* (UAMH 3568, 9004), and *S. asperula* (UAMH 8362, 9037) in all combinations, and crosses were held for 13 months.

Taxonomic Part

Microascus brevicaulis S.P. Abbott. 1998. Mycologia 90: 298. (holotype and ex-type culture UAMH 7770!) FIGS. 3.1, 3.4, 3.7, 3.10

status anamorphosis:

Scopulariopsis brevicaulis (Saccardo) Bainier. 1907. Bulletin Societé

Mycologique de France 23: 99.
≡ *Penicillium brevicaule* Saccardo. 1881. Fungi Italici No. 893.
= *Scopulariopsis koningii* (Oudemans) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 143.
≡ *Monilia koningii* Oudemans. 1902. in Oudemans and Koning, Archives Néerlandaises des Sciences, Sér. 2, 7: 287.

The nine single ascospore isolates from *Microascus brevicaulis* resulted in anamorphic strains consistent with *Scopulariopsis brevicaulis* and lacking any indication of a teleomorphic stage. These isolates produced fertile ascomata when crossed. Three isolates were designated as plus mating type strains, which crossed with six minus strains (Table 3.1). All strains produced fertile ascomata in some crosses (12 fertile crosses total), but six pairings produced only sterile ascomata along the contact zone. Plus (UAMH 9090) and minus (UAMH 9092) mating type stains were back crossed against wild type *S. brevicaulis* isolates. All wild type anamorphic strains produced fertile ascomata with only one of the mating types (Table 3.2).

Heterothallism was demonstrated by: 1) absence of a sexual stage in single ascospore isolates, 2) fertility between single ascospore isolate pairs, and 3) fertility between single ascospore isolates and wild type strains. This is the first account of this type of mating behavior in the Microascaceae. This species behaves as expected for a single gene (unifactorial) heterothallic mating system, with strains being either plus or minus, and mating only with the opposite mating type in all cases. In only a very small proportion of the single spore tests were infertile ascomata seen. It is possible, given the extreme length of time required for fertility (results given at 14 months), that these strains would have proceeded to maturity eventually. This confirms that the few sexually reproducing strains of *M. brevicaulis* originally reported by Abbott et al. (1998) were conspecific with the familiar mold *Scopulariopsis brevicaulis*.

Morton and Smith (1963) accepted *S. koningii* based on the smooth conidia and pale avellaneous colonies. Raper and Thom (1968) considered *S. koningii* synonymous with *S. brevicaulis*, although no discussion was provided. Mating reactions clearly indicate that the species are conspecific. Two of the strains (UAMH 363 and 9040) that were morphologically typical for *Scopulariopsis koningii* (*sensu* Morton and Smith 1963) produced fertile ascomata when mated with the single ascospore isolates of *Microascus brevicaulis*. Observations here support a correlation between smooth conidia and pale colonies, but these characters are not independent. The greatest concentration of pigment is seen by light microscopy in the protuberances of the conidial ornamentation, accounting for associated colonial coloration. Confirmation of conspecificity helps to alleviate the problem of species determination from reports in some of the older medical mycology literature. Many isolates from clinical sources were reported as *S. koningii* (e.g., Sartory 1916), but their identification has been questioned by many later authors (e.g., Morton and Smith 1963) who suspected that they were merely smooth-spored isolates of *S. brevicaulis*, a well known opportunistic pathogen.

Specimens examined. *Microascus brevicaulis.* CANADA: ALBERTA: Scandia. indoor air of honeybee (*Apis mellifera*) overwintering facility, 11 Mar. 1994, *S.P. Abbott OHS 428*, (holotype and ex-type culture UAMH 7770, isotype K); Calgary. indoor air from basement of home, 10 Jan. 1995, *S.P. Abbott SA-M26*, (paratype UAMH 7880); Barrhead. outside air, 20 Mar. 1996, *S.P. Abbott SA-M76*, (paratype UAMH 8627); Alberta Game Farm east of Edmonton. straw of birdhouse roosts, 8 Nov. 1961, *J.W. Carmichael 16-12-a*, (paratype UAMH 1197); Lethbridge. dead housefly larvae, 1974, *R.G. Bell.* (paratype UAMH 3753); Elk Island National Park. wood of well rotted white spruce (*Picea glauca*) log, 28 Sep. 1998, *T. Lumley and S.P. Abbott EI-02-S1D*, (UAMH 9367); 30 km east of Nordegg. dung of moose (*Alces alces*), 30 Sep. 1996, *S.P. Abbott SA-M136*, (UAMH 9458); UAMH. single ascospore isolates (+) ex UAMH 8627, *S.P. Abbott Mb4, Mb8, Mb9*, (UAMH 9090, 9091, 9407); UAMH. single ascospore isolates (–) ex UAMH 8627, *S.P. Abbott Mb1, Mb3, Mb7*, (UAMH 9092, 9093, 9406).

Scopulariopsis brevicaulis. AUSTRALIA: QUEENSLAND: Innisfail. atmosphere, cleared site, 1985, *J. Upsher*, obtained from Australian National Collection of Biodeterioration Microfungi as AMRL 1675, (UAMH 8702). CANADA: ALBERTA: north of Mariana Lake. burnt wood of black spruce (*Picea mariana*), 16 Aug. 1996, *S.P. Abbott SA-M137*, (UAMH 8628); Edmonton. hairs ex neck, *J.W. Carmichael* 1955, (UAMH 363; =LSHB Sc.114, =IMI 86929). MANITOBA: Winnipeg. outside air, 21 Dec 1994, *S.P. Abbott SA-M31*, (UAMH 9040). KOREA: Chuncheon. Meju, Korean fermented soybeans, *J.D. Lee A-1-2*, obtained from Japan Collection of Microorganisms as JCM 2619, (UAMH 8497). NETHERLANDS: pupa of *Pteronus pini*, 1935, *J. Rozsypal*, obtained from Centraalbureau voor Schimmelcultures as *S. flava*, CBS 335.35, (UAMH 9139). UNITED KINGDOM: Manchester. 1930, obtained from International Mycological Institute as IMI 61424, (UAMH 8785). VENEZUELA: Caracas. Sep. 1955, *C.B. Pinto 43-3*, obtained from United States Department of Agriculture as NRRL A-6185, (UAMH 943). ZAIRE: Mount Hawa. silk worm chrysalis, 1952, *R.L. Steyaert*, obtained from International Mycological Institute as IMI 49528, (UAMH 644).

Microascus manginii (Loubière) Curzi. 1931. Bollettino. Stazione di Patologia Vegetale di Roma (N.S.) 11: 60. FIGS. 3.2, 3.5, 3.8, 3.11

≡ *Nephrospora manginii* Loubière. 1923. Comptes Rendus. Academie des Sciences (Paris) 177: 209. (ex-type culture UAMH 9135!)

= *Scopulariopsis alboflavescens* Zach. 1934. Österreichische Botanische Zeitschrift 83: 177. (ex-type culture UAMH 934!)

status anamorphosis:

Scopulariopsis candida Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 143. (epitype culture selected UAMH 9004!)

≡ *Monilia candida* auct., sensu Guéguen. 1899. Bulletin Societé Mycologique de France 15: 271. (non Persoon; non Bonorden)

≠ *Monilia candida* Persoon. 1801. Synopsis methodica fungorum. (=*Aspergillus* fide Vuillemin 1911).

≠ *Monilia candida* Bonorden. 1851. Handbuch der allgemeinen mykologie. (=*Monilia bonordenii* Vuillemin. 1911)

= *Chrysosporium keratinophilum* var. *denticolum* Moreau. 1969.

Mycopathologia et Mycologia Applicata 37: 37. (nom invalid, ICBN Art. 36). (ex-type culture UAMH 8798!)

Although the mating trials did not produce fertile perithecia in all combinations, heterothallism is demonstrated for this species. Thirteen of 18 pairings among nine anamorphic strains yielded fertile or infertile ascomata along a zone of contact. Three isolates designated as plus mating type crossed with six minus strains (Table 3.3). Fertile ascomata produced by mated pairs of *S. candida* were similar in all respects to those produced by strains of *M. manginii*. Since the ex-type culture of *M. manginii* (UAMH 9135) failed to produce ascomata when received, it was crossed with a plus (UAMH 3568) and minus (UAMH 9004) mating type, resulting in production of fertile ascomata with the plus mating type strain.

A relatively broad range of variation is present within a sexually reproducing species, *M. manginii*. Strains that exhibited a propensity to form sclerotia-like structures independently (e.g., UAMH 3568), produced these structures randomly throughout the colony. In all cases the mated pairs produced ascomata in a line of contact in the centre of the petri dish where the two strains met, enabling the results of the crosses to be readily determined. These 'sclerotial' strains produced the most fertile crosses, while strains which appeared somewhat degenerate with glabrous colonies and sparse conidial sporulation (e.g., UAMH 931, 7924) gave the weakest results. These strains were included since they were morphologically aberrant and their identity was questioned. Another strain (UAMH 8404) exhibited conidia and colonies which were pale yellow in color, differing from the typical white to cream isolates.

The connection between *Scopulariopsis candida* and *Microascus manginii* was demonstrated by Loubière (1923, as *Monilia candida* and *Nephrospora manginii*) and accepted by several subsequent authorities (Thom 1930; Curzi 1931; Morton and Smith 1963). Zach (1934) described *S. alboflavescens* including a sexual stage, and Barron et al. (1961) treated it as a synonym of *M. manginii*. The ex-type culture of *S. alboflavescens* (UAMH 934) was strictly conidial when recovered from preserved stocks, but produced fertile ascomata when paired with two plus mating type strains of *S. candida* (Table 3.3). This behavior was also observed in the ex-type culture of *M. manginii* discussed above.

The epithet 'candida' is problematic. *Monilia candida* described by Persoon (1801), is appropriately referred to *Aspergillus* (Vuillemin 1911). *Monilia candida*, described for a different species by Bonorden (1851), was recognized as a later homonym and renamed as *Monilia bonordenii* (Vuillemin 1911). The illustration in Bonorden (1851) is clearly not a *Scopulariopsis* based on the branched conidial chains. Guéguen (1899) described a variant of *Monilia candida* Bonorden, and this is the first description that corresponds to the fungus we recognize today as *Scopulariopsis candida*. By referring Guéguen's isolate to *Scopulariopsis*, Vuillemin (1911) created the unintentional nomen novum *Scopulariopsis candida* Vuillemin (ICBN Art. 33, Greuter et al. 1994). Because of the nomenclatural confusion and since no type material is in existence, UAMH 9004 is chosen as epitype culture to stabilize the modern concept of *Scopulariopsis candida*,

supporting that defined by Vuillemin (1911).

Specimens examined. *Microascus manginii.* AUSTRIA: diseased skin of man, *F. Zach*, obtained from Centraalbureau voor Schimmelcultures as CBS 399.34, ex-type culture of *Scopulariopsis alboflavescens*, (UAMH 934). BURMA. milled rice, 1954, *S. Udagawa NHL 2278*, (UAMH 1923). CANADA: ALBERTA: Red Deer. outside air, 9 Mar 1995, *S.P. Abbott SA-M73* (UAMH 7921); Edmonton. head lesions ex chicken, 1967, *J.W. Carmichael*, (UAMH 2710); Elk Island National Park. wood of white spruce (*Picea glauca*) log, 11 Feb. 1997, *T. Lumley EI-09-S3E*, (UAMH 9147). ONTARIO. Guelph. chicken litter, 10 Jan. 1966, *G. Barron 10490*, (UAMH 2642). FRANCE: *L. Mangin*, ex-type culture of *Nephrospora manginii*, obtained from Centraalbureau voor Schimmelcultures as CBS 170.27, (UAMH 9135). INDIA: Lucknow. 1967, *J.N. Rai*, obtained from International Mycological Institute as IMI 128461 (UAMH 8796). UNITED KINGDOM: buckwheat chaff, 1974, *A. Donnelly*, obtained from International Mycological Institute as IMI 182498 (UAMH 8797). UNITED STATES: ARIZONA: dung, 29 Aug. 1958, *G.F. Orr O-425*, obtained from United States Department of Agriculture as NRRL A-8022, (UAMH 8977).

Scopulariopsis candida. CANADA: ALBERTA: Edmonton. skin from chin of man, 1954, *J.W. Carmichael*, (UAMH 238); toe nail of man, 20 Feb. 1995 *C. Sand*, (UAMH 7924). BRITISH COLUMBIA: Chilliwak. indoor air of office building, 27 Mar. 1997, *S.P. Abbott SA-M175*, (UAMH 9004). ONTARIO: Wallaceburg. carpet dust from home, 14 Apr. 1994, *D. Malloch 138-110.1*, (UAMH 8404). CHILE: soil, (UAMH 3568). FRANCE: *C. Moreau* 1969. from International Mycological Institute as IMI 139629 *Scopulariopsis candida*, ex-type of *Chrysosporium keratinophilum* var. *denticola*, (UAMH 8798). NETHERLANDS: obtained from Centraalbureau voor Schimmelcultures as *S. rufulus*, (UAMH 931). UNITED KINGDOM: soil, 1952, *BB 299*, (UAMH 961). UNITED STATES: USDA Bureau of Dairy Industry. abnormal cheese, Jun. 1938, *L.A. Rogers*, (UAMH 938).

Microascus niger (Sopp) Curzi. 1931. Bollettino. Stazione di Patologia Vegetale di Roma (N.S.) 11: 60. (neotype and ex-type culture selected UAMH 9489!)
FIGS. 3.3, 3.6, 3.9, 3.12

≡ *Acaulium nigrum* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 47.

status anamorphosis:

Scopulariopsis asperula (Saccardo) S. Hughes. 1958. Canadian Journal of Botany 36: 803. (epitype culture selected: UAMH 9037!).

≡ *Torula asperula* Saccardo 1882. Michelia 2: 560. (holotype L)

= *Scopulariopsis fusca* Castellani. 1930. British Journal of Dermatology and Syphilis 42: 365. (ex-type culture UAMH 930!).

= *Scopulariopsis bestae* (Pollacci) Nannizzi. 1934. Trattato di micopatologia umana 4: 254.

≡ *Torula bestae* Pollacci. 1922. Riv. Biol. 4: 317. (ex-type culture UAMH 924!).

= *Scopulariopsis arnoldii* (Mangin & Patouillard) Vuillemin. 1911. Bulletin

Societé Mycologique de France 27: 148.
≡ *Monilia arnoldii* Mangin & Patouillard. 1908. Bulletin Societé Mycologique de France 24: 164. (ex-type culture UAMH 923!).
= *Scopulariopsis roseola* Inagaki. 1962. Transactions of the Mycological Society of Japan 4: 1. (ex-type culture UAMH 8847!)

Crosses among nine strains produced fertile perithecia, exhibiting a heterothallic mating system (Table 3.4). The four strains designated as plus and five as minus mating type included material of *S. asperula*, *S. fusca*, *S. roseola*, *S. arnoldii* and *S. bestae*. The holomorph observed here by mating matches the adequate original description of *Acaulium nigrum* (Sopp 1912) in most details of both the conidial and sexual stages. Curzi (1931) treated the species in *Microascus* as *M. niger*. Thom (1930) and Barron et al. (1961) accept *M. niger* based on previous descriptions. Morton and Smith (1963) connect *Microascus niger* to *S. asperula* in the synonym list, yet suggest that the name *M. niger* should be disregarded due to lack of supporting evidence. Although it is difficult to be sure that recent material examined is conspecific with the fungus described by Sopp (1912), the name *M. niger* is in use and the connection with *S. asperula* has been accepted. Nomenclatural stability is best served by typifying the species based on its modern usage (Hawksworth 1993). Since no extant type specimens or other living teleomorphic isolates are known (see Morton and Smith 1963), UAMH 9489 derived from a mated cross is selected as neotype of *Microascus niger* and a redescription based on fresh material is provided below.

Perithecia 130-190 x 110-170 µm, globose to subglobose or pyriform, with a papillate to short-necked (up to 20 µm) ostiolar region, black; peridium of *textura angularis*; appendages lacking. ***Asci*** approx. 14 x 8 µm, irregularly ovoidal, octosporous, deliquescent at a very early stage and infrequently observed. ***Ascospores*** 4.5-6.5 x 3.5-4 µm, broadly reniform (plano-convex or concavo-convex) in face view, flattened, orange in mass, appearing subhyaline in transmitted light, smooth, de Bary bubbles and guttules lacking, germ pore not evident by light microscopy or SEM. ***Conidia*** 6-8 µm diam., globose to subglobose, with a truncate base, base may be slightly protruding (lightbulb-shaped), brown, some nearly smooth or only finely ornamented but many verrucose with prominent, irregular warts at maturity (degree of ornamentation may vary among strains), produced in dry chains from simple or branched annellidic conidiogenous apparatus; annellides 13-18 µm long, 3-3.5 µm diam. at apex, 3-5 µm diam. at base, elongate cylindrical to ampulliform, hyaline. ***Colonies*** dominated by the conidial stage, medium to dark fuscous brown (6C4/5-6D5/6-6E5/6/7) with white mycelium, velutinous to fasciculate, plane, margin entire, moderately slow growing, 21-36 mm diam. on OAT after 14 days.

Hughes (1958) recognized that Saccardo's (1882) species *Torula asperula* belonged in *Scopulariopsis*, similar to, but distinct from, *S. brevicaulis*. Morton and Smith (1963) accepted *S. asperula* and *S. fusca* as distinct based on differences in the ornamentation of the conidia (coarsely ornamented in *S. asperula* and smooth in *S. fusca*) and both names are widely used at present (e.g., Domsch et al. 1980). Conspecificity of

Scopulariopsis asperula, S. fusca, S. arnoldii, S. bestae and *S. roseola* was suspected based on morphological similarities between type and representative strains, and is here confirmed by mating tests. More than 25 isolates of these taxa were available for examination in the present study, and variation was found covering the entire range from virtually smooth to coarsely ornamented conidia, with the majority of strains exhibiting an intermediate ornamentation somewhat less pronounced than that typically seen in *S. brevicaulis*. Morton and Smith (1963) listed *Scopulariopsis arnoldii* as a synonym of *S. asperula* based on the verrucose conidia described in the protologue, but they disposed of an authentic culture of Mangin under *S. fusca* since it produced only smooth conidia. This is likely the ex-type culture of *S. arnoldii* and the subculture deposited at UAMH exhibits both smooth and ornamented conidia, a further indication of intra-strain variation within this variable species. *Scopulariopsis bestae* was listed as a synonym of *S. koningii* by Morton and Smith (1963), but the ex-type culture exhibits colonial coloration consistent with strains of *S. asperula*. All isolates of *S. asperula* examined have a fuscous tint to the colonies, compared to the sandy tan or avellaneous colors seen in isolates of *S. brevicaulis* (including *S. koningii*, see discussion under *Microascus brevicaulis*).

Specimens examined. *Microascus niger*. CANADA: ALBERTA: UAMH. mated cross of UAMH 8362 x 9037, 17 Apr. 1998, *S.P. Abbott* (neotype and ex-neotype culture UAMH 9489); mated cross of UAMH 7879 x 9037, 17 Apr. 1998, *S.P. Abbott* (UAMH 9490); mated cross of UAMH 8847 x 9037, 17 Apr. 1998, *S.P. Abbott* (UAMH 9491).

Scopulariopsis asperula. AUSTRIA: carcass of rabbit, *F. Zach*, ex-type culture of *Scopulariopsis fusca*, (UAMH 930). CANADA: ALBERTA: Girouxville. indoor air of honeybee (*Apis mellifera*) overwintering facility, 30 Jan. 1994, *S.P. Abbott OHS 207*, (UAMH 7879); Leduc. dung of striped skunk (*Mephitis mephitis*), 10 Jun. 1997, *S.P. Abbott SA-M183*, (UAMH 9029). SASKATCHEWAN: Saskatoon. outside air, 28 Nov. 1994, *S.P. Abbott SA-M24*, (UAMH 9037). ONTARIO: Ottawa. ex swab from home, Dec. 1995, *D. Malloch M22-2C*, (UAMH 8362). FRANCE: *L. Mangin*, authentic, probable ex-type culture of *Scopulariopsis arnoldii*, obtained from Centraalbureau voor Schimmelcultures, (UAMH 923). ITALY: *Pollacci*, ex-type culture of *Torula bestae*, (UAMH 924). JAPAN: wheat flour, 1962, *N. Inagaki I-391*, obtained from Institute for Fermentation, Osaka as IFO 7564, ex-type culture of *Scopulariopsis roseola*, (UAMH 8847). UNITED STATES: MISSOURI: hay, 12 Feb. 1992, *D.T. Wicklow DTW-001*, obtained from United States Department of Agriculture as NRRL A-28654, (UAMH 8984).

Holomorph Concepts

Mating trials showed that a large number of anamorph taxa in the *Scopulariopsis brevicaulis* Series are conspecific and represent only three holomorph taxa, *Microascus brevicaulis, M. manginii* and *M. niger*. These three taxa are distinct and easily separable. Previous confusion encountered in application of different names for isolates with slight morphological variation or intermediate features has been eliminated. The easiest and most reliable means of species differentiation is based on colonial coloration, reflecting the color of the conidia. In *M. brevicaulis*, the colonies were pale to medium sandy, tan or

avellaneous, while in *M. niger* the colonies were typically much darker brown and always exhibited a pronounced fuscous or violaceous tint. *M. manginii* colonies were dominated by a white to cream or very pale yellow conidial state. However, occasional isolates expressed a reduced conidial state and the black perithecia then comprised a noticeable part of the colonial appearance. In contrast, in all isolates of *M. brevicaulis* and *M. niger* examined, the perithecia were obscured by conidial growth. Conidial ornamentation, previously used as a primary means of defining taxa, was variable within and among strains and was not a useful character for species level determinations.

Representative mating types for each of the three species, *Scopulariopsis brevicaulis*, *S. candida*, and *S. asperula*, were crossed, but no mating reaction of any kind was observed. This supports the supposition that mating reactions only occur between isolates that are conspecific.

Of the two methods employed for mating tests, the results were easiest to read and interpret when two strains were streaked onto opposite halves of the petri plate. Strains typically grew robustly on their respective sides and formed a central contact zone characterized by sparse conidial growth. Fertile ascomata formed only in this contact zone. The same phenomenon allowed observation of positive crosses which yielded only infertile ascomata. The ascomata were best detected by observing the contact zone under the stereoscopic microscope. Small, black perithecia were often seen through the sparse central conidial layer. Ascomata could also be detected submerged in the agar by examining the edge of the petri dish in the central zone, which was especially useful where conidial growth was dense enough to hinder surface examination. Incompatible strains did not form structures of any kind in the contact zone. The crosses resulting from mixed suspensions of conidia produced ascomata in a more random fashion, in clusters and lines throughout the single colony. Frequently, the conidial overgrowth had to be removed in order to determine the presence of ascomata.

The three species examined here are the first reports of heterothallism in the Microascaceae, and homothallism was reported in another species of *Microascus* (*M. trigonosporus*, Emmons and Dodge 1931). The mating systems of species in other genera is not known. Crosses among six anamorphic isolates of *Pseudallescheria boydii* (Shear) McGinnis, Padhye & Ajello did not produce any sexual structures (Mann 1981). Nine single ascospore isolates obtained from *Kernia pachypleura* Malloch & Cain (UAMH 8857) were strictly anamorphic but pairings did not produce ascomata after 11 months on OAT (Abbott, unpublished data). Nine strains of *Cephalotrichum stemonitis* (Pers.) Link : Fr. were also crossed in all combinations, but no ascomata were observed after 11 months on OAT (Abbott, unpublished data). Further investigation is needed to elucidate mating behavior in other members of the family.

Table 3.1 Mating reactions between nine single ascospore isolates of *Microascus brevicaulis* (Mb) on OAT at 14 months.

	Single ascospore isolates		
Strains (minus mating type)	Strains (plus mating type)		
	UAMH 9090 (=Mb4)	UAMH 9407 (=Mb8)	UAMH 9091 (=Mb9)
UAMH 9406 (=Mb1)	++[a]	++	++
Mb2	++	++	++
UAMH 9092 (=Mb3)	+[b]	++	+
Mb5	+	++	+
Mb6	+	++	+
UAMH 9093 (=Mb7)	++	++	++

[a] ++ indicates fertile ascomata (with ascospores) produced.
[b] + indicates infertile ascomata produced.

Table 3.2 Mating reactions between nine wild-type isolates of *Scopulariopsis brevicaulis* crossed with plus and minus mating type single ascospore isolates of *Microascus brevicaulis* on OAT at 12 months.

	Strains (UAMH #)	
Wild-type strains	Single ascospore isolates	
	9090 (=Mb4; plus mating type)	9092 (=Mb3; minus mating type)
363	–[a]	++[b]
644	++	–
943[c]	++	–
8497	–	++
8628	++	–
8702	–	++
8785	–	++
9040	++	–
9139	++	–

[a] – indicates no ascomata were formed.

[b] ++ indicates fertile ascomata (with ascospores) produced along mating contact zone.

[c] originally identified as *S. koningii* by Morton and Smith (1963).

Table 3.3 Mating reactions between nine isolates of *Scopulariopsis candida* on OAT at 19 months, and with the type of *Microascus manginii* on OAT at 11 months.

	Strains (UAMH #)		
minus mating type	plus mating type		
	931	938	3568
238	+[a]	++[b]	++
934 ([T]*S. alboflavescens*)	–[c]	++	++
961	–	+	++
7924	–	–	++
8404	+	+	++
9004	–	++	++
9135 ([T]*M. manginii*)	NT	NT	++

[a] + indicates infertile ascomata produced along mating contact zone.
[b] ++ indicates fertile ascomata (with ascospores) produced along mating contact zone.
[c] – indicates no ascomata were formed.
[T] ex-type strain.
NT not tested

Table 3.4 Mating reactions among nine isolates of *Scopulariopsis asperula* on OAT at 19 months.

	Strains (UAMH #)			
minus mating type	**plus mating type**			
	923 ([T]*S. arnoldii*)	7879	8362	8847 ([T]*S. roseola*)
924 ([T]*S. bestae*)	+[a]	++[b]	++	+
930 ([T]*S. fusca*)	+	++	++	+
8984	+	+	++	+
9029	+	++	++	++
9037	++	++	++	++

[a] + indicates infertile ascomata produced along mating contact zone.
[b] ++ indicates fertile ascomata (with ascospores) produced along mating contact zone.
[T] ex-type strain.

Figures 3.1-3.12. ***Microascus brevicaulis, M. manginii,*** **and** ***M. niger.***

Fig. 3.1. *Microascus brevicaulis.* Colony resulting from mating cross of two strains of *Scopulariopsis brevicaulis* on OAT 12 mo at 25 C showing central contact zone and confluent growth of anamorph, note paler colony at left, typical for *S. koningii* and darker at right, typical for *S. brevicaulis* (UAMH 363 left x UAMH 9092 right), bar = 10 mm.

Fig. 3.2. *Microascus manginii.* Colony resulting from mating cross of two *Scopulariopsis candida* strains on OAT 19 mo at 25 C showing central contact zone and confluent growth of anamorph, (UAMH 3568 left x UAMH 934 right), bar = 10 mm.

Fig. 3.3. *Microascus niger.* Colony resulting from mating cross of two *Scopulariopsis asperula* strains on OAT 19 mo at 25 C showing central contact zone and confluent growth of anamorph (UAMH 8362 left x UAMH 9037 right), bar = 10 mm.

Fig. 3.4. *Microascus brevicaulis.* Ascospores (UAMH 9139 x 9092), SEM, bar = 4 μm.

Fig. 3.5. *Microascus manginii.* Ascospores (UAMH 3568 x 9135), SEM, bar = 5 μm.

Fig. 3.6. *Microascus niger.* Ascospores (UAMH 9489; neotype), SEM, bar = 3 μm.

Fig. 3.7. *Microascus brevicaulis.* Ascoma, with conidia on surface (UAMH 9040 x 9090), SEM, bar = 25 μm.

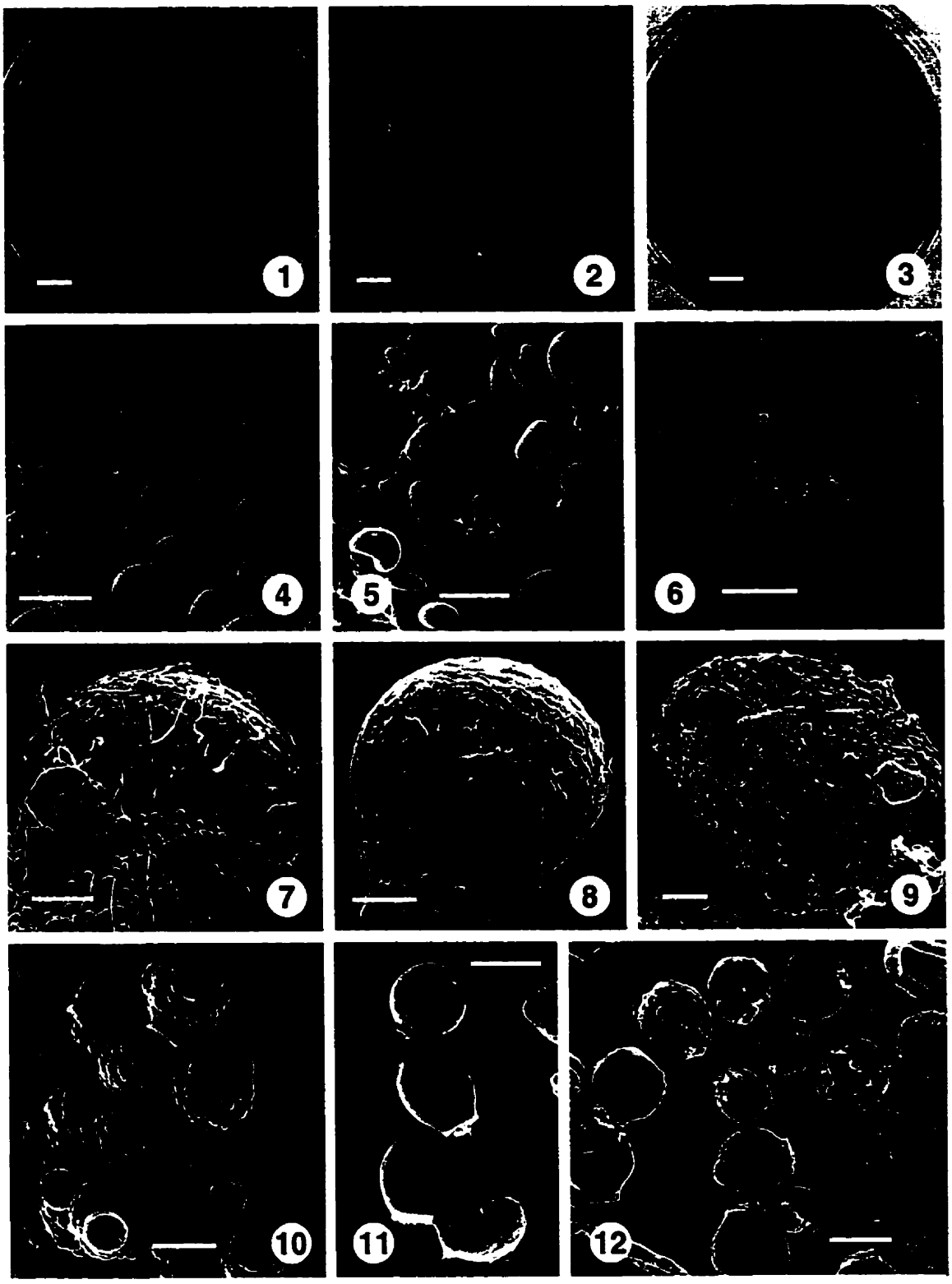
Fig. 3.8. *Microascus manginii.* Ascoma (UAMH 3568 x 9135), SEM, bar = 40 μm.

Fig. 3.9. *Microascus niger.* Mature ascoma x-section, showing ascospores (inside) (UAMH 9489; neotype), SEM, bar = 15 μm.

Fig. 3.10. *Microascus brevicaulis.* Ornamented conidia showing slightly protruding and truncate base (UAMH 9139 x 9092), SEM, bar = 4 μm.

Fig. 3.11. *Microascus manginii.* Smooth conidia showing slightly protruding and truncate base (UAMH 9004 x 938), SEM, bar = 4 μm.

Fig. 3.12. *Microascus niger.* Smooth or sparsely ornamented conidia showing slightly protruding and truncate base (UAMH 9489; neotype), SEM, bar = 5 μm.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CHAPTER 4

USE OF HOLOMORPH CHARACTERS TO DISTINGUISH *MICROASCUS NIDICOLA* AND *MICROASCUS SOPPII* SP. NOV., WITH NOTES ON THE GENUS *PITHOASCUS*

Introduction

Microascus nidicola Massee & E.S. Salmon has rarely been reported since the original specimen was collected on dung in England and described by Massee and Salmon in 1901. Several collections were made by Emmons in the desert region of Utah, and it is these collections that subsequent authorities on the group have examined and described (Barron et al. 1961; Morton and Smith 1963; Arx et al. 1988). *Microascus nidicola* is characterized by falcate to lunate (concavo-convex to plano-convex in face view and fusoidal in edge view) ascospores which are proportionally long and narrow (6-8 x 2-2.5 µm). Most other *Microascus* species have broadly reniform ascospores, including the type *M. longirostris* (typically 4.5 x 3 µm).

Arx (1973a) established a new genus, *Pithoascus*, for *Microascus nidicola* (type) and similar species having this unique ascospore morphology, perithecia which are non-ostiolate or indistinctly ostiolate and lack a distinct neck, ascospores without a germ pore, and no anamorph state (Arx 1973a, b, 1978). Benny and Kimbrough (1980) erected the family Pithoascaceae, typified by *Pithoascus* and separated from the Microascaceae based on the absence of germ pores on the ascospores. Although *Pithoascus* is currently recognized as a valid genus of the Microascaceae (Greuter et al. 1993; Eriksson and Hawksworth 1998) containing six species (Arx et al. 1988), the definitive characters of *Pithoascus* and *Microascus* overlap considerably. The generic separation has not been universally accepted (e.g., Malloch and Hubart 1987). Some species of *Pithoascus* produce a cirrus of ascospores from a prominent ostiole in age, while others exhibit a reduced conidial state consistent with the *Scopulariopsis* state of other members of *Microascus* with reniform ascospores (Roberts 1975; Valmaseda et al. 1987; Arx et al. 1988).

Several isolates of a species with ascospores resembling *M. nidicola* were recovered from rotting wood in Alberta (Lumley et al. in press). These isolates produced a *Scopulariopsis* anamorph resembling *S. flava* (Sopp) Morton & G. Smith as described by Morton and Smith (1963). Many additional strains were isolated that did not produce a sexual state, but were clearly conspecific based on anamorph characters. *Scopulariopsis flava* was originally described by Sopp (1912) as *Acaulium flavum* Sopp, and was grouped with similar anamorphic species in the '*Scopulariopsis brevicaulis* Series' by Morton and Smith (1963). Although no type material exists for Sopp's species, he described a poorly developed, 'sclerotium-like' sexual stage. Since mating trials successfully demonstrated heterothallism within other species belonging to the '*Scopulariopsis brevicaulis* Series' (see Chapter 3), this experimental method was used

here to investigate the mating behaviors and holomorph characters of *M. nidicola* and *S. flava*. This work outlines the differences between *M. nidicola* and the Alberta isolates which are here described as a new species. A discussion of other similar taxa and support for the synonymy of *Pithoascus* with *Microascus* is included.

Materials and Methods

Sampling and isolation.— White spruce (*Picea glauca*) and aspen (*Populus tremuloides*) logs of diameter greater than 15 cm and at various stages of decomposition were sampled from sites in the boreal forest of north-central and north-eastern Alberta during the summers of 1996-1998. All samples were surface-sterilized by brief flaming, and plated onto tapwater agar (TWA; 1.5% agar w:v, which served primarily as a moist chamber), cornmeal agar (CMA; Difco Laboratories, Detroit, MI), malt extract agar (MEA; 1.5% agar and malt extract w:v), MEA amended with 2 µg/mL benomyl (MEA+B), and Mycobiotic agar (MB; Difco Laboratories, Detroit, MI, containing 400 µg/mL cycloheximide). Tetracycline (100 µg/mL) was added to all media to inhibit the growth of bacteria. Primary isolation plates were incubated at room temperature (19-24°C) and examined every 2-3 months for 1.5 years. Axenic cultures were obtained by subsequent transfers onto MEA, MB, CMA, or oatmeal salts agar (OAT; Weitzman and Silva Hutner 1967).

Isolates examined and morphological observations.— Living cultures of wild type strains and single ascospore isolates are maintained in the University of Alberta Microfungus Collection and Herbarium (UAMH). Holotype herbarium material is also deposited in the UAMH and isotype material is deposited in the Herbarium, Royal Botanic Gardens, Kew (K). Microscopic mounts were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992) and ascospores were observed in squash mount preparations. The slide culture technique was employed using cereal agar (Sigler 1992), to allow observation of conidial stages. Colonial features were recorded and colony diameter was measured on OAT at 25 C after 7, 14, 21 and 28 days. Selected specimens were fixed in 2% osmium tetroxide vapor and critical-point dried for examination with a Hitachi S-2500 scanning electron microscope (SEM).

Single ascospore isolates.— Nine single ascospore isolates of *Microascus nidicola* were obtained from one of Emmon's collections (UAMH 8979) by removing one perithecium and crushing it in 5 ml of sterile water to suspend the ascospores. Approximately 1 ml of the suspension was spread across each of four Takashio agar (TAK; Takashio 1972) plates. These were incubated at 22 C for three to seven days to allow germination. Colonies were examined microscopically to ensure that colonies resulted from the germination of single ascospores. Hyphal-tip transfers were placed on OAT to obtain cultures.

Mating tests.— Crosses between eight anamorphic strains of *Scopulariopsis flava* were made in all combinations (total 36 plates including self-crosses). Conidia from each strain were suspended in semisolid detergent agar (SSD; Pitt 1973) and streaked onto one half

of an OAT plate, allowing for a central zone of contact as the isolates grew. Crosses were incubated at 22 C and monitored after 6 weeks, 3 months, 6 months, and 1 year for development of perithecia along the contact zone. Additionally, mating type strains of *S. flava* determined in the experiment above were paired with a morphologically similar strain of *Scopulariopsis brevicaulis* (Sacc.) Bainier (UAMH 9139) to support separation of the two taxa.

Taxonomic Part

Microascus nidicola Massee & E.S. Salmon. 1901. Annals of Botany (London) 15: 313. FIGS. 4.1, 4.3, 4.5, 4.8

≡ *Pithoascus nidicola* (Massee & E.S. Salmon) Arx. 1973. Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, Series C, 76: 292.

Epitype culture selected UAMH 8979 (=NRRL A-6894, =CBS 197.61, =IMI 86918, =LSHB Sc. 44).

Distinguishing morphological characters. Perithecia black, globose to ovoid, papillate; peridium of *textura angularis*; asci evanescent, irregularly subglobose, 8-spored; ascospores falcate to lunate (concavo-convex to plano-convex in face view and fusoidal in edge view), proportionally long and narrow (l:w approx. 3:1), 6-8 x 2-2.5 µm (typically 7 x 2 µm); anamorph absent; colonies slow growing (20 mm diam. in 14 days), dominated by black perithecia which produce an orange droplet or short cirrus of spores at maturity (3-4 months), mycelium white.

Single strain isolates and homothallism. The nine single ascospore isolates obtained from UAMH 8979 were homothallic and produced abundant, fertile ascomata on OAT within eight weeks. No conidial state was observed in slide culture preparations of the single spore isolates.

Specimens examined. EPITYPE. UNITED STATES: UTAH: kangaroo rat (*Dipodomys merriami*), Oct. 1956, *C.W. Emmons A1671*, (UAMH 8979; =NRRL A-6894; =CBS 197.61; =IMI 86918; =LSHB Sc. 44); soil, Oct. 1956, *C.W. Emmons A1836*, (UAMH 8980; =NRRL A-6913). CANADA: ALBERTA: UAMH. single ascospore isolates ex UAMH 8979, 10 Jul. 1998, *S.P. Abbott Mn-4, Mn-8* (UAMH 9487, 9488).

Microascus soppii **S.P. Abbott sp. nov.** FIGS. 4.2, 4.4, 4.7, 4.9-4.11

Ascomycota, Microascales, Microascaceae

status anamorphosis:

Scopulariopsis flava (Sopp) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 43.

≡ *Acaulium flavum* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 53.

Lectotype selected: illustration in Sopp 1912, Taf. IX, Figs. 77-78; Epitype culture selected: UAMH 9202.

= *Blastomycoides lanuginosus* Castellani. 1930. British Journal of Dermatology and Syphilis 42: 365.

≡ *Glenospora lanuginosa* (Castellani) Agostini. 1931. Atti. Instituto Botanico e Laboratorio Crittogamico. Universita di Pavia. III (Ser. IV): 67. (ex-type culture UAMH 831!).

Etymology: named for Olav Sopp, one of the first mycologists to study the life histories of species of Microascaceae in culture.

Peritheciis 130-200 x 110-160 μm, globosis vel subglobosis, ostiolatis, papillatis, nigris; peridiis textura angularis; ascis octosporis, globosis vel subglobosis, deliquescentibus; ascosporis 6-7 x 2.5-3 μm, falcatis vel lunatis, laevis, subhyalinis vel aurantiis en masse; conidiophora annellata; conidiis 5.5-9 x 5-8 μm, subglobosis, verrucosis, subhyalinis. Holotypus UAMH 9169.

Perithecia 130-200 x 110-160 μm, globose to subglobose or pyriform, with a papillate to short-necked (up to 40 μm) ostiolar region, black; peridium of *textura angularis*, peridial cells typically 6-10 x 4-5 μm, appendages lacking. ***Asci*** 9-14 x 6-7 μm, irregularly ovoidal, octosporous, deliquescent at a very early stage and infrequently observed. ***Ascospores*** 6-7 x 2.5-3 μm (typically 6 x 2.5 μm), falcate to lunate (typically plano-convex or infrequently concavo-convex) in face view, fusoidal in dorsal view, orange in mass, appearing subhyaline in transmitted light, smooth, de Bary bubbles and guttules lacking, single germ pore evident by light microscopy. ***Conidia*** 5.5-9 x 5-8 μm diam., globose to subglobose, with a truncate base, base may be slightly protruding (lightbulb-shaped), subhyaline to pale yellowish in mass, some nearly smooth or only finely ornamented but many verrucose with prominent, irregular warts at maturity, produced in dry chains from simple or branched annellidic conidiogenous apparatus; annellides 3 μm diam. at apex, elongate ampulliform, hyaline. ***Colonies*** dominated by the conidial stage, pale yellow-buff, mycelium white, velutinous to fasciculate, shallowly convex, margin entire, moderately fast growing, 47-60 mm diam. on OAT after 14 days.

Mating tests and heterothallism. Crosses between 6 of 8 strictly conidial strains of *Scopulariopsis flava* resulted in positive pairings (Table 4.1). Only 5 strains, all of which were from Alberta, produced fertile ascomata. UAMH 942 produced perithecia along the contact zone of the cross with UAMH 9171, but these remained infertile after one year. Two additional strains (UAMH 831 and 8895) did not form any sexual structures. UAMH 9492 was isolated after mating trials were initiated and was not included. Single ascospore isolates were not obtained from the holotype, and heterothallism is demonstrated based on crossing of wild type isolates. The anamorph stages of wild type isolates and the sexual stage produced by mating were identical to the teleomorphic strains in all respects. Crosses between mating type strains of *Scopulariopsis flava* (UAMH 9171 and 9202) and a wild type strain of *S. brevicaulis* (UAMH 9139) did not produce ascomata after 12 months.

Specimens examined. Microascus soppii. HOLOTYPE and EX-TYPE

CULTURE. CANADA: ALBERTA: Elk Island National Park. dried colony on OAT at 25 wk ex dry rotted wood of aspen (*Populus tremuloides*) log, 09 Jun. 1997, *T. Lumley and S.P. Abbott EI-13-S4G* (UAMH 9169). ISOTYPE. (K). PARATYPES. CANADA: ALBERTA: Elk Island National Park. rotted wood of white spruce (*Picea glauca*) log, 09 Jan. 1997, *T. Lumley and S.P. Abbott EI-09-S3E* (UAMH 9167); 11 Feb. 1997, *T. Lumley EI-09-S3F* (UAMH 9168).

Scopulariopsis flava. EPITYPE. CANADA: ALBERTA: Slave Lake. well rotted wood of aspen (*Populus tremuloides*) log, 25 Feb. 1997, *T. Lumley H681-01-S2F* (UAMH 9202); Elk Island National Park. rotted wood of white spruce (*Picea glauca*) log, 1996/1997, *T. Lumley EI-09-S3D/G/J* (UAMH 9170, 9171, 9172); dry rotted wood of aspen (*Populus tremuloides*) log, 06 Dec. 1997, *T. Lumley EI-13-S3G* (UAMH 9492); extremely well decayed wood of white spruce (*Picea glauca*) log, 26 Nov. 1996, *T. Lumley EI-02-S3A* (UAMH 9201); UNITED KINGDOM: ENGLAND: United Dairies. 1948, *G. Smith BB230* (UAMH 8895; =MUCL 9031; =CBS 207.61; =IMI 86921; =LSHB Sc. 7). UNITED STATES: CALIFORNIA: Pacific Grove. sandy loam soil, *A.L. Cohen* (UAMH 942; =NRRL 1848; =IMI 86923; =LSHB Sc. 68). Unknown location, America. ex man, *A. Castellani* (ex-type culture of *Glenospora lanuginosa*)(UAMH 831, =CBS 187.33).

Discussion

Although it has rarely been reported since its early discovery (Massee and Salmon 1901), *Microascus nidicola* is easily recognized by the unique ascospores. Although holotype material exists, it is the epitype culture selected here which has been the basis for modern descriptions (Barron et al. 1961; Morton and Smith 1963; Arx et al. 1988). The epitype strain matches the protologue in all respects. *Microascus nidicola* is not known to produce an anamorph. However, Arx et al. (1988) reported an anamorph for this species, but a reexamination of their strain (CBS 103.85, = UAMH 9136) showed it to represent an isolate of *M. intermedius* Emmons & Dodge. *Microascus intermedius* can be recognized by smaller ascospores (typically 5.5 x 2.5 μm) in addition to the occasional presence of a reduced anamorphic stage.

The type strain of *Microascus soppii* produced ascomata on the primary isolation plate and continues to produce fertile perithecia when revived from lyophilized or cryopreserved stocks of ascospores and conidia at UAMH, as has been shown for *Microascus brevicaulis* S.P. Abbott and *M. niger* (Sopp) Curzi (Abbott et al. 1998; see Chapters 2 and 3). Presumably, both mating types are preserved in the ascospore suspensions of these heterothallic species.

Sopp (1912) described *Acaulium flavum*, and the species was resurrected by Morton and Smith (1963) for asexual isolates with pallid yellow-buff, ornamented conidia. Although Sopp did indicate the presence of a poorly developed teleomorphic state, no ascospores were illustrated, but were merely described as oval-round as observed within the asci and no measurements were given in the protologue. Ascospore size and shape is very difficult to ascertain at this early stage when immature spores are within asci. Since

only the asexual stage was adequately described, Morton and Smith's transfer of the epithet to *Scopulariopsis* was appropriate. This decision is also indirectly supported by Curzi (1931) who treated several of Sopp's species with teleomorphic stages in the genus *Microascus* (e.g., *M. albonigrescens* (Sopp) Curzi and *M. niger*), but did not transfer *A. flavum*. I also support the use of the epithet applied to an anamorphic species, and select the illustration in Sopp (1912; Taf. IX, Figs. 77-78) as lectotype. In order to apply a permanent modern concept of this *Scopulariopsis* species, an epitype culture, UAMH 9202 is chosen.

Glenospora lanuginosa was illustrated and discussed by Agostini (1931), based on a clinical isolate, having solitary aleurioconidia. However, observations of the ex-type culture (UAMH 831) revealed some short chains of smooth to ornamented conidia produced from annellidic conidiogenous cells. This strain is somewhat degenerate and did not cross with the fresh Alberta isolates of *Scopulariopsis flava*, but appears morphologically similar to these and other isolates. It is, therefore, considered a synonym of *S. flava*.

Another strain (UAMH 8895), isolated from cheese in the United States, was identified as *Scopulariopsis flava* by Morton and Smith (1963). This strain is morphologically similar to the type of *G. lanuginosa* and it also failed to form ascomata in mating trials. While it is possible that these collections represent a different taxon, it is more likely that only the fresh isolates were sufficiently robust to mate on artificial media. The strain from soil in California included by Morton and Smith (UAMH 942) is morphologically identical to and clearly conspecific with the Alberta isolates, but produced only infertile ascomata with a single strain. Given the length of time (12 to 19 months) required to obtain the results seen here and in mating trials of other *Microascus* species (see Chapter 3), it is possible that these infertile strains could mate given the appropriate time and conditions.

Synonymy of *Pithoascus* with *Microascus*. The genus *Pithoascus* cannot be accepted as distinct from *Microascus*. The characters used to define the genus (Arx 1973a; b; 1975) vary considerably among the species included in *Pithoascus* and overlap with other species retained in *Microascus*. These characteristics include 1) proportionally long and narrow ascospores, 2) absence of germ pores, 3) nonostiolate ascomata, and 4) absence of anamorph.

Ascospores of *M. nidicola*, *M. schumacheri* (Hansen) Curzi, *M. exsertus* Skou, and *P. stoveri* Arx are long and narrow, with a length to width ratio of about 3:1 or greater (Figs. 4.5, 4.6, 4.8), versus the broadly reniform ascospores with a ratio of about 1.5:1, of the type, *M. longirostris* Zukal, and similar species. Some species with an intermediate ratio near 2:1 or 2.5:1, such as *M. intermedius*, were included in *Pithoascus*, while others, such as *M. albonigrescens*, were not. The gradation of ascospore shape from reniform to lunate, without an easily defined discontinuity, does not allow genera to be separated based on this character.

Germ pores on the ascospores of some Microascaceae, such as *Lophotrichus* and *Kernia*, are prominent and easily observed by light microscopy and SEM (see Arx et al. 1988). Others, such as *Microascus*, have indistinct germ pores recognized by the morphology of the germination process (Malloch 1970; Malloch and Hubart 1987). During germination, the ascospore does not swell and the germ tube presents as a globose 'bubble' at one apex before elongating. In contrast ascospores lacking germ pores swell noticeably before rupturing to release the germ tube at any point. *Pithoascus* is defined as lacking germ pores (Arx 1975; Benny and Kimbrough 1980). One recently described species, *M. caviariformis* Malloch & Hubart, has ascospores consistent with other *Pithoascus* species, but which germinate from a single pore (Malloch and Hubart 1987). Although germ pores are often difficult to observe, one mount of *M. soppii* (UAMH 9167) showed a single germ pore in many of the ascospores. Many of these spores were in the process of germinating and exhibited germination morphology consistent with that seen in other members of *Microascus*.

Arx (1973a) originally described *Pithoascus* as nonostiolate or with a rudimentary ostiole that remained covered by outer layers of the peridium. Although many species of *Pithoascus* lack a prominent ostiolar neck, all exude ascospores in a droplet or cirrus in age. Functional ostioles were observed in *M. nidicola* (Fig. 4.3), *M. schumacheri*, *M. intermedius*, *M. exsertus* and *P. stoveri*. Arx et al. (1988) reported that the ex-type culture of *M. exsertus* at the Centraalbureau voor Schimmelcultures is now sterile, but a subculture from the ex-type strain received from the Canadian Collection of Fungus Cultures (DAOM 146087, =UAMH 8698) produced abundant perithecia and long, red-brown cirri formed after 30 weeks on OAT.

Conidia are absent in the type of *Pithoascus*, *M. nidicola*, and in *M. exsertus*, but have been recorded in some isolates of *M. intermedius* (Roberts 1975; Arx et al. 1988), *M. schumacheri* (Valmaseda et al. 1987), and *P. stoveri* (Arx et al. 1988). The well developed conidial stages of *M. soppii* (Fig. 4.11) and *M. caviariformis* are additional evidence that this character is not correlated with ascospore shape and cannot be used for generic delineation.

Pithoascus stoveri has ascospores (Fig. 4.6) that are similar to *M. nidicola* and *M. soppii*, but differs slightly in median spore size (typically 6.5 x 2.5 µm for *P. stoveri*, 7 x 2 µm for *M. nidicola*, 6 x 2.5 µm for *M. soppii*). The conidial state of *P. stoveri* (illustrated in Arx et al. 1988) is a highly reduced annellidic or sympodial state, with ellipsoid or ovoid, smooth conidia. In contrast, an anamorphic state is absent in *M. nidicola* and a well-developed *Scopulariopsis* state with large, subglobose, ornamented conidia is present in *M. soppii*. Additionally, *P. stoveri* was characterized by small (50-110 µm diam.), nonostiolate ascomata (Arx 1973b), but droplets of ascospores at an inconspicuous ostiole have been observed on OAT after 70 days. This species has not previously been treated in *Microascus* and is here transferred as:

***Microascus stoveri* (Arx) S.P. Abbott comb. nov.**

≡ *Pithoascus stoveri* Arx. 1973. Persoonia 7: 373. (basionym)

Specimen examined. EX-TYPE CULTURE. USA: OHIO: root of *Beta vulgaris*

seedling, *W.L. White* (CBS 176.71; =UAMH 9138),

Two other species have been placed in *Pithoascus* at one time or another, but are not accepted in *Microascus*. *Pithoascus langeroni* Arx was described by Arx (1978), but was later placed in its own genus, *Pithoascina* (Valmaseda et al. 1987; Arx et al. 1988). Malloch and Sigler (1988) included this species in the Eremomycetaceae as *Eremomyces langeronii* (Arx) Malloch & Sigler. Based on the pseudoparenchymatous ascomatal initials, cleistothecial ascomata, clavate asci, small, pale ascospores, and arthroconidial anamorph, this species clearly does not belong in the Microascaceae. *Pithoascus platysporus* Arx & Veenbaas-Rijks is described as having broadly ellipsoidal to ovoidal, reddish brown or copper colored ascospores (Arx 1975). Subcultures of the ex-type strain proved to be sterile (UAMH 9138, =CBS 419.73, see also Arx et al. 1988). This strain was resistant to benomyl at 2 μg/mL, a trait consistent throughout the Microascaceae (Abbott unpublished data). The ascospore morphology as described in the protologue suggests a closer affinity to *Kernia* or *Lophotrichus* than to *Microascus*. No illustrations have been published for this species, and a re-examination of the holotype material (CBS 419.73) is required before this species can be transferred to the appropriate genus.

It is uncertain whether ascospore morphology, anamorph characters, or mating system provides the best indicator of phylogenetic affinity within the genus *Microascus*, and the relationship of *M. soppii* to other species is unclear. The ascospores are very similar to and suggest an affinity with other species formerly treated in *Pithoascus*, especially *M. nidicola*, *M. intermedius* and *P. stoveri*. These species either do not have an anamorphic state or exhibit a greatly reduced one. Conversely, the well-developed conidial stage of *M. soppii* (*Scopulariopsis flava*) was placed in the '*Scopulariopsis brevicaulis* Series' by Morton and Smith (1963) based on the similar large, pale-colored, ornamented conidia. The teleomorphs of other species in the *Scopulariopsis brevicaulis* Series, *Microascus brevicaulis*, *M. manginii* (Loub.) Curzi, and *M. niger*, all have ascospores which are broadly reniform (Abbott et al. 1998; see also Chapter 3). Heterothallism was demonstrated in these species (see Chapter 3) and *M. soppii*, while *M. nidicola* is homothallic, as are some other species of *Microascus* (Emmons and Dodge 1931). Further work is required to elucidate the relationships among species of *Microascus*.

Table 4.1 Mating reactions between six anamorphic isolates of *Scopulariopsis flava* on OAT at 12 months.

Strains (UAMH #)		
minus mating type	plus mating type	
	9202[a]	942[b]
9170[a]	++[c]	–[d]
9171[a]	++	+[e]
9172[a]	++	–
9201[a]	++	–

[a] Alberta isolate.
[b] Isolate identified by Morton and Smith (1963).
[c] ++ indicates fertile ascomata (with ascospores) produced along mating contact zone.
[d] – indicates no ascomata were formed.
[e] + indicates infertile ascomata produced along mating contact zone.

Figures 4.1-4.7. *Microascus nidicola, M. soppii,* and *M. stoveri.*

Fig. 4.1. *Microascus nidicola.* Colony on OAT 14 d at 25 C showing perithecia (UAMH 8979; epitype), bar = 15 mm.

Fig. 4.2. *Microascus soppii.* Colony resulting from mating cross of two *Scopulariopsis flava* strains on OAT 14 d at 25 C showing central contact zone and confluent growth of anamorph (UAMH 9170 left x UAMH 9292 right), bar = 15 mm.

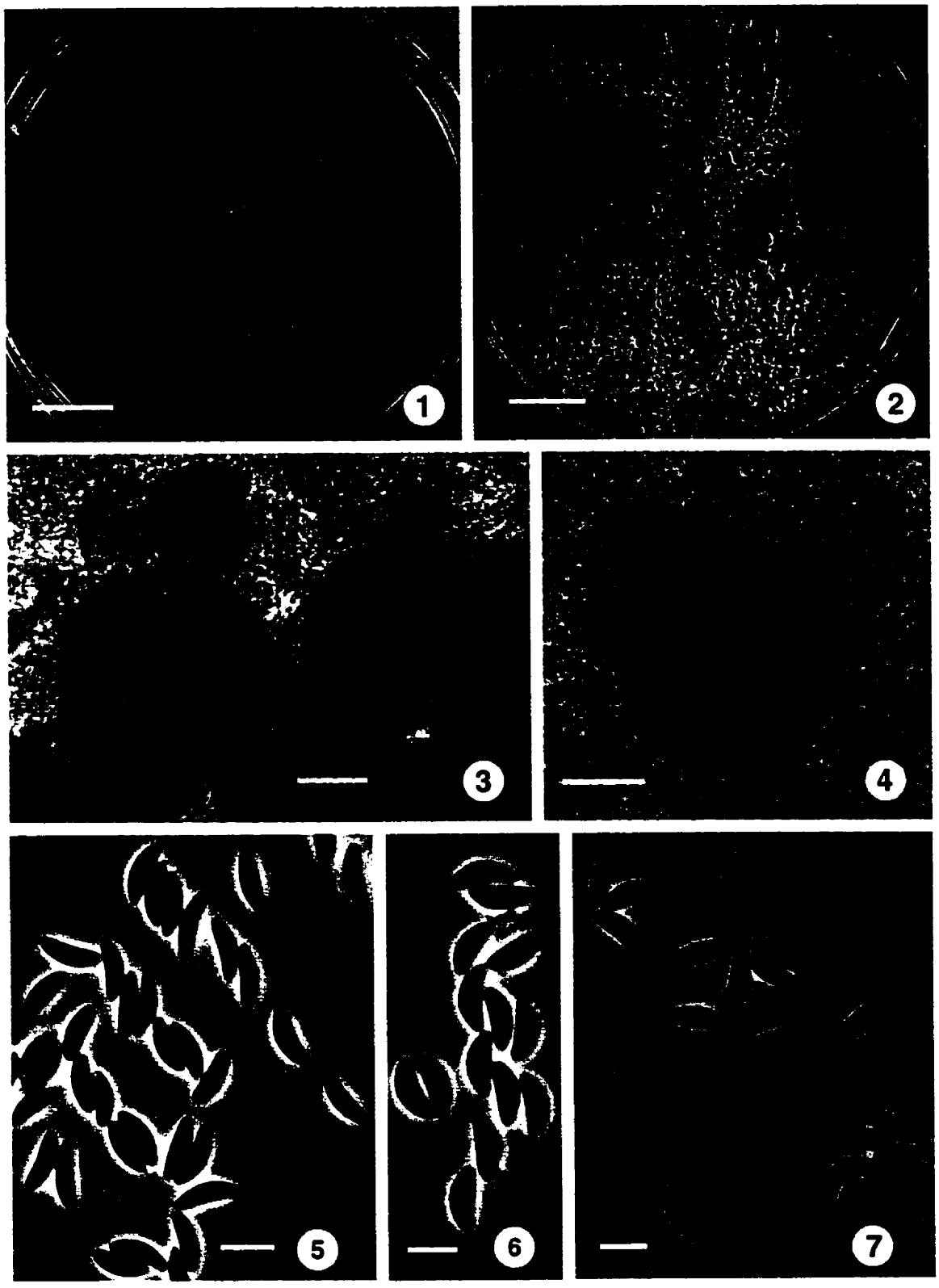
Fig. 4.3. *Microascus nidicola.* Perithecium, note ostiole and peridium of *textura angularis* (UAMH 8979, epitype), bar = 50 µm.

Fig. 4.4. *Microascus soppii.* Perithecium (UAMH 9169; holotype), bar = 50 µm.

Fig. 4.5. *Microascus nidicola.* Ascospores (UAMH 8980), bar = 7 µm.

Fig. 4.6. *Microascus stoveri.* Ascospores (UAMH 9138), bar = 5 µm.

Fig. 4.7. *Microascus soppii.* Ascospores (UAMH 9169; holotype), bar = 6 µm.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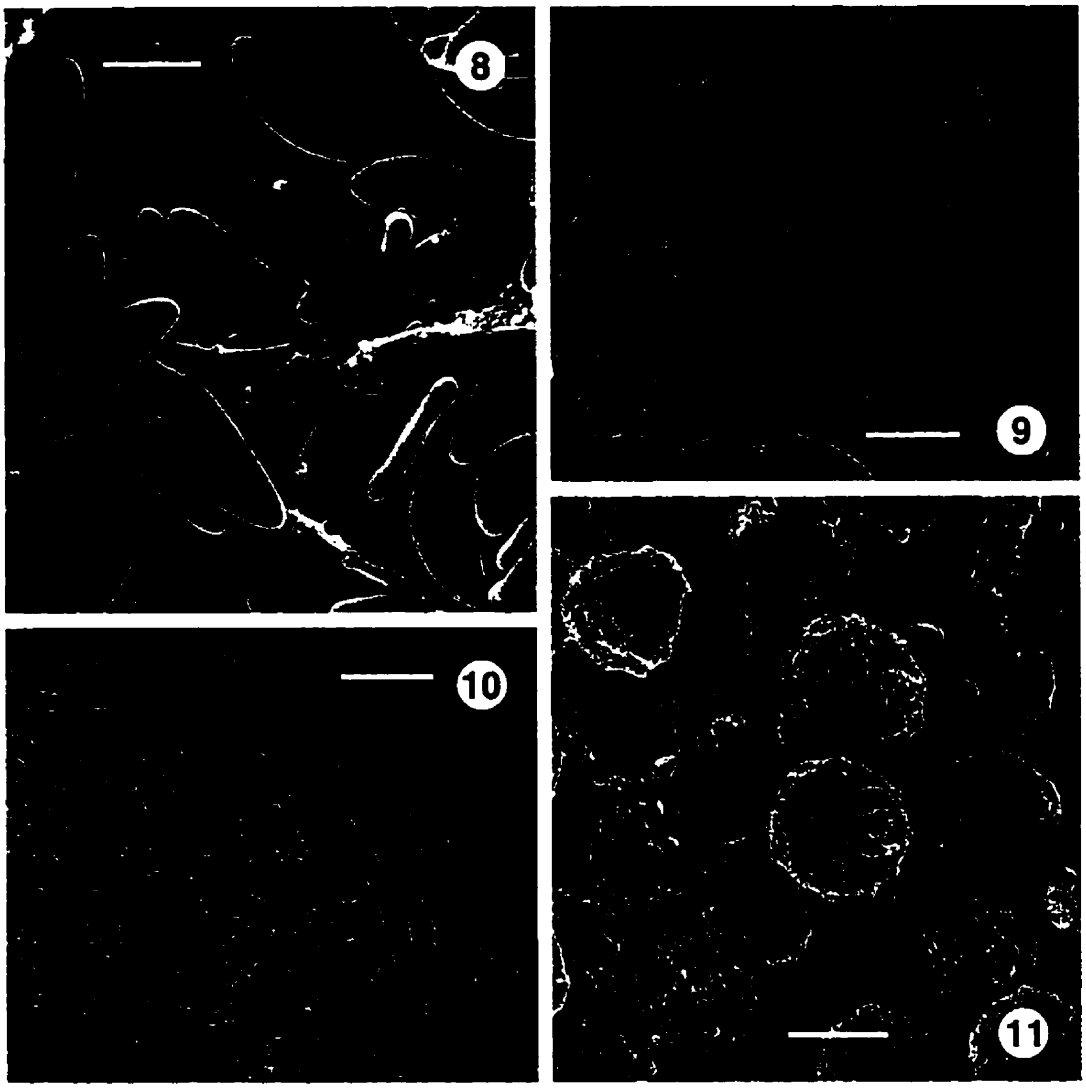
Figures 4.8-4.11. *Microascus nidicola* and *M. soppii* (SEM).

Fig. 4.8. *Microascus nidicola.* Ascospores (UAMH 9488), bar = 3 μm.

Fig. 4.9. *Microascus soppii.* Ascospores (UAMH 9169; holotype), bar = 2 μm.

Fig. 4.10. *Microascus soppii.* Mature perithecium x-section, showing ornamented conidia (outside) and smooth ascospores (inside) (UAMH 9169; holotype), bar = 15 μm.

Fig. 4.11. *Microascus soppii.* Ornamented conidia showing slightly protruding and truncate base (UAMH 9169; holotype), bar = 3 μm.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CHAPTER 5

RECOGNITION OF CONSPECIFICITY AMONG PLEOMORPHIC ISOLATES OF *PSEUDALLESCHERIA BOYDII* (MICROASCACEAE) CAPABLE OF DEGRADING HYDROCARBONS IN CRUDE OIL[2]

Introduction

Recently, our attention was directed to several strains of a mould that appeared to be able to thrive in soils heavily contaminated with petroleum. In pure culture, a *Graphium* and *Scedosporium* state were produced that were morphologically similar to the anamorphs of *Pseudallescheria boydii* (Shear) McGinnis, Padhye & Ajello. Subsequently, after a long incubation period, two strains formed cleistothecia typical of *P. boydii* (McGinnis et al. 1982). *P. boydii* has a worldwide distribution and is recovered from nutrient-rich, poorly aerated soils, polluted water, decayed wood, manure and sewage sludge (Ajello 1952, 1980; Cooke and Kabler 1955; Bell 1976; de Hoog et al. 1994). It is also a well-known opportunistic pathogen of humans and other animals (Rippon 1988).

When isolated in pure culture, *P. boydii* can be difficult to identify because cleistothecia form only after prolonged incubation or not at all (Gordon 1956; Bell 1976) and isolates may lose the ability to form cleistothecia with subculturing (Emmons 1944). Isolates often display only the characteristic anamorphic (asexual conidial) states that are assignable to the form genera *Graphium* and *Scedosporium* (Hironaga and Watanabe 1980; Campbell and Smith 1982). Neither of these genera are specific to *Pseudallescheria* and, consequently, reports of "*Graphium* species" and "*Scedosporium* species" in the literature are difficult to interpret. For example, *Graphium* species have been reported from soil (Barron 1968), woody materials (Morris 1963) and raw sewage (Zajic et al. 1969; Davies et al. 1973), but it is uncertain if these isolates represent the anamorph of *P. boydii* or anamorphs of other teleomorph genera such as species of *Ophiostoma*, *Petriella*, *Kernia*, and *Chaetosphaeria* (Carmichael et al. 1980; Seifert and Okada 1993).

Our isolates were obtained from oil-well flare pits, which are areas where hydrocarbon wastes from gas and oil facilities are burned. The soils in these flare pits are saturated with pyrolized petroleum residues. The profuse growth of *P. boydii* on soil samples from these sites suggests that the medium to heavy molecular weight petroleum compounds are utilized as a source of carbon. An unidentified isolate of *Graphium* was reported as having the ability to degrade low molecular weight alkanes such as ethane, propane and *n*-butane (Zajic et al. 1969; Davies et al. 1973), but was unable to utilize

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[2] This chapter has been modified from published form to reflect the primary contributions and focus of the author of this thesis and comprises part of a larger study published as:

April, T.M., S.P. Abbott, J.M. Foght, and R.S. Currah. 1998. Degradation of hydrocarbons in crude oil by the ascomycete *Pseudallescheria boydii* (Microascaceae). Canadian Journal of Microbiology 44: 270-278.

higher molecular-weight hydrocarbons such as found in crude oil or pyrolized petroleum residues (Volesky and Zajic 1970). *Graphium rubrum* Rumbold and *Graphium fructicolum* Marchal & E. J. Marchal were observed to utilize higher molecular weight *n*-alkanes (Lowery et al. 1968; Llanos and Kjoller 1976). *Graphium fructicolum* was repeatedly isolated from treated, oil-contaminated soils and was almost entirely absent from control soils (Llanos and Kjoller 1976), indicating that the presence of hydrocarbons favored its growth.

The taxonomic relatedness of six strains with one or more spore states resembling *P. boydii* was assessed, and, using gas chromatography, their relative abilities to degrade a range of crude oil hydrocarbons were determined.

Materials and Methods

Hydrocarbon-contaminated soil samples were collected from flare pits at Boundary Lake, British Columbia, and Drayton Valley and Willesden Green, Alberta. Approximately 10 g of soil were sprinkled on corn meal agar (CMA; Difco), malt extract agar (MEA; Difco) and potato dextrose agar (PDA; Difco). All media contained 100 mg oxytetracycline and 2 mg benomyl per litre to control the growth of bacteria and minimize the development of various hyphomycetes (moulds). *P. boydii* was established from the primary isolation plates by transferring conidia or mycelium to MEA with oxytetracycline. On the primary isolation plates, colonies of *P. boydii* were distinguished from other fungi present by white to gray, floccose, aerial mycelia and/or the presence of synnemata.

The isolates from flare pit soils were compared using morphological, molecular and biochemical data with a strain expressing similar *Graphium* and *Scedosporium* states obtained from the American Type Culture Collection (ATCC; Zajic et al. 1969), and with ascocarpic strains of *P. boydii* (DAOM 148868; Bell 1976) and *Petriella sordida* (Zukal) G.L. Barron & J.C. Gilman (DAOM 162159) obtained from the Canadian Collection of Fungus Cultures (CCFC). All strains examined (Table 5.1) are deposited in the University of Alberta Microfungus Collection and Herbarium (UAMH).

The six *P. boydii* strains (Table 5.1) were inoculated onto PDA, PDA + 2 mg benomyl per litre (PDA+B), and Mycosel agar (MYC; Becton Dickinson) plates and incubated at 25°C and on PDA plates also incubated at 37°C. Colonial appearance, diameter and ability to grow at 37°C were observed after fourteen days incubation. Cultures were prepared by inserting a sterile straight needle into a suspension of conidia and/or ascospores prepared for each strain in semisolid detergent agar (Pitt 1973) and then stab inoculated into the center of the Petri plates containing 35 mL PDA, PDA+B or MYC (Abbott et al. 1995). Colors were determined using the color standards of Kornerup and Wanscher (1978). Morphology of conidial structures was examined by slide culture preparations (Sigler 1992). Mounts of ascomata and synnemata were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992) and ascospores were observed in squash mount preparations. To induce ascoma formation, cultures were incubated on MEA and oatmeal agar (OAT; Weitzman and Silva-Hutner 1967) and incubated with

ultraviolet light (both black light and natural day light) (Seifert et al. 1993). Selected specimens were prepared by established methods of fixation in glutaraldehyde and post-fixation in osmium tetroxide, drying to critical point and examination with a Cambridge Stereoscan S-250 scanning electron microscope (SEM).

For restriction fragment length polymorphism (RFLP) analysis, the internally transcribed spacer region (ITS) of the nuclear ribosomal DNA (rDNA) of *P. boydii* strains UAMH 8598, 8792, 8794 and 8897 and *P. sordida* (UAMH 8695) (for comparison) was amplified using the PCR primers ITS 1F and ITS 4 (Gardes and Bruns 1993; White et al. 1990) and digested with the restriction enzymes *Alu 1*, *Hha 1*, *Hinf 1* and *Rsa 1*. Extraction, amplification and restriction followed procedures described by Gardes and Bruns (1996) and Kernaghan et al. (1997); data were analyzed by Gel Pro software (Media Cybernetics, Silver Springs, MD).

[Materials and methods for hydrocarbon degradation tests, including gas chromatographic analysis, are provided in: April, T.M., S.P. Abbott, J.M. Foght, and R.S. Currah. 1998. Degradation of hydrocarbons in crude oil by the ascomycete *Pseudallescheria boydii* (Microascaceae). Canadian Journal of Microbiology 44: 270-278.]

Results

Isolation and characteristics of strains. Colonies of *P. boydii* were observed on all primary isolation media containing flare pit soils from Drayton Valley and Willesden Green, Alberta, and Boundary Lake, British Columbia.

Colonies (obverse) on PDA at 25°C after 14 days were grey brown (4B1-4B2) to pallid greyish (1B1 - 3B1 - 3B2), especially at margin, often slightly darker (4B3-4C3-4D3) on MYC and PDA at 37°C, floccose to woolly-fasciculate, shallowly convex, with margin entire or slightly fimbriate (Fig. 5.1). Colonies of UAMH 8598 were pale and extremely floccose, while cultures producing cleistothecia were darker, less floccose and had more uniform mycelial growth across the medium. Ultraviolet light enhanced cleistothecium formation. A clear to brown exudate was frequently observed, especially at 37°C. The *P. boydii* teleomorph and *Graphium* state often were not produced at the same time in culture.

Cleistothecia were scattered throughout the colony in the aerial mycelium and submerged in the agar. They were black, globose, 60-140 µm diam., lacked appendages, and had a peridium of *textura epidermoidea* with cells 2-6 µm diam. Asci were evanescent and rarely seen, subglobose, 14-16 x 10-14 µm diam., and contained 8 reddish brown, smooth-walled, ellipsoidal ascospores, 7.5-8.5 x 4.5-5.5 µm, with de Bary bubbles in a large proportion of spores in the polyvinyl alcohol and lactofuchsin mounting media (inset, Fig. 5.2). The *Scedosporium* state consisted of lightly pigmented conidia, 6-13 x 3-6 µm, which varied from subglobose, ellipsoidal to clavate and with a truncate base (Fig. 5.3) and a distinct attachment scar. They were produced singly or annellidically on hyaline,

lateral or terminal conidiogenous hyphae of uniform diameter and variable length, 5-50 x 3-4 µm. The *Graphium* state was recognized by dematiaceous synnemata, 160-225 µm tall that produced slimy masses of cylindrical, 6-8 x 2-3 µm, hyaline conidia (Fig. 5.4). SEM (Fig. 5.5) revealed distinct annellidic conidiogenous cells, 15-20 x 2.5-3 µm, on the conidiophores, with attachment scars similar to those of the *Scedosporium* state.

As shown in Table 5.2, growth of the strains at 25°C and 37°C varied, and formation of teleomorphic and anamorphic states was inconsistent among the six strains. The addition of benomyl to the medium did not affect colony size (± 3mm), and all strains were resistant to cycloheximide as demonstrated by growth on MYC, although growth of one strain (UAMH 8598) was markedly reduced (Table 5.2).

RFLP analysis. Identical RFLP profiles were observed among the four strains of *P. boydii* for each restriction enzyme: *Alu I* (112 and 417 bp), *Hha I* (105, 132 and 205 bp), *Hinf I* (130, 196 and 326 bp) and *Rsa I* (651 bp), indicating that restriction sites were the same for all strains within the amplified ITS region. *P. sordida*, a closely related taxon used to assess the sensitivity of the RFLP analysis, displayed a different profile: *Alu I* (134, 168 and 301 bp), *Hha I* (104, 136 and 329 bp), *Hinf I* (doublet at 315 bp) and *Rsa I* (626 bp). Fragment sizes (bp) are accurate to ± 3%.

GC analysis. [Results reported below are included to show morphological and physiological similarities and differences among the strains examined. Complete results for hydrocarbon degradation tests, including gas chromatographic analysis, tables and figures, are provided in: April, T.M., S.P. Abbott, J.M. Foght, and R.S. Currah. 1998. Degradation of hydrocarbons in crude oil by the ascomycete *Pseudallescheria boydii* (Microascaceae). Canadian Journal of Microbiology 44: 270-278.]

Three flare pit isolates (UAMH 8792, 8793 and 8794) and the sewage isolate (UAMH 8598) were grown for one week at room temperature (approximately 22°C), and then inoculated onto mineral salts agar solution with crude oil added as the sole carbon source. The flare pit isolates exhibited considerable growth, forming a leathery layer of oil and mycelium. In contrast, the sewage isolate demonstrated little growth. When inoculated on mineral agar with a gasoline vapor carbon source, this isolate (UAMH 8598) grew better than the parallel control incubated without gasoline. Floccose, white aerial mycelia developed in the presence of gasoline compared to scant surface mycelia in the control. UAMH 8792 did not grow appreciably in the presence of gasoline vapors and resembled the control.

The saturate profile of fractionated residual oil showed that *n*-alkanes had been removed from oil incubated with isolates from the hydrocarbon-contaminated soil (UAMH 8792, 8793 and 8794), whereas UAMH 8598 (isolated from raw sewage) showed no *n*-alkane degradation. UAMH 8792 showed complete removal of *n*-C_{12} to *n*-C_{21} and partial removal of *n*-C_{22} to *n*-C_{27} in comparison to the sterile control GC profile. A similar saturate profile was observed with UAMH 8794, with identical peak removal and peak reduction indicating degradation of those compounds. UAMH 8793 showed the

greatest *n*-alkane removal of the four strains incubated on the crude oil, with the saturates *n*-C_{12} to *n*-C_{25} completely degraded and *n*-C_{26} to *n*-C_{28} considerably reduced.

GC analysis did not indicate any degradation of the aromatic fraction. Profiles of all four strains incubated on crude oil were almost identical to the control. However, both UAMH 8792 and 8794 did exhibit a peak not present in the profile of the other two strains or the control. The additional peak, found between those of the C_2 and C_3 methylnaphthalenes, is unidentified.

Discussion

Considering the genetic variation in this species (Gordon 1956) and the tendency for each strain to exhibit different sporogenous states in response to changing environmental parameters, it is understandable that the specific name for this apparently common inhabitant of oil-soaked soils has not been reported previously. Although considerable variation in morphology and physiology was present among the six strains of *P. boydii* (Table 5.2), the production of at least two of the three characteristic sporogenous states suggested conspecificity, an observation supported by molecular analysis. All strains consistently produced the *Scedosporium* state. Cleistothecia were produced inconsistently in UAMH 8792, with only some subcultures developing ascomata. Further subculture from cleistothecium-producing sectors of the colony enhanced ascoma development. Although ascocarpic strains produced cleistothecia on all media under varied conditions, ascoma production was greatest on minimal media, especially OAT, and with growth under ultraviolet light. Synnemata production was sporadic, most abundant on PDA and MEA, but not observed in the same culture plate as the ascomata. Gordon (1956) suggests that strain variation is genetic, but it appears that environmental stimuli may also influence cleistothecial and synnematal production. The polymorphism of this fungus adds to the taxonomic confusion with different strains potentially producing one to three different states (Hironaga and Watanabe 1980; Hoog et al. 1994).

All strains were capable of growth at 37°C, but strains varied in their response with two growing faster, two slower and two unchanged at the higher temperature (Table 5.2). Similarly, all strains grew on MYC, although growth of UAMH 8598 was reduced. Hoog et al. (1994) observed comparable results with strains of *P. boydii* growing on a similar cycloheximide-containing medium: all strains grew on solid medium containing cycloheximide, but there was variable growth of strains in liquid cultures containing cycloheximide. Resistance to benomyl was useful to differentiate *P. boydii* and related species in the Microascaceae from morphologically similar anamorphic states of *Ophiostoma* species (Abbott, unpublished data).

Utilization of a wide range of linear saturated hydrocarbons by some strains of *P. boydii* potentially makes this ascomycete a good candidate in a consortium of microorganisms for bioremediation. Zajic et al. (1969) showed that UAMH 8598 (= ATCC 58400), previously known as "*Graphium* sp." and here shown to be conspecific

with *P. boydii*, degraded volatile saturates such as ethane, propane and *n*-butane by, but no growth was observed on hydrocarbons of higher molecular weight than *n*-butane. Further tests on the same strain showed that methane alone was not oxidized, but may be co-oxidized in the presence of ethane (Volesky and Zajic 1970). *n*-Alkynes and *n*-alkenes (acetylene, 1-butyne, ethylene and propylene) inhibited the growth of *Graphium* utilizing *n*-alkanes (Curry et al. 1996). In addition, a recent study by Hardison et al. (1997) showed that this isolate can also degrade the gasoline oxygenate, methyl tert-butyl ether (MTBE), and may be applied for the remediation of MTBE-contaminated soils.

In addition to the ability to utilize gaseous hydrocarbons present in gasoline, at least some strains of *P. boydii* (UAMH 8791, 8792, 8793 and 8794) can degrade mid- to higher molecular weight alkanes (*n*-C_{12} to *n*-C_{26}) found in crude oil. This is of particular importance because most oil-contaminated sites requiring reclamation have been weathered and contain only the higher molecular weight saturates, including the *n*-alkanes degradable by these strains of *P. boydii*. While the change in the saturate GC profile after incubation with *P. boydii* can be interpreted as carbon mineralization, an alternative explanation would be that the organism is transforming the *n*-alkanes into intermediate compounds less toxic for growth. However, considering that the fungus grows luxuriantly when crude oil is the only carbon source, it is more likely the process is degradative with the release of CO_2, rather than the process of detoxification.

Other *Graphium* species (reported as *G. rubrum* and *G. fructicolum;* Lowery et al. 1968; Llanos and Kjoller 1976) also have been observed to utilize higher molecular weight *n*-alkanes (*n*-C_{10} to n-C_{16}). *Graphium putredinis*, a species complex with a number of teleomorphic affinities including *Pseudallescheria* (Ellis 1971; Seifert and Okada 1993), was observed to degrade saturates and aromatics and, to a lesser extent, resins and asphaltenes (Oudot et al. 1993). As observed with the *P. boydii* strains isolated from flare pits, *G. putredinis* showed a high degree of variability in its ability to degrade hydrocarbons. While one strain was able to degrade a wide range of hydrocarbons, a second isolate exhibited much less activity (Oudot et al. 1993).

P. boydii has adapted to environments of low oxygen levels and high salt concentrations (2% NaCl and 5% $MgCl_2$) (Hoog et al. 1994). Because these conditions are found in water-logged, hydrocarbon-contaminated soils that often have low oxygen levels and high salt content due to the brine used in drilling, *P. boydii* may be a candidate for use in bioremediation. The presence of hydrocarbons may naturally favour the development of *P. boydii* as was seen with *G. fructicolum* in hydrocarbon-contaminated soils (Llanos and Kjoller 1976) and is indicated by this study. Tolerance of the *P. boydii* strains isolated from flare pits to elevated temperatures may influence their potential use in various bioremediation strategies (e.g., soils versus higher temperature oil-composting biopiles). Conversely, further biodegradative studies are in progress at low temperatures more representative of surface soils.

P. boydii is a ubiquitous saprobic fungus commonly isolated from soil and waste material (Cooke and Kabler 1955; Ajello 1980), which accounts for the spectrum of

opportunistic diseases (pseudallescheriosis) that it causes (Rippon 1988). Cases of infection due to *P. boydii* have been reported in Alberta (e.g., Dowding 1935), and many other isolates from clinical and natural sources in Alberta are known (over 20 strains in UAMH examined). Bell (1978) demonstrated considerable variation in pathogenicity of strains, with an isolate from manure significantly less virulent than one isolated from a human mycetoma. The virulence of the strains isolated from flare pits remains to be tested.

The apparent widespread occurrence of *P. boydii* indicates that it may already be an inherent part of petroleum-contaminated soils in western Canada. However, the organism's behaviour under typical *in situ* conditions remains unclear, including its response to various nutrient conditions, low and fluctuating temperatures, and the presence of other microbial populations. Under properly controlled conditions, selected non-pathogenic strains of *P. boydii* may have the potential to be used safely as an integral and effective part of the intrinsic bioremediation process.

Table 5.1. Substratum, location and isolation data of *Pseudallescheria boydii* and *Petriella sordida* strains examined.

Strain	Source
Pseudallescheria boydii	
UAMH 8791	hydrocarbon-contaminated flare pit soil; Willesden Green northeast of Rocky Mountain House, Alberta; C. Zelmer; 13-Apr-1994.
UAMH 8792	hydrocarbon-contaminated flare pit soil; Willesden Green northeast of Rocky Mountain House, Alberta; T. April; 16-Aug-1995.
UAMH 8793	hydrocarbon-contaminated flare pit soil; Cynthia west of Drayton Valley, Alberta; T. April; 16-Aug-1995.
UAMH 8794	hydrocarbon-contaminated flare pit soil; Boundary Lake, British Columbia; T. April; 21-Jun-1996.
UAMH 8598	raw sewage; London, Ontario; Zajic et al.; 1967; obtained from ATCC as 58400 (=NRRL 3915).
UAMH 8897	fresh faeces of beef cattle; Lethbridge, Alberta; R. Bell; 1975; obtained from CCFC as DAOM as 148868.
Petriella sordida	
UAMH 8695	twigs of apple; Kentville, Nova Scotia; C. O. Gourley; 1976; obtained from CCFC as DAOM 162159

Table 5.2. Colony diameters, temperature tolerance and sporulation in six strains of *Pseudallescheria boydii* after incubation at 25°C or 37°C for 14 days on PDA, PDA+B or MYC.

Strain (UAMH #)	Colony diameter at 14 days (mm)				Ascomata	*Graphium* state	*Scedosporium* state
	PDA 25°C	PDA+B 25°C	MYC 25°C	PDA 37°C			
8791	58	57	42	85	-	+	+
8792	55	55	45	56	+	+	+
8793	64	65	52	63	-	+	+
8794	58	55	46	80	+	-	+
8598	70	70	10	47	-	+	+
8897	55	55	42	43	+	-	+

Figures 5.1 - 5.5. *Pseudallescheria boydii* (UAMH 8794).

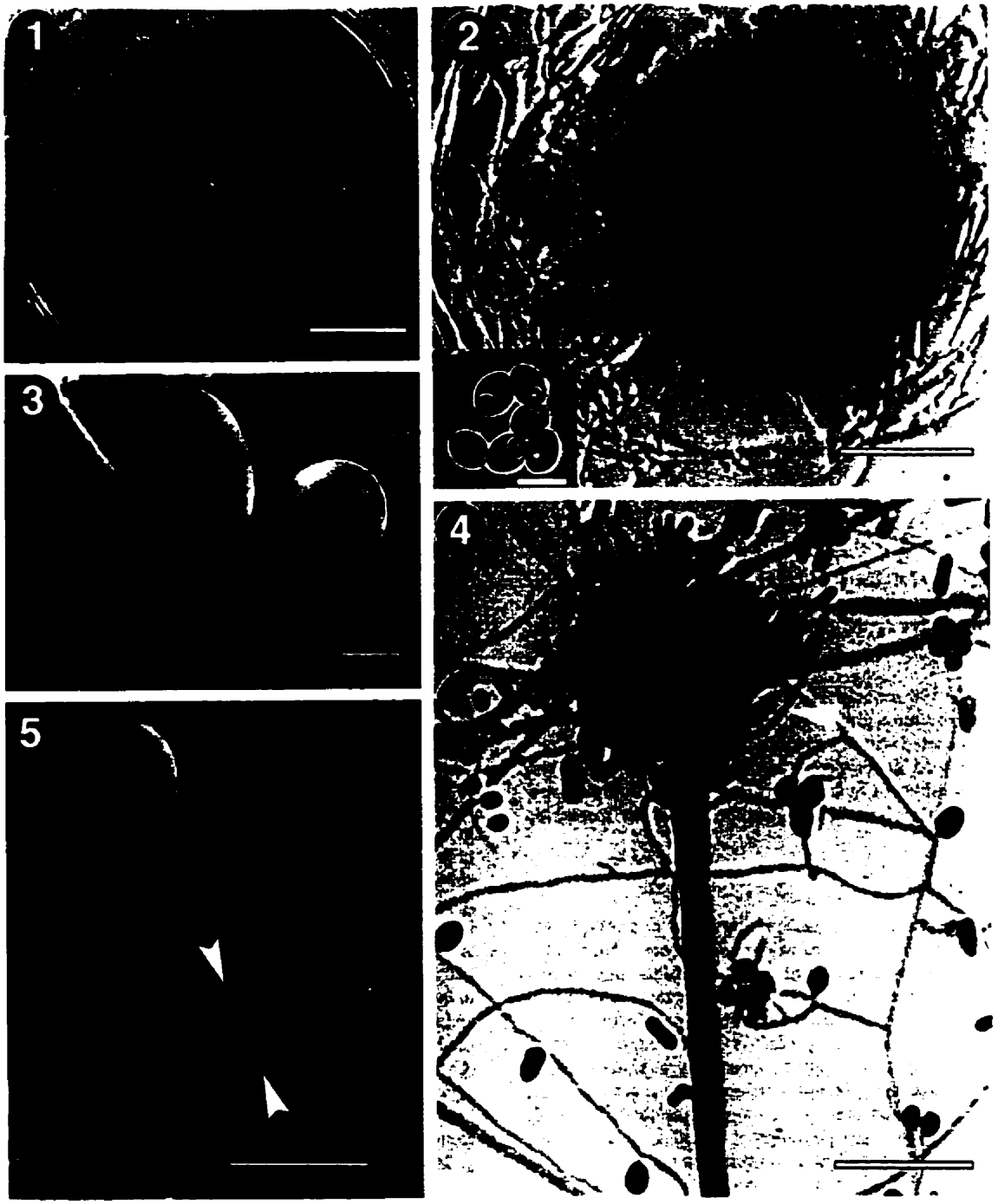
Fig. 5.1. Colony on PDA incubated at 37°C at 14 days, bar = 20 mm.

Fig. 5.2. Ruptured cleistothecium with ascospores and surrounding hyphae, bar = 40 µm. Inset: ascospores with de Bary bubbles, bar = 10 µm.

Fig. 5.3. Conidia of the *Scedosporium* state, SEM, bar = 2 µm.

Fig. 5.4. Synnematous conidiophore of *Graphium* state (arrowhead) with the synanamorphic *Scedosporium* state (double arrowheads), bar = 25 µm.

Fig. 5.5. Conidia and annellations (arrowheads) of the *Graphium* state, SEM, bar = 4 µm.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CHAPTER 6

THE DRY-SPORED SYNNEMATOUS ANAMORPHS OF MICROASCACEAE: REVISION OF *CEPHALOTRICHUM*, INCLUDING SYNONYMY OF *DORATOMYCES*, *STYSANUS* AND *TRICHURUS*

Introduction

The synnematous anamorphs were the first described of the asexual states now affiliated with the Microascaceae because of their distinctive 'bottle brush' appearance and relatively large size (up to several mm high) (e.g., Persoon 1801; Link 1809; Fries 1832; Corda 1837-54). Dry-spored synnemata, producing chains of powdery conidia are distinct from other microascaceous anamorphs producing synnemata with droplets of slimy conidia. The slimy-spored synnematous anamorphs of Microascales are placed in the genus *Graphium* (Okada et al. 1998), originally described by Corda in 1837. The dry spored synnematous species have had a confused nomenclatural history, and numerous form-genera have been described to accommodate them. Currently, several names (*Cephalotrichum*, *Doratomyces*, *Stysanus*) are disputed as to nomenclatural priority and synonymy, while another (*Trichurus*) is accepted as a distinct form-genus based on slight morphological differences.

The dry-spored synnematous fungi were referred to the genus *Stysanus*, described by Corda in 1837, throughout much of the latter half of the 19th century and first half of the 20th century, but two earlier generic names have been reexamined in modern times. The genus *Cephalotrichum* was established for two species, *C. rigescens* Link : Fr. and *C. stemonitis* (Pers.) Link : Fr. (Link 1809). It was the earliest name for species of this group, and was included in Fries (1832). Although *C. rigescens* and *C. stemonitis* may not be congeneric (Morton and Smith 1963), Hughes (1958) chose *C. stemonitis* as lectotype, establishing a clear concept for the genus. *Doratomyces* was described later by Corda (1829), and resurrected by Morton and Smith (1963). They rejected the lectotypification of *Cephalotrichum* and argue that *Doratomyces* should be retained. *Trichurus*, described much later by Clements and Shear (Clements and Pound 1896), was separated by the presence of sterile appendages on the synnemata. *Scopulariopsis* (Bainier 1907) is a morphologically and developmentally similar non-synnematous genus.

There is currently a lack of consensus, and the dry spored synnematous species are placed in various genera by different authors (e.g., Morris 1963; Carmichael et al. 1980; Domsch et al. 1980). Due to morphological reassessment of the type species and lectotypification, *Cephalotrichum*, *Doratomyces* and *Stysanus* are all typified by the species originally described as *Isaria stemonitis* Persoon. Hughes' (1958) lectotypification of *Cephalotrichum* is valid under ICBN Art. 9.13 (Greuter et al. 1994). Although many authors have recognized a similarity between *Trichurus* and *Cephalotrichum* (e.g., Hasselbring 1900; Swart 1964; Barron 1968; Hammill 1977; Carmichael et al. 1980), synonymy has not been formally proposed. Greuter et al. (1993) list *Cephalotrichum*,

Doratomyces, and *Trichurus* in their 'Names of genera in current use.' Because *Cephalotrichum* is the oldest described name, and because it was included in Fries (1932) and therefore treated as sanctioned under ICBN Art. 13.1 (Greuter et al. 1994), it is here retained as the oldest valid name for all dry spored synnematous anamorphs of the Microascaceae.

This review of the accepted species is accompanied by a nomenclatural bibliography and key to species. Since most species were described in the early 1800's and do not have adequate type specimens with associated living cultures, epitype cultures are chosen which represent modern concepts of the species and help to stabilize the nomenclature in accordance with ICBN Art. 9.7 (Greuter et al. 1994).

Material and Methods

Living cultures of all strains examined are maintained in the University of Alberta Microfungus Collection and Herbarium (UAMH). Microscopic mounts were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992). Conidiogenesis was observed with the slide culture technique using cereal agar (Sigler 1992), and synnemata were observed in tease mounts. Colonial features were recorded and colony diameter was measured on oatmeal agar (OAT; Weitzman and Silva-Hutner 1967) and potato dextrose agar (PDA; Difco Laboratories, Detroit, MI) at 25 C after 7, 14, 21 and 28 days. Measurements and observations of colonies reflect the range seen among all isolates examined of each species on both media. Selected specimens were fixed in 2% osmium tetroxide vapor and critical-point dried for examination with a Hitachi S-2500 scanning electron microscope (SEM).

Taxonomic Part

Cephalotrichum Link : Fries. 1832. Systema Mycologicum 3: 280. emend. nov.
≡ *Cephalotrichum* Link. 1809. Berlinische Magazin 3: 20.
= *Doratomyces* Corda. 1829. in Sturm, Deutschlands Flora, III (Pilze) 2: 65.
= *Stysanus* Corda. 1837. Icones Fungorum 1: 21.
= *Trichurus* Clements & Shear. 1896. in Clements and Pound, Botanical Survey of Nebraska 4: 7.
Type species: *Cephalotrichum stemonitis* (Persoon) Link : Fries. 1832. Systema Mycologicum 3: 280.
FIGS. 6.1-6.59.

Generic delimitation. The genus *Cephalotrichum* includes synnematous anamorphs of Microascaceae producing chains of dry conidia from annellidic conidiogenous cells. In their typical form, the synnemata are large (up to several mm high), dark gray-brown, have an elongated sporogenous area with annellides covering the upper third of the synnema and lack sterile appendages (Figs. 6.21, 6.24, 6.29, 6.36, 6.38 6.58). Sterile appendages are present on synnemata of three species (*C. cylindricus*, *C. dendrocephalus*, *C. spiralis*)(Figs. 6.10, 6.11, 6.13, 6.17, 6.19, 6.20, 6.49, 6.51). These

are sterile, hypha-like or seta-like extensions from the conidiophores (Swart 1964)(Figs. 6.9, 6.14, 6.48). Sterile appendages are also known in certain species of other form-genera (e.g., *Trichoderma*) and their presence is not sufficient for generic distinction. Swart (1964) and Hammill (1977) examined conidiogenesis and synnema development in species of *Trichurus* and found it was identical to *Doratomyces* (=*Cephalotrichum*) as described by Morton and Smith (1963) and Hammill (1972).

Species of *Cephalotrichum* produce parallel indeterminate synnemata (Seifert 1985). Several to many parallel hyphae compose the stipe and extend into the fertile portion of the synnema (Fig. 48). The stipe continues to elongate with annellides oriented laterally, the youngest of which being produced at the synnema apex. Morton and Smith (1963) suggested that shape of the synnemata (i.e., globose versus elongate sporulating heads) was species specific, but their finding is not supported here. In many cases, variation in shape was demonstrated within and among strains of each species. Synnematal heads may vary from globose through elongate-cylindrical, and are influenced by age of colonies, with synnemata tending to become more elongate in age (e.g., Fig. 6.24). In two species (*C. columnaris*, *C. putredinus*), the synnemata are not as large or well developed, with many mononematous conidiophores and reduced synnemata (frequently 50-300 μm). The sporogenous area is composed of a flared region of conidiophores at synnema apex (Figs. 6.4-6.6, 6.43). The resulting synnemata are similar shape to those seen in *Graphium*. The species accommodated in *Graphium* differ by the conidia aggregating in a slimy mass at the apex of the synnema (Seifert and Okada 1993; Okada et al. 1998).

Although synnematal production in *Graphium* species was enhanced by ultraviolet light (Seifert and Okada 1993; April et al. 1998), these wavelengths did not affect the production or orientation of synnemata of *Cephalotrichum* species which were routinely incubated upside down in the dark in this study (data not shown). This supports the findings of Lodha (1963).

The synnemata of Microascaceae are likely an adaptation for insect vector spore dispersal (e.g., Seifert and Okada 1993; Spatafora and Blackwell 1994). Laboratory manipulation of cultures by touching synnemata with a probe suggests that the dry synnemata of *Cephalotrichum* species are held rigidly upright on flexible stalks which spring back into position and release small clouds of spores when disturbed. They are thus acting as 'dusters' to leave spores covering the small vector as it passes through the synnematal 'forest'. Disturbance of the synnemata may also contribute to airborne dispersal of these small dry spores. In contrast, the slimy conidial masses of *Graphium* species act as 'paint-brushes', covering the vector with sticky spores as it brushes against the synnemata.

Synanamorphs and teleomorphs. Conidial morphology, conidiogenous cell (annellide) structure, and conidiogenesis (Figs. 6.2, 6.30, 6.37, 6.38, 6.53, 6.54) are consistent with *Scopulariopsis* (Hammill 1971, 1972, 1977), but the production of well developed synnemata warrants retention of a distinct form-genus to aid in identification of these hyphomycetes. All species of *Cephalotrichum* produce a reduced, non-synnematous

state in axenic culture which can be considered as a *Scopulariopsis* synanamorph (Fig. 6.23, 6.26, 6.46).

An *Echinobotryum* synanamorph is present only in the type species, *C. stemonitis* (Figs. 6.55, 6.59). It has been described as *Echinobotryum atrum*, the type of a monotypic form-genus (Corda 1831). This anamorphic state produces large, non-catenate, warted and beaked conidia in clusters from a repetitively branched conidiophore. Conidiogenesis is similar to *Wardomyces*, but *Echinobotryum* differs in the ornamented, beaked conidia which lack germ slits.

A teleomorph state is not known for any of the *Cephalotrichum* species recognized here. Mating trials among nine strains of *Cephalotrichum stemonitis* did not produce ascomata after 11 months (Abbott unpublished, see also Chapter 3). One species, *Microascus stysanophorus* (Matt.) Curzi, was described with a synnematous anamorph (Guégen 1903 as *Stysanus mandlii* Montagne; Curzi 1931 as *Microascus stysanosporus*), but at present no strains exhibiting both a sexual state and synnematous anamorph are known. The ascomata were redescribed by Doguet (1957) and the species was tentatively accepted by Barron et al. (1961), although the isolates from Paris observed by these authors did not produce a conidial state. This taxon was considered a *nomen dubium* by Morton and Smith (1963) and Arx et al. (1988) because no type or correlative extant material was available.

Key to species of *Cephalotrichum*

1. Sterile appendages present on synnemata 2
1'. Sterile appendages on synnemata lacking 4

2. Synnematal appendages curved, twisted or flexuous 3
2'. Synnematal appendages straight, seta-like ..... ***C. cylindricus***

3. Synnematal appendages loosely coiled, curved or flexuous, unbranched ..... ***C. spiralis***
3'. Synnematal appendages undulate, dichotomously branched ..... ***C. dendrocephalus***

4. Conidia and colonies white ..... ***C. putredinus***
4'. Conidia and colonies dark gray-brown 5

5. *Echinobotryum* synanamorph present ..... ***C. stemonitis***
5'. *Echinobotryum* synanamorph absent 6

6. Conidia coarsely warted, subglobose ..... ***C. nanum***
6'. Conidia smooth (or very finely ornamented), ellipsoid 7

7. Colonies fast growing (40-65 mm in 14 d) 8
7'. Colonies slow growing (20-30 mm in 14 d) ..... ***C. columnaris***

8. Conidia small (3-5 x 2-3 μm) ..... *C. microsporum*
8'. Conidia larger (5-8.5 x 3.5-4.5 μm) ..... *C. purpureofuscum*

Cephalotrichum columnaris (H.J. Swart) S.P. Abbott, comb. nov.
≡ *Doratomyces columnaris* H.J. Swart. 1967. Acta Botanica Neerlandica 15: 521. Type: holotype CBS; ex-type culture UAMH 9281 (=CBS 159.66; =IMI 116691)!
FIGS. 6.1-6.6.

Distinguishing features. Synnemata often poorly developed in culture, relatively small (50-700 μm), conidiophores often mononematous or synnematal stipes consisting of few aggregated hyphae, conidiogenous cells present in flared region of synnema at apex, annellides subcylindrical to ampuliform, conidia ellipsoid, often slightly asymmetrical, apex rounded or bluntly pointed, smooth, 5-6 x 2.5-4 μm, commonly 5.5 x 3 μm, colonies gray, slow growing (20-30 mm in 14 d @ 25 C).

The most conspicuous characteristics are the reduced, *Graphium*-like synnemata with chains of dry conidia from a flared synnematal apex. Additionally, the slow growing, gray colonies and often slightly asymmetrical conidia are reliable diagnostic features.

Taxonomic notes. A type herbarium specimen was not listed in the protologue (Swart 1967), and, therefore, the preserved culture deposited in the Centraalbureau voor Schimmelcultures is designated as type in accordance with ICBN Art. 8 (Greuter et al. 1994). Synnemata are more reduced than in most other species of *Cephalotrichum*, the shape suggesting an affinity to *Graphium*. Synnemata are also similar to synnematous anamorphs of *Kernia hippocrepida* Malloch & Cain and *K. pachypleura* Malloch & Cain (Malloch and Cain 1971). These *Kernia* anamorphs were described as *Scopulariopsis* or *Graphium* states, suggesting that both dry and sticky spores may be produced. Synnemata were not produced in axenic culture in seven isolates of these two species examined at UAMH. Further investigation is required to determine if the type of *C. columnaris* is a non-ascocarpic isolate conspecific with a described species of *Kernia*.

Specimens examined. CANADA: ALBERTA: St. Lina. indoor air of honeybee (*Apis mellifera*) overwintering facility, 10 Dec. 1993, S.P. Abbott OHS 111, (UAMH 8042); Vegreville. nail, 60 yr. old male, Provincial Laboratory MY 0750 (UAMH 8597). SOUTH AFRICA: dung of hare, H.J. Swart, obtained from Centraalbureau voor Schimmelcultures as *Doratomyces columnaris* CBS 159.66, (UAMH 9281, =IMI 116691) (ex-type of *Doratomyces columnaris*).

Cephalotrichum cylindricum (Clements & Shear) S.P. Abbott comb. nov.
≡ *Trichurus cylindricus* Clements & Shear. 1896. in Clements and Pound, Botanical Survey of Nebraska 4: 7. Type: holotype MICH; epitype culture selected UAMH 1348 (=IMI 96753, DAOM 45913)!
= *Trichurus terrophilus* Swift & Povah. 1929. Mycologia 21: 214.

FIGS. 6.7-6.12.

Distinguishing features. Synnemata typically 450-700 µm, covered by straight, tapered, pointed, seta-like appendages, appendages simple or, more frequently, branched, annellides ampuliform, conidia ellipsoidal to ovoid, apex rounded, 3-8 x 2-3.5 µm, commonly 4.5-5.5 x 3-3.5 µm, colonies gray to gray brown, relatively fast growing (55-65 mm in 14 d @ 25 C).

The appendages are the most distinctive feature and are sufficient for confident identification. Problems of identification can occur in strains with poorly developed synnemata and appendages, but a few sterile elements are typically seen in mononematous conidiophores observed in slide culture. Similarity in conidia could lead to confusion with *C. purpureofuscum* if appendages are overlooked.

Taxonomic notes. Most modern isolates are referred to *Trichurus terrophilus*, and *T. cylindricus* has been regarded as a 'lost' species (e.g., Domsch et al. 1980). Confusion has centered on spore size since the conidia of *T. cylindricus* were reported in the protologue as 8-9 µm long (Clements and Pound 1896), while those of *T. terrophilus* are smaller (3-6 µm long in Swift 1929). Reevaluation of the type and other isolates assigned to *T. cylindricus* has shown that the original report of conidial size is in error (Udagawa et al. 1985; Seifert pers. comm.). Udagawa et al. (1985) maintain *T. cylindricus* and *T. terrophilus* as distinct species based on the simple versus branched appendages, but the original description of *T. terrophilus* illustrates both branched and unbranched setae (Swift 1929). A wide range in degree of seta development and conidium size was seen among the isolates here assigned to *C. cylindricum*. An isolate collected from sorghum seed in Kansas and assigned to *T. cylindricus* (Udagawa et al. 1985) is representative of the species and is here selected as epitype. The culture produces abundant synnemata (on OAT in 14 d) with straight, unbranched and branched appendages, with conidia 4.5-5.5 x 3-3.5 µm.

Specimens examined. BRAZIL: Pará, Belem. soil under primary Amazonian forest, Dec. 1993. *L. Pfenning*, obtained from Colleção de Culturas Tropical as *Scopulariopsis carbonaria* CCT 3815, (UAMH 8912). FRANCE: soil, *A. Russo*, obtained from Centraalbureau voor Schimmelcultures as *Trichurus terrophilus* CBS 646.70, (UAMH 9141). SOUTH AFRICA: timber of eucalyptus (*Eucalyptus saligna*), 1951, *TRL8-FPRL (S590)* obtained from Institute for Fermentation Osaka as *Trichurus terrophilus* IFO 7660 UAMH 8848, =IMI 46251, =LSHB BB344, =CBS 448.51). UNITED STATES: KANSAS: seed of sorghum, 1955, *C.T. Rogerson S.129*, obtained from Canadian Collection of Fungus Cultures as DAOM 45913, (UAMH 1348, =IMI 96753) (epitype culture). MICHIGAN: Huron National Forest. soil under white pine (*Pinus strobus*), 19 Jul. 1962, *NRRL isolate*, obtained from United States Department of Agriculture as *Doratomyces stemonitis* NRRL A-11628, (UAMH 8976).

Cephalotrichum dendrocephalum (Udagawa, Horie & Abdullah) S.P. Abbott comb. nov.
≡ *Trichurus dendrocephalus* Udagawa, Horie & Abdullah. 1985. Mycotaxon 23: 253.

Type: holotype NHL; ex-type culture UAMH 5372 (=NHL 2927)!
FIGS. 6.13-6.20.

Distinguishing features. Synnemata large (frequently 1000-2000 µm high and with stipes 70 µm diam.) covered with undulate, dichotomously branched appendages, annellides ampuliform, conidia ellipsoid to ovoid, apex rounded, smooth, 2.5-7 x 2-4 µm, commonly 3.5-4.5 x 2.5-3 µm, colonies gray to gray brown, relatively fast growing (40-45 mm in 14 d @ 25 C).

The dense, undulating, branched appendages are diagnostic and reliable for identification. Additionally, spores are relatively small (typically 3.5-4.5 x 2.5-3 µm) and synnemata very large and robust (1500-2000 µm). *C. cylindricum* and *C. spiralis* are similar, but these taxa differ in their larger conidia and different appendages. *C. cylindricum* spores are typically 4.5-5.5 x 3-3.5 µm, and appendages are always straight and seta-like. Conidia of *C. spiralis* are commonly 5 x 3.5 µm and appendages are loosely coiled and unbranched (see notes below).

Taxonomic notes. This species was formerly known only from the type specimen, but a second collection from Alberta supports its status as a distinct taxon. The variation in appendage morphology among the isolates of *C. spiralis* and *C. cylindricum* examined here does not overlap with *C. dendrocephalum*.

Specimens examined. CANADA: ALBERTA: Edmonton. Richardson's ground squirrel (*Spermophilus richardsonii*), 8 Aug. 1962, *J.W. Carmichael*, (UAMH 1383). IRAQ: Basrah City. soil date palm plantation, Jul. 1983, *S. Abdullah*, (UAMH 5372, =NHL 2927) (ex-type of *Trichurus dendrocephalus*).

Cephalotrichum microsporum (Saccardo) P.M. Kirk. 1984. Kew Bulletin 38: 578.
≡ *Stysanus microsporus* Saccardo. 1878. Michelia 1: 274. Type: holotype BM; epitype culture selected UAMH 9365!
≡ *Doratomyces microsporus* (Saccardo) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 77.
= *Graphium graminum* Cooke. 1887. Grevillea 16: 11.
FIGS. 6.21-6.25.

Distinguishing features. Synnemata typically 500-1000 µm, lacking appendages, annellides ampuliform, conidia ellipsoid to 'bullet-shaped', typically pointed at apex or occasionally rounded, smooth, 3.5-5 x 2.5-3 µm (commonly 4.5 x 3 µm), colonies gray to gray brown, relatively fast growing (40-60 mm in 14 d @ 25 C).

Most similar to *C. purpureofuscum*, but *C. microsporum* can be easily separated by the smaller, bullet-shaped conidia and grayer rather than dark brown colonies. Cultures of *C. microsporum* also tend to maintain production of abundant synnemata with less degeneration to a predominance of mononematous conidiophores, as is seen in species such as *C. nanum*.

Taxonomic notes. This taxon was not transferred by Hughes (1958), but is one of the most commonly encountered species of *Cephalotrichum*. The epitype culture selected here is consistent with the description in Saccardo (1886) and modern descriptions (e.g., Morton and Smith 1963; Domsch et al. 1980, as *Doratomyces microsporus*).

Specimens examined. CANADA: ALBERTA: Cardston. manure pile, Jun. 1967, *D. Remington*, (UAMH 2791); Edmonton. soil, Sep. 1990, *L. Rosmus*, (UAMH 6751); bronchial washings, male, 59 yr, 27 May 1996, *G. Man/ N. Brown MY 2296*, (UAMH 8625); right heel, female 35 yr, 12 Jan. 1995, *C. Sand MY 148*, (UAMH 9003); UAMH. contaminant ex culture, Dec 1976, (UAMH 4019); Provincial Laboratory for Southern Alberta. bronchial wash, male 50 yr, 29 Jun. 1995, *MY 2217*, (UAMH 8295). Elk Island National Park. well decayed wood of white spruce (*Picea glauca*) log, 12 Feb. 1997. *T. Lumley EI-01-S2A*, (UAMH 9143); near Peace River. indoor air of home, 9 Sep. 1998, *S.P. Abbott SA-M270*, (UAMH 9365); North Buck Lake near Lac La Biche. dung of coyote (*Canis latrans*) in birch/pine woods (*Betula papyrifera/Pinus banksiana*), 8 Jan. 1999, *S.P. Abbott SA-M277*, (UAMH 9456). JAPAN: Otoineppu, Nakagawa-gun, Hokkaido. Japan, decaying higher fungus (*Coriolus hirsutus*), 6 Sep. 1969, *S. Udagawa NHL 2446*, obtained from Institute for Fermentation Osaka as IFO 9383 (UAMH 8845). NEW ZEALAND: Mt. Albert. potato (*Solanum tuberosum*), Jan. 1962, *F.J. Morton H97*, obtained from International Collection of Micro-organisms from Plants as ICMP 1054 (UAMH 8789).

Cephalotrichum nanum (Ehrenberg) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Periconia nana* Ehrenberg 1818. Sylvae Mycol. Berol. pp. 13, 24. Type: holotype unavailable (*fide* Morton and Smith 1963), authentic material B, L, DAOM (*fide* Hughes 1958; Seifert 1985); epitype culture selected UAMH 9126!

≡ *Stilbum nanum* (Ehrenberg) Sprengel. 1827. Linn. Syst. Veg., Ed. 16, 4(1): 547.

≡ *Graphium nanum* (Ehrenberg) Saccardo. 1886. Sylloge Fungorum 4: 616.

≡ *Doratomyces nanus* (Ehrenberg) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 80.

= *Stysanus fimetarius* (Karsten) Massee & E.S. Salmon. 1902. Annals of Botany 16: 86.

≡ *Stysanus stemonitis* var. *fimetarius* Karsten. 1887. Meddelanden af Societas pro Fauna et Flora Fennica 14: 93.

= *Periconia phillipsii* Berkeley & Leighton. 1875. in Berkeley and Broome, Annals and Magazine of Natural History, Ser. 4, 15: 33.

≡ *Sporocybe phillipsii* (Berkeley & Leighton) Saccardo. 1886. Sylloge Fungorum 4: 609.

≡ *Stysanus phillipsii* (Berkeley & Leighton) E.W. Mason & M.B. Ellis. 1953. Mycological Papers 56: 40.

≡ *Cephalotrichum phillipsii* (Berkeley & Leighton) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Doratomyces phillipsii* (Berkeley & Leighton) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 82.

= *Doratomyces asperulus* auct. *sensu* Domsch et al. 1980.

≠ *Doratomyces asperulus* Wright & Marchand. 1972. Boletin de la Sociedad Argentina de Botánica 14: 308. (= *Cephalotrichum purpureofuscum*)

(for additional synonyms see Hughes 1958; Morton and Smith 1963)

FIGS. 6.26-6.31.

Distinguishing features. Synnemata typically 500-2000 µm, lacking appendages, annellides ampuliform, mononematous conidiophores often abundant in axenic culture, conidia subglobose, coarsely warted, 6-8.5 x 5-7 µm, commonly 7.5 x 7 µm, colonies dark brown to gray brown, relatively slow growing (25-30 mm in 14 d @ 25 C).

This species is readily distinguished by the large, warted conidia. Subcultures of *C. nanum* frequently lack synnemata, but synnema development can usually be induced on OAT agar.

Taxonomic notes. The unique conidia suggest a position taxonomically isolated from the other *Cephalotrichum* species. Conidium morphology is similar to that seen in *Scopulariopsis brevicaulis* (Sacc.) Bainier and *S. asperula* (Sacc.) S. Hughes (Hammil 1972; Abbott et al. 1998; see Chapter 3). The epitype culture produces abundant synnemata and is typical of this distinctive species.

Although *Cephalotrichum phillipsii* has been treated as a distinct species based on larger conidia and synnemata (Hughes 1958; Morton and Smith 1963), the illustration in Mason and Ellis shows most spores 7-9 µm diam., approaching the range seen in *C. nanum*. *C. phillipsii* is tentatively considered a synonym of *C. nanum* based on the descriptions and illustrations made from the holotype (the only collection known) by others (e.g., Mason & Ellis 1953; Morton & Smith 1963).

The concept of *Doratomyces asperulus* outlined and illustrated in Domsch et al. (1980) is based on an aberrant isolate of *C. nanum* (CBS 187.78, =UAMH 9128) and is not conspecific with the type of *D. asperulus* (see notes under *C. purpureofuscum* below). In this isolate, the ornamentation on the conidia appears 'banded' from the arrangement of small, sparse warts. A similar conidial morphology was observed in several isolates of *C. nanum* from Alberta (e.g., UAMH 8741), but variation was observed among subcultures of different ages on different media, with a morphology typical for *C. nanum* seen in some mounts. Similar variation in the degree of conidium ornamentation has also been illustrated in several species of *Scopulariopsis* (see Chapter 3).

Specimens examined. CANADA: ALBERTA: Michel Reservoir, southern Alberta. dung, Mar. 1983, *R. Currah*, (UAMH 4758); Fairview. indoor air of honeybee (*Apis mellifera*) overwintering facility, 31 Jan. 1994, *S.P. Abbott OHS 181*, (UAMH 7755); Elk Island National Park. dung of bison (*Bison bison*) in white spruce (*Picea glauca*) and poplar (*Populus tremuloides* and *P. balsamifera*) forest, 18 Aug. 1997, *S.P.*

Abbott SA-M198, (UAMH 9126); well decayed wood of white spruce (*Picea glauca*) log, Sep. 1995, *T. Lumley EI-01-S2E, EI-01-S3G*, (UAMH 8485, 8486); Fish Lake near Nordegg. deer (*Odocoileus* sp.) dung in spruce (*Picea glauca*) forest, 14 Jun. 1996, *S.P. Abbott SA-M134*, (UAMH 8620); Astoria River valley, Jasper National Park. marten (*Martes americana*) dung, 28 Aug. 1996, *S.P. Abbott SA-M140*, (UAMH 8621); near Moraine Lake. hoary marmot (*Marmota caligata*) dung, 28 Aug. 1996, *S.P. Abbott SA-M141*, (UAMH 8622); Wagner Natural Area near Spruce Grove. snowshoe hare (*Lepus americanus*) dung in spruce/larch (*Picea mariana/Larix laricina*) forest, 16 Dec. 1996, *S.P. Abbott SA-M168*, (UAMH 8740); soil of northern pocket gopher (*Thomomys talpoides*) mound in hay field, 16 Dec. 1996, *S.P. Abbott SA-M167*, (UAMH 8741); Devonian Botanic Garden near Devon. porcupine (*Erethizon dorsatum*) dung, 17 Dec. 1996, *S.P. Abbott SA-M166*, (UAMH 8742). JAPAN: soil, 1985, *T. Yokoyama R-1607-21*, obtained from Institute for Fermentation Osaka as IFO 31957, (UAMH 8855). NETHERLANDS: sand dune soil, obtained from Centraalbureau voor Schimmelcultures as *Doratomyces asperulus* CBS 187.78 (UAMH 9128). UNITED KINGDOM: ENGLAND: deer dung, 1956, *J. Hawkins*, obtained from Institute for Fermentation Osaka as IFO 8180, (UAMH 8854, =IMI 68394 =LSHB Sc. 142 =CBS 119.61).

Cephalotrichum purpureofuscum (Schweinitz : Fries) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Aspergillus purpureofuscus* Schweinitz. 1832. Transactions. American Philosophical Society, Ser. II, 4: 282. Type: holotype K; epitype culture selected UAMH 9209!

≡ *Aspergillus purpureofuscus* Schweinitz : Fries. 1832. Systema Mycologicum 3: 388.

≡ *Stysanus purpureofuscus* (Fries) S. Hughes. 1953. Canadian Journal of Botany 31: 744.

≡ *Doratomyces purpureofuscus* (Fries) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 74.

= *Periconia fusca* Corda. 1837. Icones Fungorum 1: 19.

≡ *Stysanus fuscus* (Corda) E.W. Mason & M.B. Ellis. 1953. Mycological Papers 56: 31.

= *Stysanus mandlii* Montagne. 1837. Annaes de Sciencias Naturaes, Sér. 3, 4: 345.

= *Stysanus medius* Saccardo. 1881. Michelia 2: 300.

≡ *Doratomyces medius* (Saccardo) Matsushima. 1980. Matsushima Mycological Memoirs 1: 33.

≡ *Cephalotrichum medium* (Saccardo) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Stysanopsis media* (Saccardo) Ferr. 1909. Annales Mycologici 7: 281.

= *Doratomyces asperulus* Wright & Marchand. 1972. Boletin de la Sociedad Argentina de Botánica 14: 308.

(for additional synonyms see Hughes 1958; Morton and Smith 1963; Mason and Ellis 1953)

FIGS. 6.33-6.38.

Distinguishing features. Synnemata typically 800-1250 µm, lacking appendages, annellides ampuliform, conidia ellipsoidal to ovoidal, apices rounded, smooth to finely roughened, 5-8 x 3-4.5 µm, commonly 6 x 3.5 µm, colonies dark brown to gray brown, relatively fast growing (40-70 mm in 14 d @ 25 C).

No single feature distinguishes this species. Conidia are similar to several other species but *C. purpureofuscum* lacks appendages, distinguishing it from *C. cylindricus* and *C. spiralis*. *C. purpureofuscum* also lacks an *Echinobotryum* synanamorph, separating it from *C. stemonitis*, which also tends to have more pointed conidia. Some isolates of these species that fail to demonstrate well developed appendages or synanamorph may be erroneously identified as *C. purpureofuscum*. Although the synnemata of *C. purpureofuscum* are frequently illustrated with subglobose conidiogenous heads (e.g., Mason and Ellis 1953 as *Stysanus fuscus*; Morton and Smith 1963 as *Doratomyces purpureofuscus*), elongate, ovoid to cylindrical heads were more frequent in this study.

Taxonomic notes. This taxon has been described on a number of occasions, but *Aspergillus purpureofuscus* is the oldest name and is sanctioned by inclusion in Fries (1832). *Stysanus medius* was tentatively accepted by Matsushima (1980) and Hughes (1958), but the description in Saccardo (1886) is consistent with *C. purpureofuscum* as suggested by Morton and Smith (1963). *Doratomyces asperulus* was described based on ornamented, banded conidia. Several isolates from Alberta (e.g., UAHM 8237, 9158) are identical to the type (CBS 582.71, =UAMH 9127) which all exhibit a fine ornamentation visible as irregular bands around the conidia. Other isolates (e.g., UAMH 989, 2775) appear very slightly roughened but not banded and are somewhat intermediate between typical isolates of *C. purpureofuscum* and *D. asperulus*. Examination by SEM (Figs. 34, 35, 37) demonstrates considerable variation in degree of roughening within and among isolates. *D. asperulus* is here considered conspecific with *C. purpureofuscum*.

Specimens examined. ARGENTINA: Buenos Aires, Tordillo, Arroyo Las Viboras, humus-rich soil, 1970, *A.M. Godeas*, obtained from Centraalbureau voor Schimmelcultures as *Doratomyces asperulus* CBS 582.71, (UAMH 9127, =ATCC 26885) (ex-type of *Doratomyces asperulus*). AUSTRALIA: Lord Howe Island. soil, banyan rhizosphere, 1977, *A.D. Hocking*, obtained from CSIRO Food Science and Technology Culture Collection as *Doratomyces stemonitis* FRR 1903, (UAMH 8739). BELGIUM: Han-sur-Lesse. wood of decaying furniture in underground laboratory cave, Sep. 1959, *G.L. Hennebert 882-18*, obtained from Mycothèque de l'Université Catholique de Louvain as MUCL 536, (UAMH 8892). BRAZIL: São Paulo, Peruibe. soil under primary Atlantic forest, Oct. 1994, *A.B. Garlipp*, obtained from Colleção de Culturas Tropical as *Doratomyces stemonitis* CCT 4299, (UAMH 8910). CANADA: ALBERTA: Bittern Lake. lung Richardson's ground squirrel (*Spermophilus richardsonii*), May 1959, *J.W. Carmichael*, (UAMH 989); Cardston. hair of Richardson's Ground Squirrel (*Spermophilus richardsonii*), Jun. 1967, *D. Remington 1*, (UAMH 2771, 2775); Edmonton. Alberta Game Farm. soil of guanaco paddock, 7 Jul. 1962, *J.W. Carmichael 18-5-c*, (UAMH 1299); UAMH, plate contaminant in walk-in cooler, 28 Apr. 1993, *S.P. Abbott SA-M3*, (UAMH 9002); ex nail, male 59 yr, 11 Jan. 1993, *C. Sand MY 5858b*,

(UAMH 7303); Calgary. ex fingernail, female 35 yr, 8 Nov. 1994. *MY 3483* (UAMH 7743); Provincial Laboratory for Southern Alberta. bronchial wash, male 65 yr, 29 Jun. 1995, *MY 2216*, (UAMH 8237); bronchial wash, male 16 yr, 1997, *MY 6111*, (UAMH 9158). BRITISH COLUMBIA: Pemberton. indoor air of school library, 18 Feb. 1998, *S.P. Abbott SA-M209*, (UAMH 9209); unknown. *C.J. Anastasiou S55 (A20)*, (UAMH 1767). GERMANY: wheat field soil, 1963, *K. Domsch*, obtained from Institute for Fermentation Osaka as IFO 31240, (UAMH 8853, =CBS 523.63, =ATCC 16224). JAPAN: leaves of needle-leafed tree, 1986, *T. Ito ISR 47-1*, obtained from Institute for Fermentation Osaka as *Doratomyces stemonitis* IFO 32040, (UAMH 8844). NEW ZEALAND: Mt. Albert. cave wall, Nov. 1961, *F.J. Morton H56*, obtained from International Collection of Micro-organisms from Plants as *Trichurus terrophilus* ICMP 1165, (UAMH 8788); leaf of swede (*Brassica napus* var. *napobrassica*), Jul. 1963, *F.J. Morton H286*, obtained from International Collection of Micro-organisms from Plants as *Doratomyces microsporus* ICMP 1094 (UAMH 8790). SPAIN: soil, *J. Guarro FFBA 217*, (UAMH 4455). UNITED STATES: CALIFORNIA: San Diego. soil, *G.F. Orr 217* obtained from Canadian Collection of Fungus Cultures as DAOM 84432, (UAMH 1416).

Cephalotrichum putredinis (Corda) S.P. Abbott comb. nov.

≡ *Stysanus putredinis* Corda. 1839. Icones fungorum 3: 12. Type: lectotype selected, Taf. II, Fig. 36, Corda 1839; epitype culture selected UAMH 8891 (=MUCL 4039; CBS 192.62; IMI 86950; LSHB Sc. 152)!

≡ *Doratomyces putredinis* (Corda) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 83.

≠ *Graphium putredimus* auct. *sensu* Hughes 1958; Ellis 1971; Seifert et al. 1993. (= *Graphium cuneiferum* (Berkeley & Broome) Mason & Ellis)

= *Sympenicillium album* Costantin. 1888. Bulletin Societé Mycologique de France 4: 67.

≡ *Coremium album* (Costantin) Saccardo & Traverso. 1839. in Saccardo, Sylloge Fungorum 22: 1444.

≡ *Penicillium costantini* Bainier. 1906. Bulletin Societé Mycologique de France 22: 205. (*nomen novum*).

≡ *Scopulariopsis costantini* (Bainier) Dale. 1914. Annales Mycologici 12: 57.

= *Scopulariopsis alba* Szilvinyi. 1941. Zentralblatt fuer Bakteriologie, Parasitenkunde, Infektionskrankheiten, und Hygiene, Abteilung II, 103: 172.

≡ *Doratomyces albus* (Szilvinyi) Dominik. 1970. Zeszyty Naukowe Wyzszej Szkoly Rolniczej W Szczecinie 32: 89.

FIGS. 6.39-6.46.

Distinguishing features. Synnemata poorly developed (up to 250 µm) and frequently only mononematous conidiophores or coremia (loose fascicles of conidiophores not necessarily united at the base; Tubaki 1966) produced in axenic culture, synnemata primarily produced on natural substrata, composed of hyaline hyphae, conidiogenous cells at flared apex of synnema, annellides cylindrical to ampuliform, conidia hyaline, narrowly ellipsoidal to ellipsoidal or ovoidal, typically rounded at apex, occasionally bluntly pointed, smooth, 4.5-6 x 2-3 µm, colonies white to cream, relatively slow growing (25-35 mm in

14 d @ 25 C).

The reduced white synnemata, and slow growing, white colonies clearly distinguish *C. putredinus* from all other taxa. The conidia are typically narrowly ellipsoidal in young cultures and become more swollen ellipsoidal to ovoidal in age (i.e., after a month), and remain attached in long chains. Synnematal shape is most similar to *C. columnaris*. Because of the coloration and predominance of mononematous conidiophores in culture, this species could most easily be confused with *Scopulariopsis* species such as *S. candida* Vuillemin, the latter differing by larger, 5-8 x 4-7 µm, subglobose conidia (see Chapter 3).

Taxonomic notes. A great deal of confusion has surrounded this species since its original description and illustration in Corda (1839) as a species of *Stysanus*, and the epithet 'putredinus' has been applied to more than one taxon in modern times. The concept supported here is based on that of Morton and Smith (1963 as *Doratomyces putredinus*). They describe a white synnematous fungus with dry chains of hyaline conidia based on their examination of the holotype collection of Corda in addition to a modern isolate made by Gams (=UAMH 8891). This concept was adopted by Udagawa and Horie (1971), who described another isolate from a decaying agaric (=UAMH 8849). Hughes (1958) also examined the holotype and renamed the species *Graphium putredinus*, but his concept was based on a synnematous fungus with larger, pigmented conidia, produced in a slimy droplet. Hughes' concept reflects a true *Graphium* species, and has been supported by two important subsequent works (Ellis 1971; Seifert and Okada 1993) and is still used in the current literature (e.g., Mercado-Sierra et al. 1997). The '*Graphium putredinus* complex' as outlined by Seifert and Okada (1993) and Okada et al. (1998) includes the synnematous anamorphs of *Pseudallescheria boydii* (Shear) McGinnis, Padhye & Ajello, *P. fusoidea* (Arx) McGinnis, Padhye & Ajello, *P. fimeti* (Arx) McGinnis, Padhye & Ajello, *Petriella sordida* (Zukal) Barron & Gilman, *P. setifera* (Schmidt) Curzi, and *P. guttulata* Barron & Cain. Because the two 'putredinus' concepts are fundamentally different, we must assume that the holotype contained two different synnematous fungi. Although Corda's (1839) original description is brief, the illustration clearly shows long chains of narrowly ellipsoid conidia from the upper portion of a flared synnema (Fig. 7.46). Based on the assumption that the holotype specimen contains more than one taxon, the illustration in Corda (1839, Taf. II, Fig. 36) is chosen as lectotype in accordance with ICBN Art. 9.9 (Greuter et al. 1994). In order to stabilize the nomenclature of this confused species, the isolate examined by Morton and Smith (UAMH 8891; =LSHB Sc. 152) that produces reduced synnemata in culture is chosen as epitype (ICBN Art. 9.7; Greuter et al. 1994). The *Graphium* interpretation is in serious conflict with the protologue and cannot be accepted under this epithet, but should, however, be considered a segregate taxon and be named accordingly (ICBN Art. 9A.5; Greuter et al. 1994). This taxon is conspecific with *Graphium cuneiferum* (see illustration in Mason and Ellis 1953), a synonymy suggested by Hughes (1958) and Seifert (1985), but further investigation is required to determine if this is the oldest available name for this taxon.

Morton and Smith (1963) list *Scopulariopsis alba* as unidentifiable, but the

specimen of *Doratomyces albus* illustrated in Dominik (1970) is clearly conspecific with *C. putredinus* as outlined above. The small synnemata are similar to those seen on natural substrata (especially grass stems) in this study (e.g., UAMH 1301), those illustrated along a herbaceous stem in Corda (1839), and on a decaying agaric by Udagawa and Horie (1971). *Sympenicillium album* is also synonymous, but based on a different type. It was later transferred to the genera *Coremium*, *Penicillium* (as *P. costantini, nomen novum*, since the epithet 'album' was unavailable in *Penicillium*), and *Scopulariopsis*. The treatment of this taxon in these genera reflect the reduced nature of the synnemata, with coremia and mononematous conidiophores predominating in axenic culture.

The synonymy of Sopp's (1912) *Acaulium fulvum* Sopp with *C. putredinus* proposed by Morton and Smith (1963) cannot be accepted since the spore size, given in the protologue as 10-14 x 5 µm, is much larger than seen here. Since there is no type specimen, it is impossible to determine the true identity of this taxon and *A. fulvum* is best regarded as a *nomen dubium*.

Collections examined: AUSTRIA: Innsbruck. culture contaminant, 1960, *W. Gams*, obtained from Mycothèque de l'Université Catholique de Louvain as *Doratomyces putredinus* MUCL 4039, (UAMH 8891, =IMI 86950, =LSHB Sc. 152, =CBS 192.62) (epitype culture). CANADA: ALBERTA: Edmonton. shavings ex rabbit cages, May 1959, *J.W. Carmichael* (UAMH 637); Alberta Game Farm. soil, cougar pen, 8 Nov. 1961 and 7 Jul. 1962, *J.W. Carmichael*, (UAMH 1145, 1318); soil nursery paddock, 7 Jul. 1962, *J.W. Carmichael*, (UAMH 1290); soil under falcon roost, 7 Jul. 1962, *J.W. Carmichael*, (UAMH 1321); straw under bird roosts, 7 Jul. 1962, *J.W. Carmichael*, (UAMH 1331, 1332); coyote (*Canis latrans*) dung, *R. Currah D-7*, (UAMH 5623); 10 km south of Leduc. striped skunk (*Mephitis mephitis*) dung on ground in farm yard, 10 Jun. 1997. *S.P. Abbott SA-M185*, (UAMH 9028). ONTARIO: North York. air of mold-contaminated building, 30 Jul. 1986, *R.C. Summerbell FR 1395.86*, (UAMH 5739). JAPAN: Sugadaira, Sanada-machi, Chiisagata-gun, Nagano Pref. decaying higher fungus (*Macrolepiota procera*), 2 Oct. 1969, *S. Udagawa NHL 2440*, obtained from Institute for Fermentation Osaka as *Doratomyces putredinus* IFO 9384, (UAMH 8849). UNITED STATES: wood treated with fungicide, 16 May 1995, *D.T. Wicklow*, obtained from United States Department of Agriculture as *Scopulariopsis candida* NRRL 25172, (UAMH 8990). CALIFORNIA: Chino. soil in chicken pens of poultry ranch, 17 Feb. 1969, *J.W. Carmichael*, (UAMH 3238).

Cephalotrichum spiralis (Hasselbring) S.P. Abbott comb. nov.

≡ *Trichurus spiralis* Hasselbring. 1900. Botantical Gazette 29: 321. Type: syntypes BPI; epitype culture selected UAMH 3585!

= *Trichurus gorgonifer* Bainier. 1907. Bulletin Societé Mycologique de France 23: 230.

FIGS. 6.47-6.53.

Distinguishing features. Synnemata typically 500-1000 µm, covered with loosely coiled or spiral to curved, bent or flexuous, unbranched appendages, appendages often

seta-like and tapered to a blunt point at apex, annellides ampuliform, conidia ellipsoidal to ovoidal, apices rounded, smooth, 4-6.6 x 2.5-3.5 µm, commonly 5 x 3.5 µm, colonies gray to gray-brown, relatively fast growing (60-75 mm in 14 d @ 25 C).

This species is easily recognized by its distinctive spiral appendages, although these are reduced in some isolates, making identification more problematic. Conidial size is similar to *C. purpureofuscum*. *C. dendrocephalum* has branched, undulating appendages (never loosely coiled) and slightly smaller conidia on average (3.5-4.5 x 2.5-3 µm), while *C. terrophilus* has branched or unbranched, straight, seta-like appendages.

Taxonomic notes. No holotype was designated by Hasselbring (1900), but the three collections cited in the protologue are presumably deposited in BPI. These syntypes were not examined, but the specimen collected on decayed wood in autumn of 1898 by Hasselbring should be chosen as lectotype if available. The epitype culture selected (UAMH 3585) produces colonies, synnemata and conidia typical for this taxon. *Trichurus gorgonifer* is synonymous (Lodha 1963).

Specimens examined. CANADA: ALBERTA: Spruce Grove. steamed decomposing mushroom compost, 8 Mar. 1973, *L. Sigler* (UAMH 3585) (epitype culture); Nisku. ex growth pouch with alfalfa seeds in growth chamber, 25 Nov. 1992, *M. Matlock*, (UAMH 7259); Edmonton. air, 1995, *J.P. Tewari*, (UAMH 9319); Provincial Laboratory for Southern Alberta. sputum, male 63 yr, 11 Dec. 1996, *MY 251* (UAMH 8836); finger nail, 21 Aug. 1998, *MY 5540*, (UAMH 9405). BRITISH COLUMBIA: contaminant in tray of sawdust and straw used for growing shiitake (*Lentinula edodes*), 2 Feb. 1978, *R.J. Bandoni*, (UAMH 4093). ONTARIO: Ottawa. airborne contaminant of wheat-straw agar plate, *R.A. Shoemaker*, obtained from Canadian Collection of Fungus Cultures as DAOM 147400 (UAMH 8689); egg of gypsy moth (*Lymantria dispar*), *M.I. Timonin*, obtained from Canadian Collection of Fungus Cultures as DAOM 190434, (UAMH 8690); air, 1942, *M.E. Elliott MEE 42-I-342B*, obtained from Canadian Collection of Fungus Cultures as DAOM 196858, (UAMH 8691). CYPRUS: Nicosia. soil, on roots of potato (*Solanum tuberosum*), Oct. 1932, *R.M. Nattrass 285*, obtained from Mycothèque de l'Université Catholique de Louvain as MUCL 9829, (UAMH 8882, =CBS 336.32). INDIA: Bihar. paper, Sep. 1992, *D.S. Attili* obtained from Colleção de Culturas Tropical as CCT 3035, (UAMH 8911, =IMI 145114). JAPAN: soil, 1989, *T. Ito 1726-7*, obtained from Institute for Fermentation Osaka as IFO 32272, (UAMH 8843). NEW ZEALAND: ex nail, female 35 yr, *A. Woodgyer 94.600*, (UAMH 7892). UNITED STATES: NEW YORK: basidiomycete detritus in moisture chamber, *Preston Lowe, Hammill 210-72*, (UAMH 4094).

Cephalotrichum stemonitis (Persoon) Link : Fries. 1832. Systema Mycologicum 3: 280.
≡ *Cephalotrichum stemonitis* (Persoon) Link. 1809. Berlinische Magazin 3: 20.
≡ *Isaria stemonitis* Persoon. 1797. Commentarius Fungis Clavaeform. p 234. Type: holotype L; epitype culture selected UAMH 1532!
≡ *Periconia stemonitis* (Persoon) Persoon. 1801. Synopsis Methodica Fungorum p 687.

≡ *Stysanus stemonitis* (Persoon) Corda. 1837. Icones Fungorum 1: 22.

≡ *Doratomyces stemonitis* (Persoon) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 70.

= *Doratomyces neesii* Corda. 1829. in Sturm, Deutschlands Flora, III (Pilze) 2: 65.

Synanamorph:

Echinobotryum atrum Corda. 1831. in Sturm, Deutschlands Flora, III (Pilze) 3: 51.

≡ *Dematium echinobotryum* Fries. 1829. Systema Mycologicum 3: 87.

(for additional synonyms see Hughes 1958; Morton and Smith 1963)

FIGS. 6.54-6.59.

Distinguishing features. Synnemata typically 400-2000 µm, lacking appendages, annellides ampuliform, conidia ellipsoidal to ovoidal, apices often bluntly pointed, smooth, 6.5-8 x 4.5-5 µm, commonly 7 x 4.5 µm, colonies dark brown to gray brown, moderately slow growing (25-40 mm in 14 d @ 25 C). *Echinobotryum* synanamorph present, single conidia in clusters produced from branching conidiophore, conidia darkly pigmented, subfusoidal and typically beaked at apex, coarsely warted, 13-16 x 6.5-7.5 µm.

The *Echinobotryum* synanamorph is diagnostic. It is produced throughout the mycelium of the colony and along the stipes of the *Cephalotrichum* synnemata. Morton and Smith (1963) report some isolates which produce abundant *Echinobotryum* conidia without synnemata, but all isolates examined here produced the *Cephalotrichum* state (optimally on OAT). No isolates are known which lack the *Echinobotryum* state. If such isolates exist, they may be confused with *C. purpureofuscum*, although the conidia of *C. stemonitis* are slightly larger on average (7 x 4.5 µm vs. 6 x 3.5 µm) and are frequently bluntly pointed (rather than rounded) at the apex. Some isolates (e.g., UAMH 8624, 8914) exhibit a reduced *Echinobotryum* state, with sparsely roughened, bluntly pointed (not beaked) conidia.

Taxonomic notes. The holomorph of this species consists of two asexual stages. It is the type species for both *Cephalotrichum* and *Echinobotryum*, and, therefore, has two valid binomials. The combination of these two synanamorphs is distinctive, yet surprisingly, this common species was described on several occasions during the 1800's (see synonymy list in Morton and Smith 1963). Also, the name has been applied to other taxa (e.g., *Stysanus stemonites* of Sopp 1912 represents *Cephalotrichum nanum*). Part of the confusion may be explained by the frequent presence of only one state on the natural substratum or lack of recognition that the two states were linked, during the period before growing hyphomycetes in culture was routine.

Specimens examined. CANADA: ALBERTA: Slave Lake. coyote (*Canis latrans*) dung, Sep. 1983, *L. Sigler*, (UAMH 4834); Girouxville. indoor air of honeybee (*Apis mellifera*) overwintering facility, 30 Jan. 1994, *S.P. Abbott OHS 182*, (UAMH 7754); Fish Lake near Nordegg. cone of white spruce (*Picea glauca*), 14 Jun. 1996, *S.P. Abbott SA-M135*, (UAMH 8623); North Buck Lake near Lac La Biche. sandy soil with hair at entrance of woodchuck (*Marmota monax*) burrow in jack pine (*Pinus banksiana*) forest, 16 Aug. 1996, *S.P. Abbott SA-M138*, (UAMH 8624); Elk Island National Park. extremely

well decayed wood of white spruce (*Picea glauca*) log, 15 Apr. 1996, *T. Lumley EI-02-S6H*, (UAMH 9142). ONTARIO: near Guelph. soil of elm (*Ulmus americanus*) woods, 11 Dec. 1961, *G.L. Barron 9504*, obtained from United States Department of Agriculture as *Echinobotryum atrum* NRRL A-11326, (UAMH 8913); *G.L. Barron 9503* (UAMH 1532). ICELAND: agricultural soil, 26 Oct. 1966, *NRRL isolate ss-831*, obtained from United States Department of Agriculture as *Echinobotryum* sp. NRRL A-14847, (UAMH 8914). UNITED STATES: CALIFORNIA: Fallbrook. rat dung, 09 Aug. 1960, *G.F. Orr O-714*, obtained from United States Department of Agriculture as *Echinobotryum* sp. NRRL A-10079, (UAMH 8502).

Excluded Taxon

Doratomyces eichhorniae Conway & Kimbrough. 1975. Mycotaxon 2:128.
≡ *Doratomyces eichhornius* Conway & Kimbrough. 1975. Mycotaxon 2: 128. (orthographic variant).
Type: holotype FLAS; ex-type culture UAMH 9288 (=ATCC 28418)!

Distinguishing features. characterized in culture by lack of distinct synnemata, elongate acerose conidiogenous cells with gradually tapered apex, conidiogenesis described as annellidic (Conway and Kimbrough 1975), but in this study no annellations were observed on the conidiophores by light microscopy or SEM, conidia narrowly ellipsoidal, subhyaline, ornamented, verruculose by light microscopy and with a pronounced irregular roughening over the surface by SEM, colonies brown with white mycelial tufts, producing copious dark brown exudate and diffusing pigment.

Taxonomic notes. Known only from the type collection (Conway and Kimbrough 1975), this species is clearly unrelated to the dry-spored synnematous Microascaceae. Incongruous features include morphological characters such as conidium ornamentation and conidiogenous cell shape, developmental features associated with conidiogenesis and production of copious exudate and pigment in the colonies (especially on PDA). No alternative genus is currently available that is appropriate for transfer of this species. The ex-type culture produces only a limited number of conidia on poorly developed coremial structures. Optimal sporulation was seen on V-8 juice agar (Miller 1955) and no true synnemata were observed on any media. Further work is required to clarify the mode of conidiogenesis and morphological details of the synnemata before a new genus can be erected to accommodate this unusual species.

Specimens examined. UNITED STATES: FLORIDA: Lake Alice, Gainesville. decaying laminae of water hyacinth (*Eichhornia crassipes*), Feb. 1974, *F.W. Zettler WH 47*, obtained from American Type Culture Collection as *Doratomyces eichhornius* ATCC 28418, (UAMH 9288, =FLAS F 50399) (ex-type of *Doratomyces eichhorniae*).

Figures 6.1-6.6. ***Cephalotrichum columnaris.***

Fig. 6.1. Colony on OAT 21 d at 25 C (UAMH 9281), bar = 15 mm.

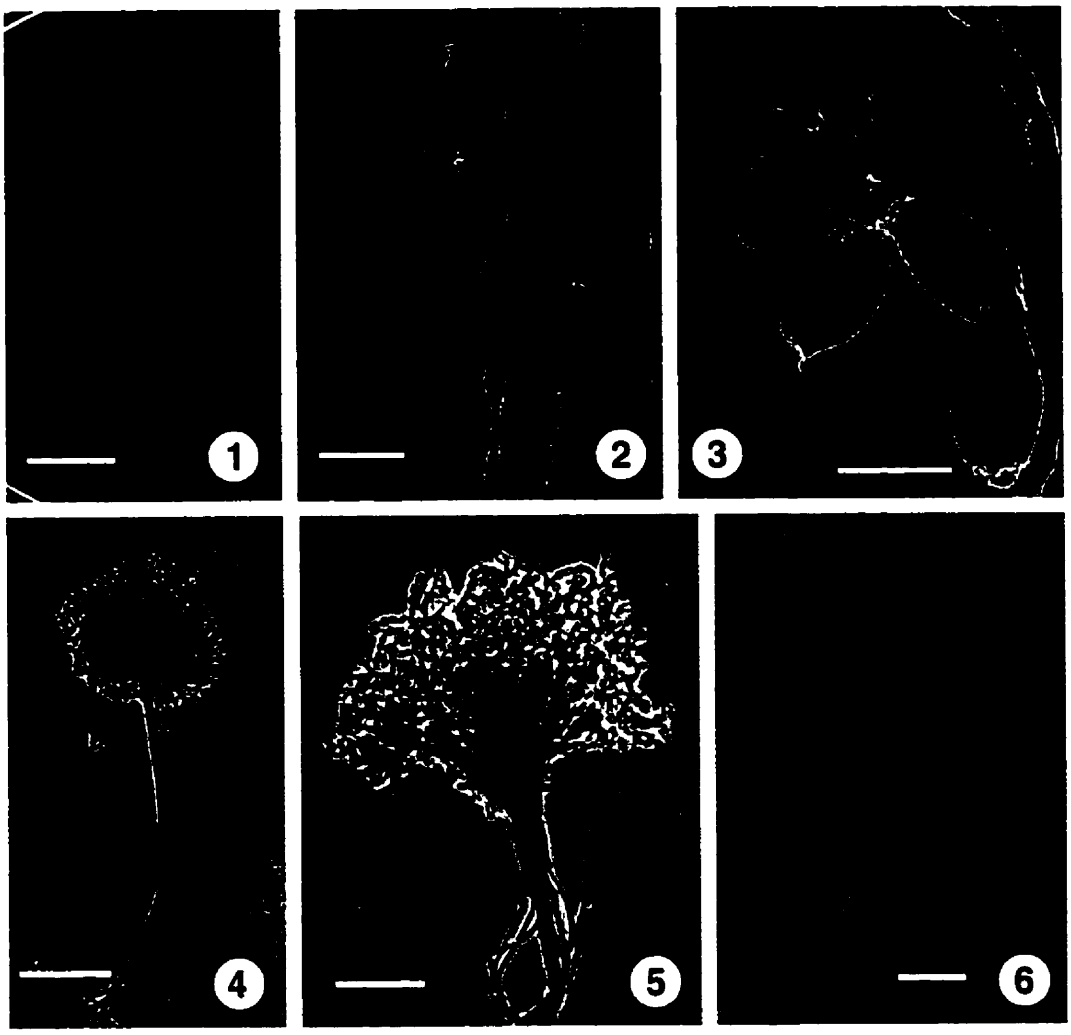
Fig. 6.2. Annellides and conidia (UAMH 9281), SEM, bar = 3 µm.

Fig. 6.3. Ellipsoid, slightly asymmetrical conidia (UAMH 9281), SEM, bar = 3 µm.

Fig. 6.4. Synnema (UAMH 8042), bar = 100 µm.

Fig. 6.5. Synnema (UAMH 8042), bar = 10 µm.

Fig. 6.6. Synnema apex (UAMH 8042), bar = 15 µm.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Figures 6.7-6.12. ***Cephalotrichum cylindricum.***

Fig. 6.7. Colony on PDA 21 d at 25 C (UAMH 9141), bar = 10 mm.

Fig. 6.8. Ellipsoidal conidia (UAMH 8976), bar = 5 µm.

Fig. 6.9. Synnema apex, showing dichotomously branched appendages (UAMH 8976), bar = 10 µm.

Fig. 6.10. Synnema, showing seta-like appendages (UAMH 1348), bar = 50 µm.

Fig. 6.11. Synnemata, showing seta-like appendages (UAMH 9141), SEM, bar = 50 µm.

Fig. 6.12. Conidia (UAMH 9141), SEM, bar = 4 µm.


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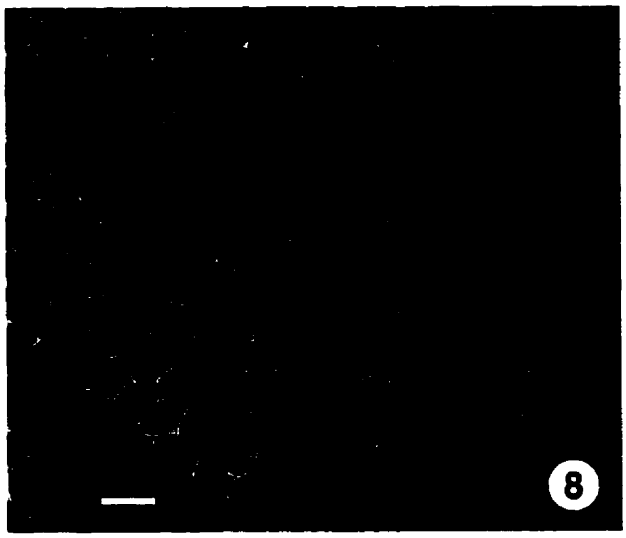
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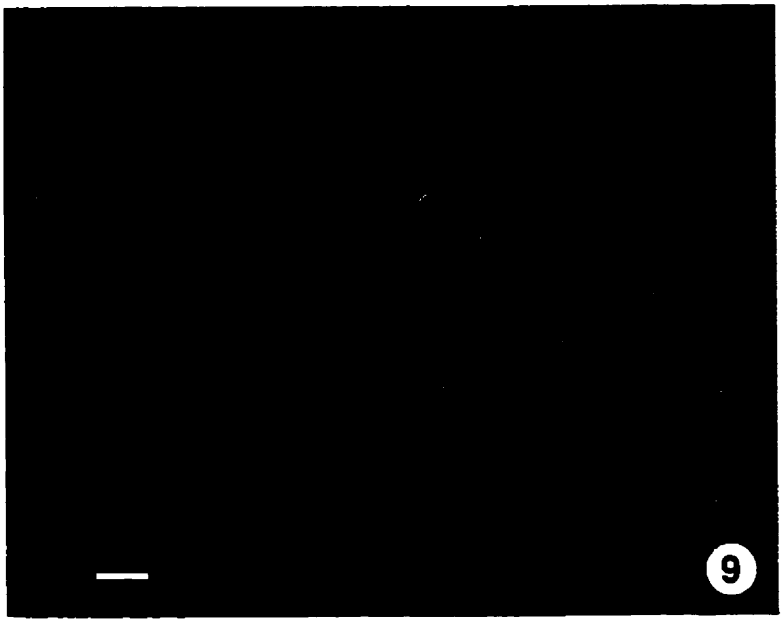
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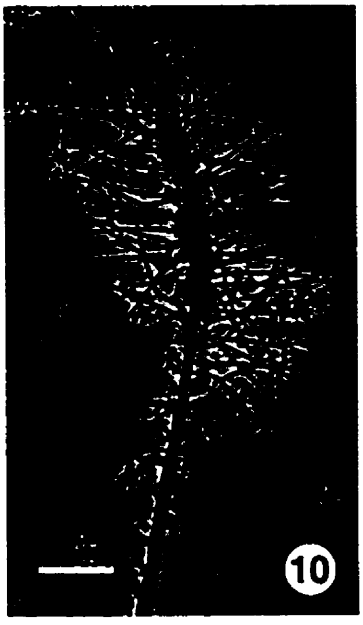
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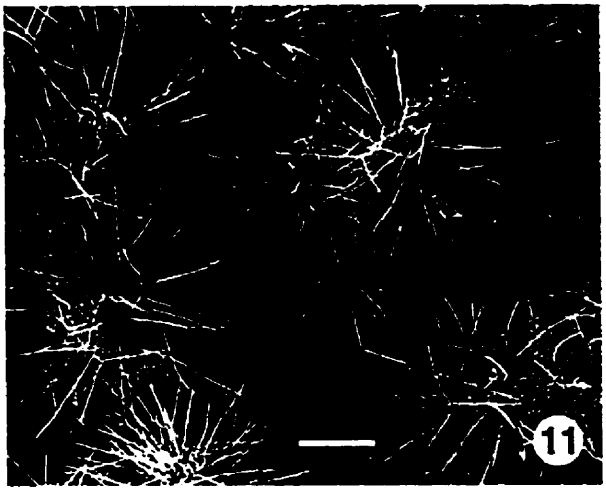
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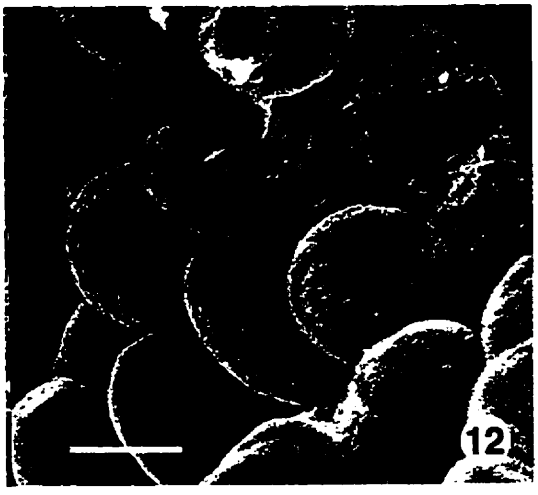
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Figures 6.13-6.20. ***Cephalotrichum dendrocephalum.***

Fig. 6.13. Synnema, showing undulate appendages (UAMH 5372), SEM, bar = 50 μm.

Fig. 6.14. Synnema apex, showing conidiophores and undulate, branched appendages (UAMH 5372), SEM, bar = 25 μm.

Fig. 6.15. Undulate, dichotomously branched appendages and conidia (UAMH 5372), SEM, bar = 8 μm.

Fig. 6.16. Conidia (UAMH 5372), SEM, bar = 2 μm.

Fig. 6.17. Synnemata apex (from above), showing undulate, branched appendages (UAMH 5372), SEM, bar = 50 μm.

Fig. 6.18. Broadly ellipsoidal to ovoidal conidia (UAMH 1383), bar = 5 μm.

Fig. 6.19. Synnema apex, showing branched appendages (UAMH 1383), bar = 50 μm.

Fig. 6.20. Synnemata, showing undulate appendages (UAMH 5372), bar = 100 μm.


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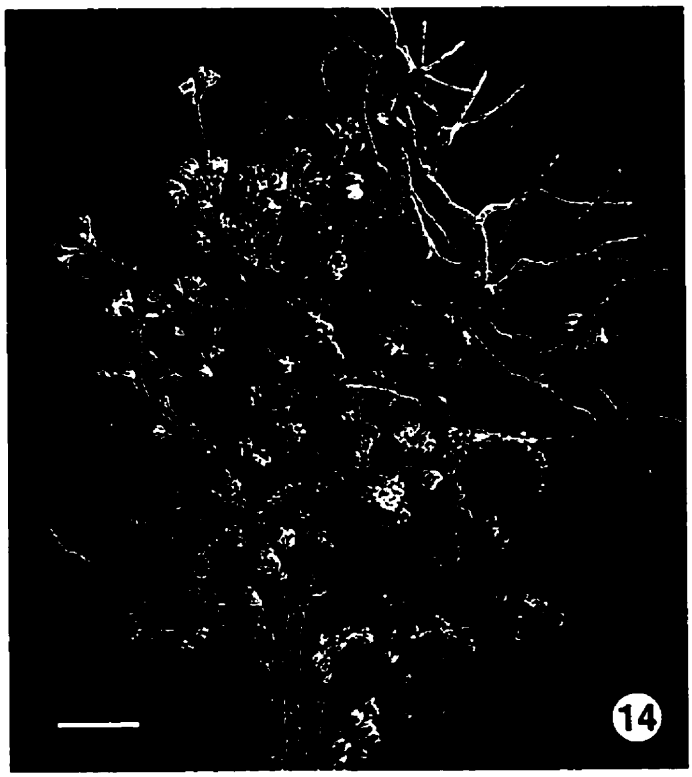
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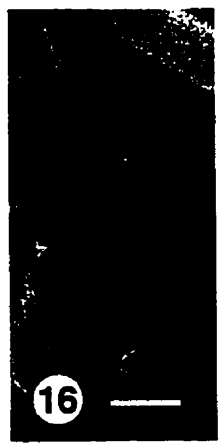
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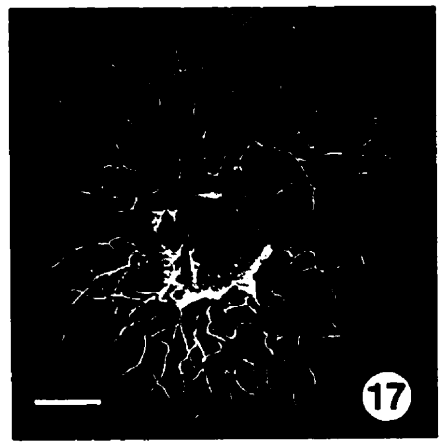
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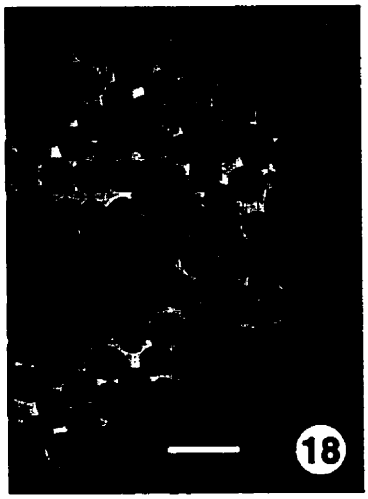
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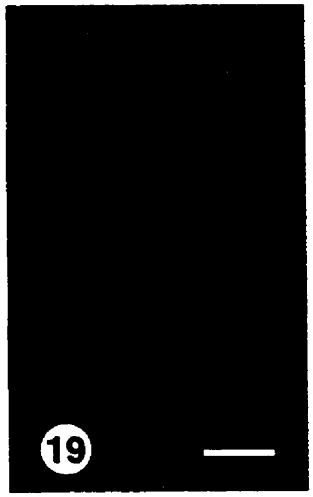
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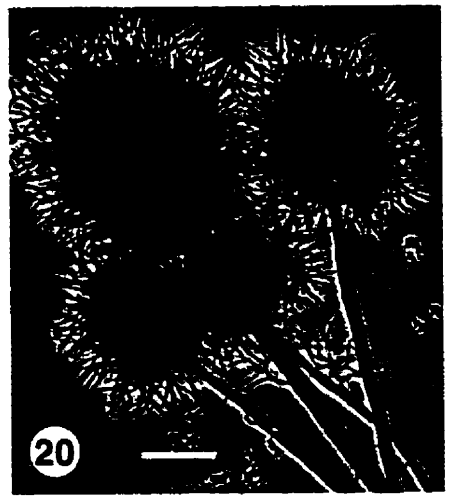
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Figures 6.21-6.31. ***Cephalotrichum microsporum*** **and** ***C. nanum.***

Fig. 6.21. Synnema (UAMH 9365), SEM, bar = 25 µm.

Fig. 6.22. Chains of conidia (UAMH 9365), SEM, bar = 5 µm.

Fig. 6.23. Non-synnematous conidiophore, showing annellides and conidia (UAMH 9365), SEM, bar = 5 µm.

Fig. 6.24. Synnema (UAMH 9456), bar = 100 µm.

Fig. 6.25. Bullet-shaped conidia (UAMH 9456), bar = 10 µm.

Fig. 6.26. Non-synnematous conidiophore, showing annellides and conidia (UAMH 8486), bar = 10 µm.

Fig. 6.27. Coarsely ornamented, broadly ellipsoidal conidia (UAMH 8854), bar = 10 µm.

Fig. 6.28. Coarsely ornamented conidia (UAMH 8854), bar = 10 µm.

Fig. 6.29. Synnema (UAMH 9126), SEM, bar = 50 µm.

Fig. 6.30. Synnema apex, showing annellides and conidia (UAMH 9126), SEM, bar = 5 µm.

Fig. 6.31. Coarsely ornamented conidia (UAMH 9126), SEM, bar = 5 µm.


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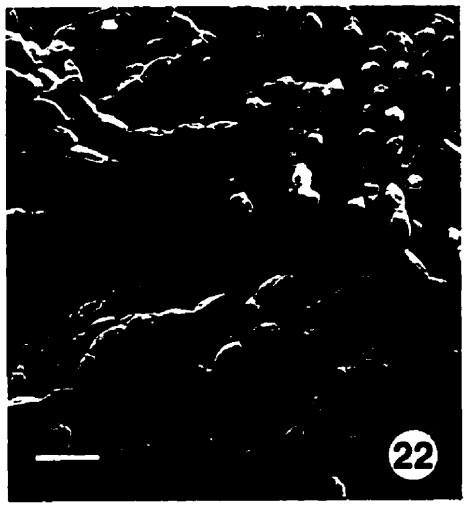
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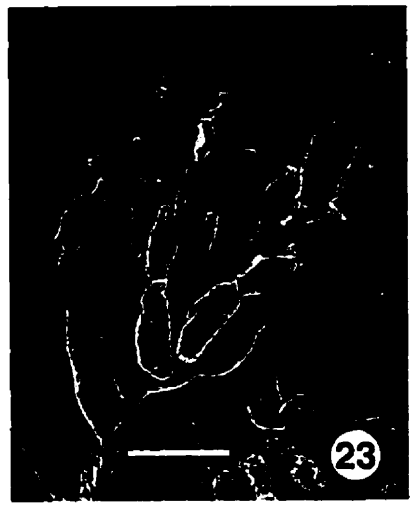
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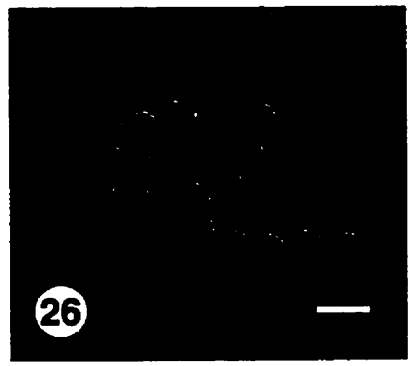
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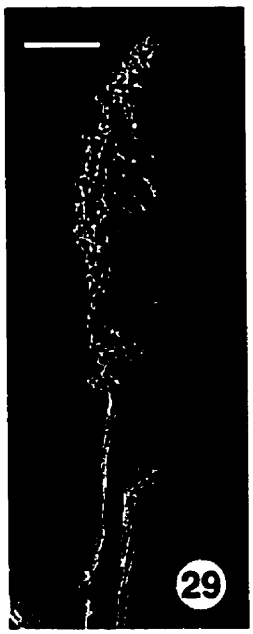
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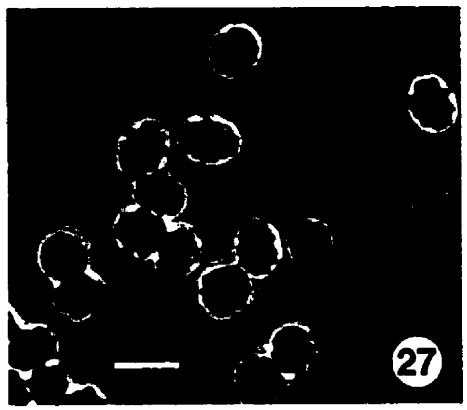
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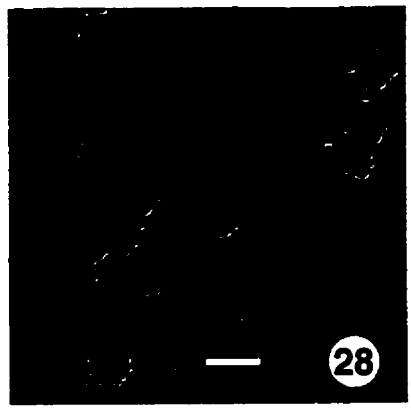
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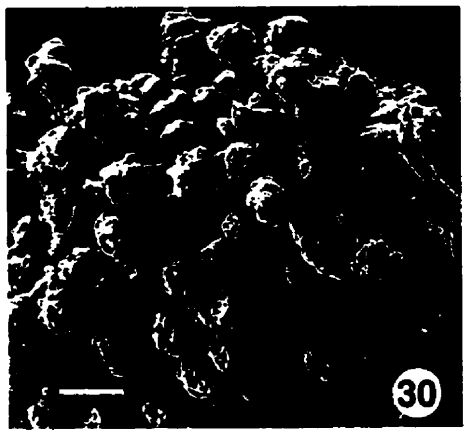
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Figures 6.32-6.38. ***Cephalotrichum purpureofuscum.***

Fig. 6.32. Colony on OAT 21 d at 25 C (UAMH 8739), bar = 15 mm.

Fig. 6.33. Ellipsoidal conidia with rounded apices (UAMH 8739), bar = 10 µm.

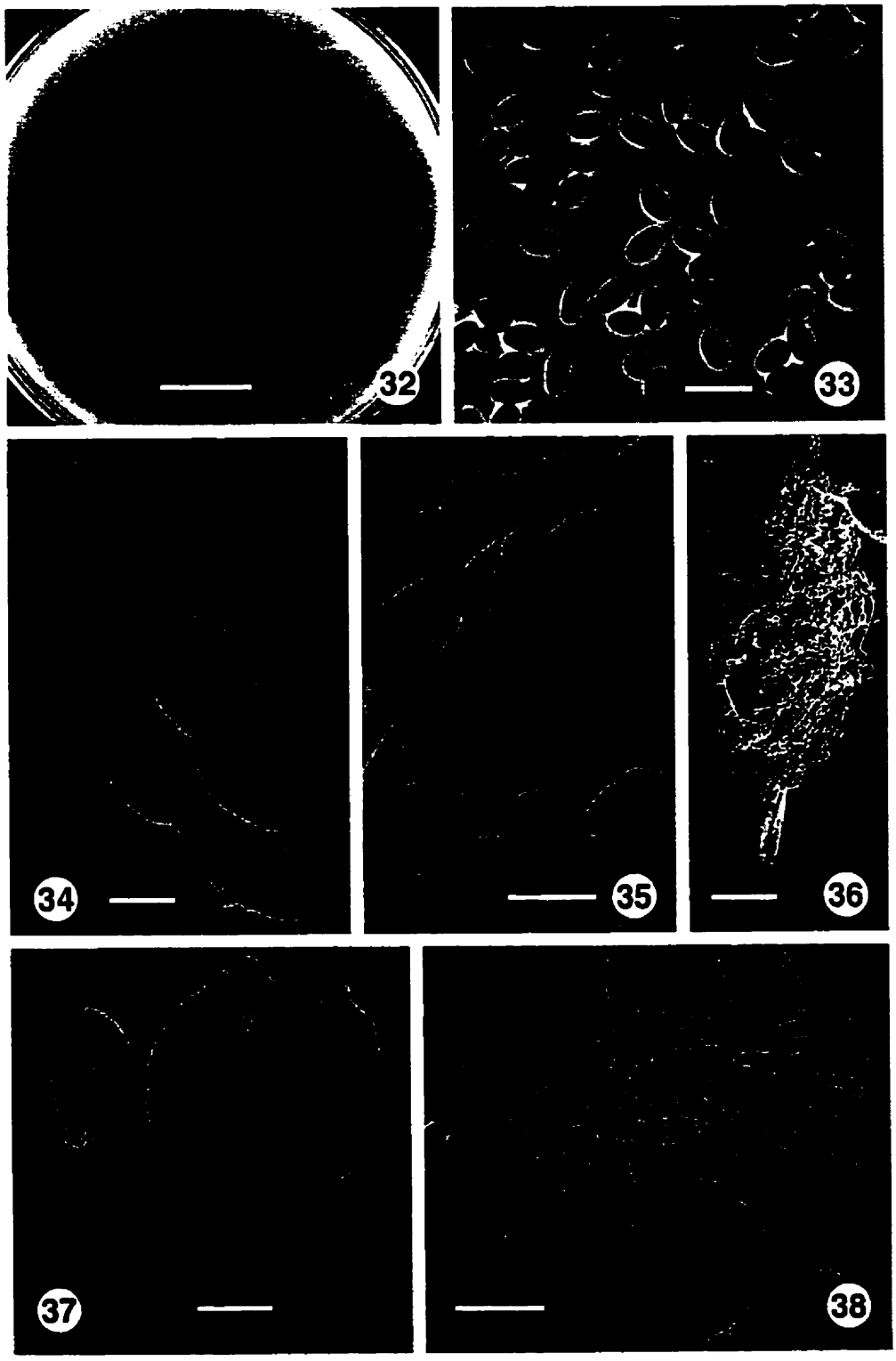
Fig. 6.34. Chains of conidia (UAMH 8910), SEM, bar = 2 µm.

Fig. 6.35. Conidia, note slightly roughened surface (UAMH 8910), SEM, bar = 5 µm.

Fig. 6.36. Synnema (UAMH 8910), SEM, bar = 50 µm.

Fig. 6.37. Annellides and slightly roughened conidia (UAMH 9127, ex-type of *Doratomyces asperulus*), SEM, bar = 2 µm.

Fig. 6.38. Synnemata x-section, showing conidiophores, annellides and conidia (UAMH 9127), SEM, bar = 10 µm.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Figures 6.39-6.46. ***Cephalotrichum putredinus.***

Fig. 6.39. Colony on PDA 21 d at 25 C (UAMH 1290), bar = 10 mm.

Fig. 6.40. Ellipsoidal conidia with rounded apices (UAMH 1321), bar = 6 µm.

Fig. 6.41. Non-synnematous conidiophore (UAMH 8891), bar = 10 µm.

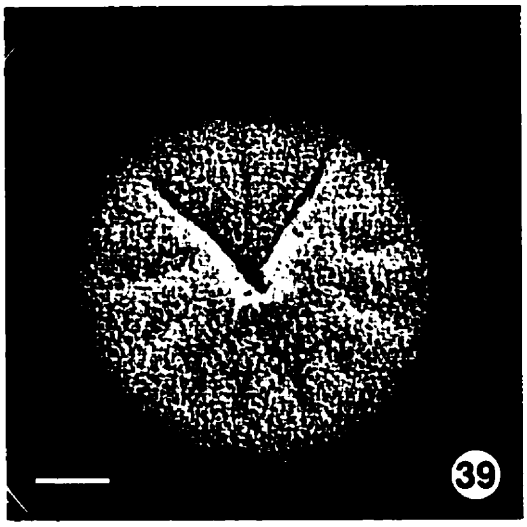
Fig. 6.42. Coremium covered with chains of conidia (UAMH 9028), SEM, bar = 15 µm.

Fig. 6.43. Synnema (UAMH 1332), bar = 25 µm.

Fig. 6.44. Chains of conidia (UAMH 9028), SEM, bar = 5 µm.

Fig. 6.45. Conidia (UAMH 9028), SEM, bar = 2 µm.

Fig. 6.46. Synnemata and conidia, after Corda (1839).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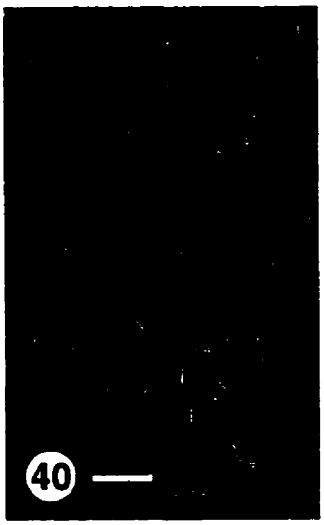
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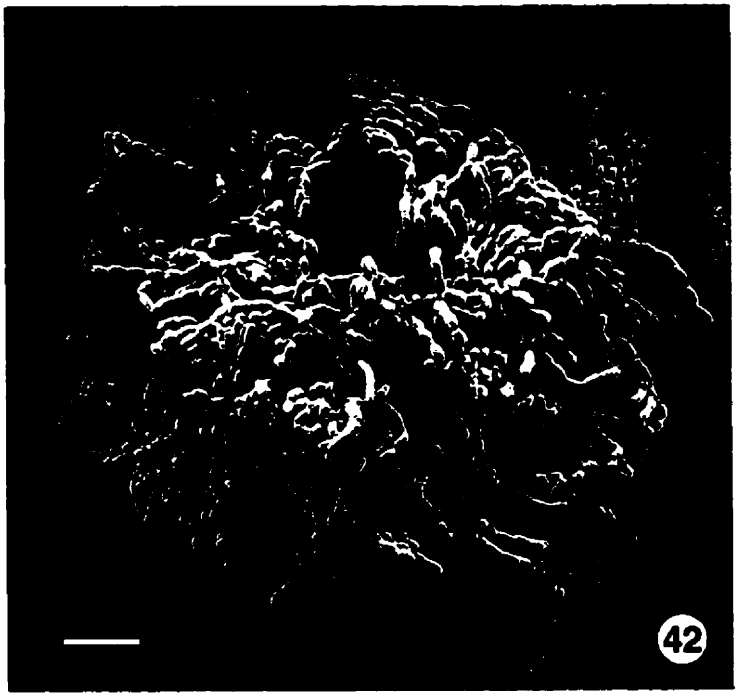
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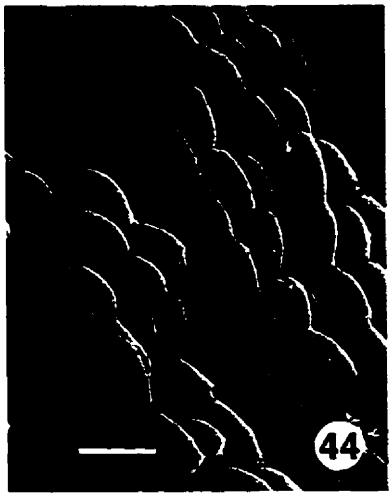
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Figures 6.47-6.53. ***Cephalotrichum spiralis.***

Fig. 6.47. Colony on PDA 21 d at 25 C (UAMH 3585), bar = 15 mm.

Fig. 6.48. Synnema, showing flexuous and loosely coiled, unbranched appendages (UAMH 3585), SEM, bar = 25 µm.

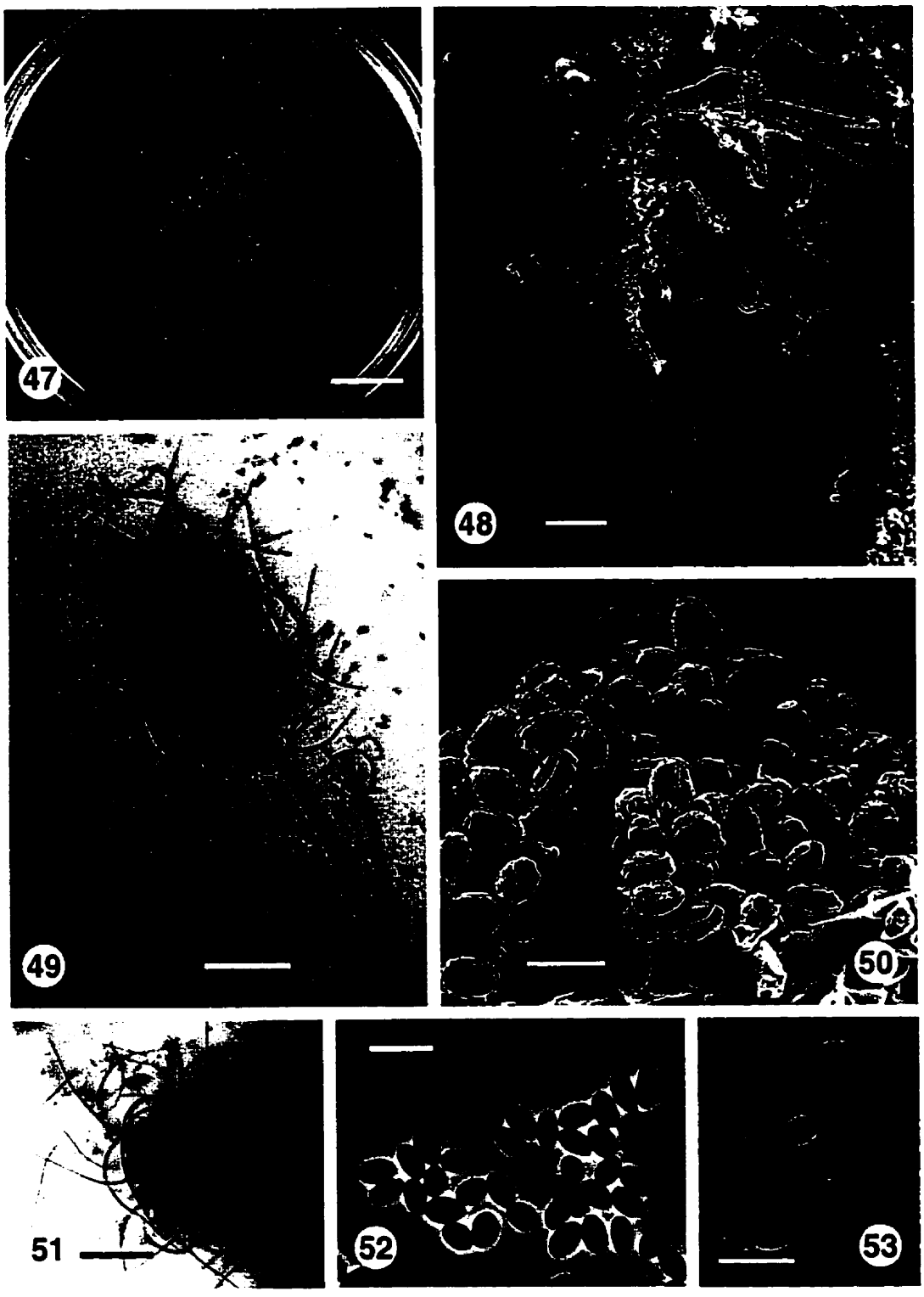
Fig. 6.49. Synnema, showing curved and loosely coiled appendages (UAMH 8689), bar = 75 µm.

Fig. 6.50. Ellipsoidal conidia (UAMH 9405), SEM, bar = 15 µm.

Fig. 6.51. Loosely coiled, unbranched appendages (UAMH 8911), bar = 50 µm.

Fig. 6.52. Broadly ellipsoidal conidia (UAMH 8911), bar = 10 µm.

Fig. 6.53. Ampuliform annellides (UAMH 9405), SEM, bar = 4 µm.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Figures 6.54-6.59. *Cephalotrichum stemonitis.*

Fig. 6.54. Conidiophore with ampuliform annellides (UAMH 8914), SEM, bar = 2 µm.

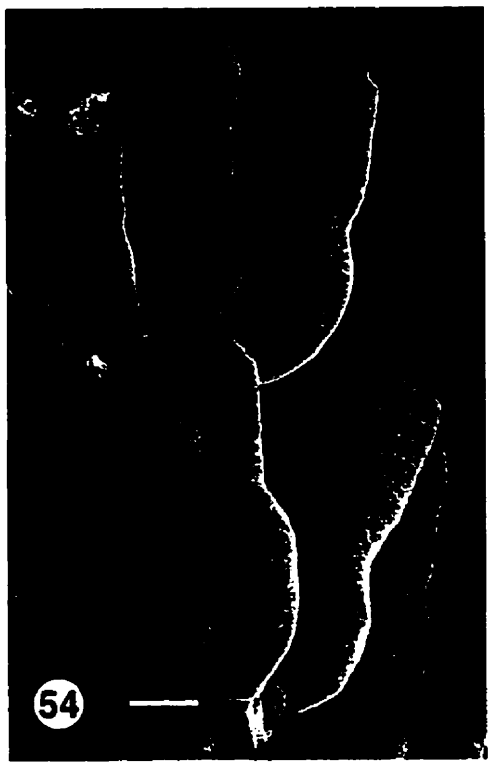
Fig. 6.55. Synanamorphs, showing cluster of ornamented, beaked *Echinobotryum* conidia and chains of ellipsoidal *Cephalotrichum* conidia (UAMH 8623), bar = 10 µm.

Fig. 6.56. Conidia, note pointed apices (UAMH 8914), bar = 7 µm.

Fig. 6.57. Chains of conidia (UAMH 1532), SEM, bar = 4 µm.

Fig. 6.58. Synnemata (UAMH 1532), SEM, bar = 50 µm.

Fig. 6.59. Cluster of ornamented, beaked *Echinobotryum* conidia along synnema stipe (UAMH 1532), SEM, bar = 10 µm.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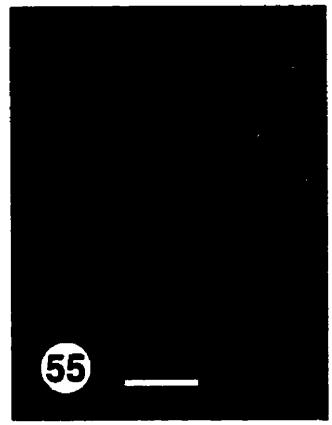
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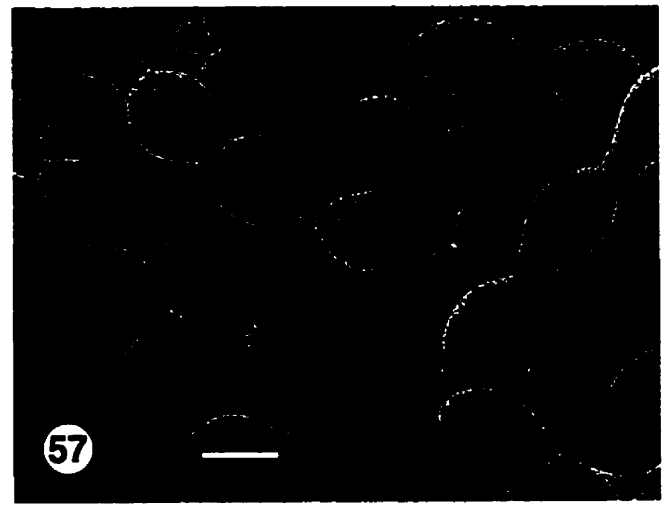
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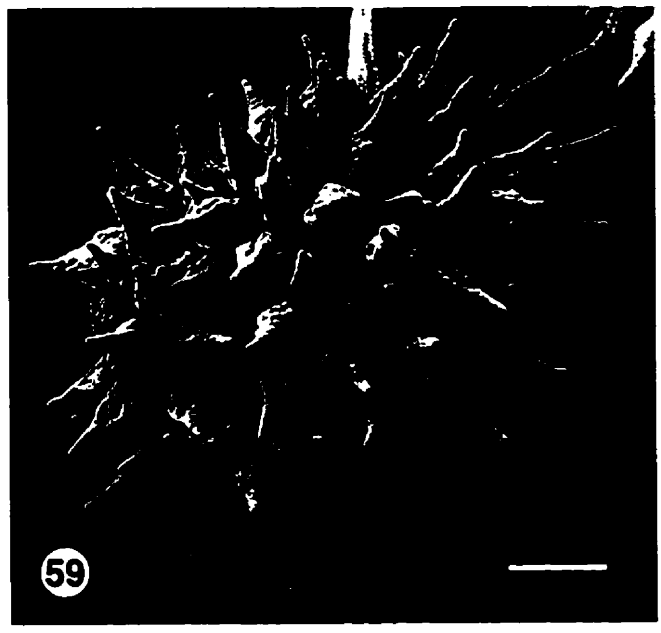
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CHAPTER 7

INTEGRATION OF ANAMORPH AND TELEOMORPH TAXA INTO A MONOPHYLETIC MICROASCACEAE SUPPORTED BY MOLECULAR AND PHYSIOLOGICAL CHARACTERS

Introduction

The Microascaceae are saprobic perithecial and cleistothecial ascomycetes, united by single-celled, smooth, orange to red brown, dextrinoid ascospores and ovoid, evanescent asci irregularly disposed throughout the central cavity (Luttrell 1951; Malloch 1970). Many species have associated asexual states (anamorphs) which produce conidia from annellidic conidiogenous cells. Connections between the anamorphic genus *Scopulariopsis* and teleomorphic states of *Microascus* were first recognized by growth in pure culture (Emmons and Dodge 1931; Barron et al. 1961b; Morton and Smith 1963), and recognition of pleomorphism (the production of different states by a single species) has allowed for a better understanding of the holomorph species concept in the Microascaceae. Abbott et al. (1998a) discovered the teleomorph for the type species of *Scopulariopsis*, *S. brevicaulis* (Sacc.) Bainier, confirming the relatedness of *Scopulariopsis* and *Microascus*. Links between other strictly anamorphic genera (placed with other molds in the form-class Hyphomycetes under the broad category of Fungi Imperfecti) and the Microascaceae have been inferred by similarity of conidiogenesis. Conidiogenesis is still of primary importance in classification and allows for phylogenetic inferences among the hyphomycetes (e.g., Hughes 1953; Campbell and Smith 1982; Valmaseda et al. 1987; Mouton et al. 1993).

The family comprises six genera (e.g., Malloch 1970; Barr 1990), although some authors include additional genera (e.g., Arx et al. 1988; Eriksson and Hawksworth 1998). Approximately 45 species are placed in these six genera, and an additional eight anamorphic genera containing about 50 species show sufficient morphological similarity to infer relationship to the family. Teleomorphic genera currently assigned to the Microascaceae include *Microascus*, *Kernia*, *Petriella*, *Pseudallescheria*, *Pithoascus*, and *Lophotrichus* (Barr 1990), distinguished primarily on characters of ascomata type (i.e., perithecium or cleistothecium) and ascospore morphology (size, shape and coloration). Other teleomorphic taxa with uncertain relations have been allied to the Microascaceae, including *Canariomyces*, *Emilmuelleria*, *Enterocarpus*, *Faurelina*, *Leuconeurospora*, *Pithoascina*, *Halosphaeriopsis*, and *Chaetomium* (Locquin-Linard 1977; Arx et al. 1984, 1988; Valmaseda et al. 1987; Spatafora and Blackwell 1994), but many have been excluded from the Microascaceae based on morphological or molecular evidence (e.g., Malloch and Sigler 1988; Lee and Hanlin 1999; Suh and Blackwell 1999). Affiliated anamorphic taxa include *Scopulariopsis*, *Cephalotrichum*, *Trichurus*, *Wardomyces*, *Wardomycopsis*, *Echinobotryum*, *Scedosporium*, and *Graphium* (e.g., Carmichael et al. 1980; Barr 1990). Current distinction between anamorphic genera is based on conidiophore structure (i.e., simple conidiophores versus compound structures formed by

aggregations of conidiophores into synnemata) or conidium morphology and development (i.e., conidia in dry chains, slimy masses, or solitary).

Recent phylogenetic analyses using DNA sequence comparisons (e.g., Berbee and Taylor 1992; Hausner et al. 1993b; Spatafora and Blackwell 1994; Issakainen et al. 1997; Lee and Hanlin 1999) have supported the Microascaceae as a distinct group, but are based on few taxa. Two families, the Microascaceae and Ophiostomataceae, were classified together in the Microascales (e.g., Luttrell 1951; Barr 1990), but the relationships among taxa assigned to these families has been questioned based on morphological, developmental and physiological differences. The Ophiostomataceae, as traditionally delimited, were shown to be polyphyletic. *Ophiostoma* and *Ceratocystis* were separated primarily on the basis of anamorph conidiogenesis (*Sporothrix* and *Pesotum* anamorphs in *Ophiostoma* versus *Chalara* anamorph in *Ceratocystis*). Also, cycloheximide tolerance in *Ophiostoma* versus sensitivity in *Ceratocystis* provided a simple diagnostic test to separate the taxa (Harrington 1981). Recent DNA sequence analyses have supported placement of the Ceratocystidaceae (formerly included within the Ophiostomataceae sensu lato) in the Microascales, while the Ophiostomataceae *sensu stricto* occupies an isolated phylogenetic position as the sole member of the Ophiostomatales (Hausner et al. 1993a, b; Spatafora and Blackwell 1994; Cassar and Blackwell 1996). Teleomorphs and anamorphs of some taxa in the Microascales and Ophiostomatales possess long necked, black perithecia, deliquescent asci, ascospores extruded in sticky masses, synnematous anamorphs with sticky conidia, and annellidic conidiogenesis. Morphological similarities are interpreted as convergent evolution for insect dispersal (Arx et al. 1984; Spatafora and Blackwell 1994). Preliminary screening for benomyl tolerance among a few representatives demonstrated a uniform tolerance in the Microascaceae and sensitivity in the Ophiostomataceae (Summerbell 1993), suggesting another physiological test with potential to distinguish these morphologically similar taxa.

Two additional families have been proposed within the Microascales. The genus *Pithoascus* was placed in the monotypic family, Pithoascaceae (Benny and Kimbrough 1980; Arx et al. 1988), but was synonymized with *Microascus* (Abbott unpublished, see Chapter 4) based on morphological evidence. It has not been included in previous molecular analyses. *Lophotrichus* was also placed in its own family, the Lophotrichaceae (Seth 1970), but evidence from DNA sequence analysis supports its inclusion within the Microascaceae (Lee and Hanlin 1999). The teleomorphic genera *Microascus, Petriella, Pseudallescheria, Lophotrichus* and *Kernia* form a clade representing the Microascaceae based on molecular analyses (Berbee and Taylor 1992; Spatafora and Blackwell 1994; Lee and Hanlin 1999).

Only two anamorphic microascaceous taxa (*Scedosporium* and *Graphium*) have been included in DNA sequence analyses (LeClerc et al. 1994; Issakainen et al. 1997; Okada et al. 1998). In other groups of ascomycetes, sequence analyses have demonstrated the possibility of integrating anamorphic taxa into a phylogenetic framework (e.g., Bowman and Taylor 1993; LeClerc et al. 1994; Pan et al. 1994; Glenn et al. 1996; Messner et al. 1996; Hambleton et al. 1998).

The DNA sequence analyses that included taxa of Microascaceae have examined relatively few taxa and these frequently did not include the type species of the various genera, making broader implications of monophyly for the family difficult. In order to test the monophyly of the family and to place the genera in a phylogenetic outline, the type species of teleomorph and anamorph genera of the Microascaceae were analyzed. DNA amplification by polymerase chain reaction (PCR) from living cultures allowed for sequence analysis of the nuclear encoded small subunit (18S) rDNA. This region contained phylogenetically informative sites in other closely related taxa (e.g., Spatafora and Blackwell 1994; Cassar and Blackwell 1996) and was appropriate to test the above hypothesis. Physiological data of tolerance to antifungal compounds was correlated with molecular data to provide support for a monophyletic Microascaceae.

Materials and Methods

Molecular.— The 34 taxa sampled for this study were chosen based on their position in past and contemporary classifications and possession of particular morphological characters. Ten were newly sequenced, while sequences of the remainder were selected from previous studies (Berbee and Taylor 1992; Wilmotte et al. 1993; Melchers et al. 1994; Spatafora and Blackwell 1994; Issakainen et al. 1997; Okada et al. 1998; Suh and Blackwell 1999) and obtained from GenBank. Where possible, the culture, from which the deposited sequence was derived, was examined to confirm the identity by morphology. Type species of the genera were chosen where possible to allow a valid discussion of the relationships between genera. Fungal isolates used in this study are listed in Table 7.1. The aligned sequence matrix is provided in Appendix 2.

Isolates were grown on oatmeal salts agar (Weitzman and Silva-Hutner 1967) for 14 to 35 days. Mycelium, conidia, and/or ascomata with ascospores were scraped from the agar surface and air dried. Approximately 5 mg of dried tissue was used for extraction of total DNA using the methodology employed in Gardes and Bruns (1993) and Kernaghan et al. (1997). Total DNA was cleaned using the Ultrafree-MC filter unit (Cetus Corp.) before amplification by polymerase chain reaction (PCR) using the amplification procedures of Hambleton et al. (1998) with primers NS1 and NS4 (White et al. 1990). PCR products were purified with the Wizard PCR Preps DNA Purification System (Promega Corp., Madison, WI) following the manufacturer's instructions prior to sequencing and sequenced directly using the Thermosequenase II Kit (Amersham Pharmacia Biotech, Baie d'Urfe, PQ). Electrophoresis of the resulting products was done on an ABI 373A automatic DNA sequencer (Perkin-Elmer: Applied Biosystems, Foster, CA) following protocols suggested by the manufacturer. Sequences of complementary strands were determined for all isolates using the primers NS1, NS2, NS3, and NS4 (White et al. 1990).

Consensus sequences were determined using Sequencher v. 3.1 (Gene Codes Corp., Ann Arbor, MI) and were aligned by hand. The aligned data matrix was analyzed and trees were generated with the PAUP (Phylogenetic Analysis Using Parsimony) v.

4.0b2 to distinguish possible phylogenetic relationships among isolates (Swofford 1998). Heuristic searches were performed and trees were obtained by simple-stepwise addition and branch swapping with tree bisection reconnection algorithm. Support for the inferred clades was estimated by calculating bootstrap confidence levels from 100 replicates (Felsenstein 1985). *Emericella nidulans* and *Saccharomyces cerevisiae* were chosen as outgroup taxa because of their systematic position in prior sequence analyses (e.g. Berbee and Taylor 1992; Melchers et al. 1994).

Physiological.— Over 250 isolates comprising 55 taxa of Microascaceae and 20 extrafamilial taxa (Table 7.2; see Apendix 1 for strain data) were tested for tolerance to fungal inhibitors. Tolerance was determined by comparing colony diameters on potato dextrose agar (PDA; Difco, Detroit, MI) with those on PDA supplemented with 2 µg/mL benomyl and on mycosel agar containing cycloheximide at 400 µg/mL (MYC; Becton Dickinson Microbiology Systems, Cockeysville, MD) at 25 C after 7 and 14 d following the methodology of Abbott et al. (1998a). Ten isolates of Microascaceae were randomly chosen and also tested on media supplemented with 10 µg/mL benomyl. For cycloheximide tolerance tests, colony diam. on MYC of greater than 50% that of unamended PDA diam. was considered tolerant, and for benomyl, tolerance was determined by colony diam. greater than 90% that of the unamended medium.

Results

The rDNA data matrix consists of 1019 bp/strain of sequence from the region amplified by the primers NS1/NS4 and corresponds to the 5' two-thirds of the small subunit (18S) rDNA molecule. This region was shown to contain a greater number of synapomorphies than the 3' end in similar taxa (Spatafora and Blackwell 1996). In the data set, 697 characters were constant, 182 were variable but parsimony-uninformative, and 140 were parsimony-informative; thus 14% of the region was phylogenetically informative. Phylogenetic analysis of this region for 34 taxa resulted in a single most parsimonious tree of 604 steps (Fig. 7.1). Bootstrap values are superimposed on branches with greater than 50% support.

Two clades, corresponding to the Microascales and Microascaceae, are strongly supported by molecular analyses with bootstrap values of 100 and 83 respectively (Fig. 7.1). At the ordinal level, a clade contains the Microascaceae, Halosphaeriaceae, Ceratocystidaceae and *Graphium penicillioides* (=Microascales clade). The type species of each teleomorph and anamorph genus assigned to the Microascaceae form a distinct clade (=Micrascaceae clade).

Three primary clades are delimited within the Microascaceae. The first (=*Microascus* clade) has strong bootstrap support (93%) and contains five species of *Microascus*, including *M. nidicola* the type of *Pithoascus*. It also includes the type species of the anamorph genera *Scopulariopsis* (holomorph *Microascus brevicaulis*), *Wardomyces*, *Cephalotrichum*, *Trichurus* (=*Cephalotrichum cylindricum*), and *Echinobotryum* (synanamorph of *Cephalotrichum stemonitis*). The second clade

(=*Petriella* clade) contains *Petriella* and *Pseudallescheria*, along with species of *Scedosporium* and some species of *Graphium*, but excluding the type *G. penicillioides* which forms an independent clade within the Microascales. The third clade (=*Kernia* clade) contains *Kernia* and *Lophotrichus*. Bootstrap values for the *Petriella* (61%) and *Kernia* (64%) clades were lower than the *Microascus* clade (93%). One species with aberrant morphology, *Scopulariopsis parva*, is not included in the Microascales clade.

Tolerance to benomyl and cycloheximide is compiled for 76 species (Table 7.2; see Appendix 1 for list of strains). Members of the Microascaceae were essentially uninhibited by benomyl (colony diameters ± 5% of control). All were benomyl tolerant at 2 μg/mL, and the 10 strains tested at 10 μg/mL were equally tolerant at the higher concentration. Tolerance to cycloheximide varied between and within taxa, but patterns of tolerance and sensitivity were discernable at the species and genus level (see Discussion).

Discussion

The Microascaceae were first considered a separate taxonomic entity by Luttrell (1951) based on developmental features of ascus formation within the centrum, and Malloch's (1970) circumscription has been accepted in modern classifications (e.g., Barr 1990, Eriksson and Hawksworth 1998). The teleomorph taxa assigned to the Microascaceae by Malloch (1970) and Barr (1990) (*Microascus*, *Pithoascus*, *Petriella*, *Pseudallescheria*, *Kernia*, and *Lophotrichus*) are shown here to form a monophyletic group based on sequence analysis of type and additional species, supporting this family concept (Fig. 7.1).

The Pithoascaceae were separated by Benny and Kimbrough (1980), based on the lack of germ pores on ascospores of species in the genus *Pithoascus* (Arx 1973), but this separation has not been widely adopted (e.g., Eriksson and Hawksworth 1998). Abbott (unpublished, see Chapter 4) provides morphological evidence for the synonymy of *Pithoascus* with *Microascus*. In the present study, *Microascus nidicola*, the type species of *Pithoascus*, falls within the clade containing the type of *Microascus*, *M. longirostris*, and several other species (Fig. 7.1), supporting this synonymy and the traditional concept of *Microascus* delimited by Barron et al. (1961b).

The separation of *Petriella* from *Microascus* was proposed by Curzi (1930). Several authors (e.g., Cain and Weresub 1957; Morton and Smith 1963) have questioned this separation, arguing that the primary character used in the original diagnosis, the presence of ascomatal hairs, is of questionable taxonomic value, but Barron et al. (1961a) provided additional characters to support the generic distinction. They separated *Petriella* by larger, more darkly pigmented ascospores, *Graphium* anamorph state and rapid growth in culture. The two taxa appear in separate clades within the Microascaceae by molecular analysis in this (Fig. 7.1) and other studies (Issakainen et al. 1997; Lee and Hanlin 1999), supporting the retention of two genera.

Lophotrichus was originally included in the Chaetomiaceae (Benjamin 1949; Ames

1963) based primarily on the well developed ascomatal hairs. Whiteside (1962) questioned this placement based on developmental characters and Seth (1970) recognized that the genus had affinities to the Microascales and errected a new family, the Lophotrichaceae. DNA sequence analysis of two species, *L. plumbescens* and *L. indicus* supported an affinity to the Microascaceae (Lee and Hanlin 1999). The inclusion of the type species, *L. ampullus*, in this study definitively links *Lophotrichus* to the Microascaceae (Fig. 7.1). Morphological and molecular evidence do not support retention of a separate family for this taxon.

Kernia and *Lophotrichus* are distinguished primarily by non-ostiolate versus ostiolate ascomata. However, some species exhibit intermediate ascomata type, producing frequently non-ostiolate ascomata that only occasionally form rudimentary ostioles. Overlap occurs also in other characters used to define the genera, including morphology of ascospores and ascomatal hairs. Two species, *Kernia bartlettii* and *K. macrospora*, have been transferred to *Lophotrichus* (Malloch and Cain 1971; Arx et al. 1988). The DNA sequence data of Lee and Hanlin (1999) and that provided here supports the close relationship between the two genera, although bootstrap support for the clade was relatively low. Further investigations incorporating a greater number of taxa are required to clearly define relationships within the *Kernia* clade.

The genus *Enterocarpus* was placed in the Microascaceae by Locquin-Linard (1977) and is tentatively accepted by Eriksson and Hawksworth (1998). The type species, *E. uniporus*, was unavailable for cultural studies, but the original description suggests a strong similarity to *Lophotrichus* and *Kernia*. A second species, *E. grenotii*, has been synonymized with *Lophotrichus bartlettii* (Arx et al. 1988). Further investigations are required to assess the distinction of *Enterocarpus* from similar genera and determine the relationship of *E. uniporus* to other members of the *Kernia* clade.

Integration of anamorphic taxa into the phylogenetic framework of the Microascaceae was a primary goal of this study. Although anamorphs have been known for some teleomorph species for many years (e.g., Sopp 1912; Curzi 1930, 1931; Emmons and Dodge 1931), the connection of strictly asexual species to the Microascaceae has been tentatively based on similarity in morphology and development of the conidia. This DNA sequence analysis shows that the type species of the anamorph genera *Scopulariopsis* (holomorph *Microascus brevicaulis*), *Cephalotrichum*, *Trichurus* (=*Cephalotrichum cylindricum*), *Echinobotryum* (synanamorph *Cephalotrichum stemonitis*), *Wardomyces*, and *Scedosporium* (holomorph *Pseudallescheria boydii*) nest within the Microascaceae clade (Fig. 7.1).

Scopulariopsis states are known for many species of *Microascus* and *Kernia* (Barron et al. 1961b; Morton and Smith 1963; Malloch and Cain 1971), and the type of *Scopulariopsis*, *S. brevicaulis*, was shown to have a *Microascus* teleomorph (Abbott et al. 1998a). Species with *Scopulariopsis* states included in this analysis are *Microascus brevicaulis*, *M. cirrosus*, *M. trigonosporus*, *M. longirostris*, and *Kernia nitida*, as well as the *Scopulariopsis* synanamorphs of *Cephalotrichum stemonitis* and *C. cylindricum*. One

morphologically aberrant species, *Scopulariopsis parva*, was included to test the supposition that it is unrelated to the type and other typical members of *Scopulariopsis*. As suggested by Abbott et al. (1998a), the form-genus *Scopulariopsis* should be restricted to anamorphs of Microascaceae.

Cephalotrichum is a synnematous hyphomycete genus showing a definite connection to *Scopulariopsis* based on the similarity of annellidic conidiogenesis (Hammill 1971, 1972). *Trichurus* was originally separated based on sterile appendages on the synnemata, but Abbott (unpublished, see Chapter 6) suggested that the criteria are insufficient to maintain separate genera and synonymized *Trichurus* with *Cephalotrichum*. The close placement of the type species of *Cephalotrichum* and *Trichurus* with the types of *Microascus* and *Scopulariopsis* in the *Microascus* clade supports the close relationship and synonymy.

Echinobotryum is a monotypic anamorph genus, and *E. atrum* is the synanamorph of the type species of *Cephalotrichum*, *C. stemonitis*. Conidiogenesis in *Echinobotryum* and *Wardomyces* is similar, but *Echinobotryum* is separated by the coarsely ornamented, beaked conidia that lack germ slits. Although the type species of *Wardomyces*, *W. anomalus*, has no known teleomorph or synanamorph, a *Wardomyces* state is described for one species of *Microascus*, *M. giganteus* (Malloch 1970). Several other species of *Wardomyces* (*W. columbinus*, *W. ovalis*, *W. simplex*) have *Scopulariopsis* synanamorphs. The inclusion of *Wardomyces anomalus* in the *Microascus* clade by DNA sequence analysis (Fig. 7.1) supports the relationships inferred through morphology.

Wardomycopsis was not included in this analysis because cultures of the type species, *W. inopinatus*, were unavailable. The anamorph genus was described by Udagawa and Furuya (1978) along with its teleomorph, *Microascus inopinatus*. Two other species were included in *Wardomycopsis*, the *Wardomycopsis* state of *Microascus singularis* and *W. humicola* (Udagawa and Furuya 1978). The form-genus shares characters with both *Scopulariopsis* and *Wardomyces*, forming chains of darkly pigmented conidia with germ slits. Considering the placement of other species of *Microascus*, *Scopulariopsis* and *Wardomyces*, it seems probable that members of this anamorphic genus also belong within the *Microascus* clade.

Although several species of *Graphium* (including *G. tectonae*, *G. cuneiferum*, and the anamorphs of *Pseudallescheria boydii*, *P. ellipsoidea*, *Petriella sordida* and *P. setifera*) are within the Microascaceae clade, the type species (*G. penicillioides*) falls outside the family, but within the Microascales clade (Fig. 7.1), as was demonstrated by Okada et al. (1998). Since this indicates a reasonably close relationship and there are few morphological features upon which the two groups could be separated, the form-genus *Graphium* is accepted for anamorphs of Microascales. Okada et al. (1998) separate these taxa from the morphologically similar but unrelated synnematous anamorphs of *Ophiostoma* (Ophiostomataceae, Ophiostomatales) which they place in *Pesotum*. The Microascaceae were sister group to *G. penicillioides* in Okada et al. (1998), but species of Ceratocystidaceae were not included. Sampling a greater number of taxa from the

Ceratocystidiaceae may further elucidate the familial placement of *G. penicillioides*.

The type species of *Scedosporium*, *S. apiospermum*, is the anamorph of *Pseudallescheria boydii* (Malloch 1970; Guého and Hoog 1991). In this study, teleomorph species with *Scedosporium* anamorphs include *Pseudallescheria boydii*, *P. ellipsoidea*, *Petriella sordida*, and *P. setifera*. Additionally, *Scedosporium prolificans* and the *Scedosporium* synanamorphs of *Graphium cuneiferum*, *G. tectonae* and *G. penicillioides*, which have no known teleomorph were included. These taxa cluster together in the *Petriella* clade, except *G. penicillioides* which is placed within the Microascales but outside the Microascaceae. *Scedosporium* is defined by annellidic conidiogenesis, although often conidiophores are reduced and few conidia are produced on each conidiogenous cell (Hironaga and Watanabe 1980; Campbell and Smith 1982). Sympodial conidiogenesis was observed in some species of *Petriella* and the anamorph referred to *Sporothrix* or *Sporotrichum* (e.g., Barron et al. 1961a). These form-genera are typified by species unrelated to the Microascaceae and are inappropriate for the microascaceous taxa. The distinction between annellidic and sympodial conidiogenesis has been reevaluated in a number of other form-genera and has resulted in a broadening of generic concepts to include both types of conidiogenesis (e.g., Tsuneda and Hiratsuka 1984; Wingfield 1985; Seifert and Okada 1993). Placement of *Pseudallescheria boydii* within the Microascaceae was demonstrated by small subunit rDNA sequence analysis (Berbee and Taylor 1992; Hausner et al. 1993b). *P. boydii* also groups together with other species of *Scedosporium* in a clade based on large and small subunit rDNA sequence analyses (LeClerc et al. 1994; Issakainen et al. 1997). Okada et al. (1998) report the presence of a *Scedosporium*-like synanamorph in some strains of *Graphium penicillioides*, observed here in one strain (UAMH 8494). A broad morphological concept of *Scedosporium* is supported here for this group of microascaceous anamorphs, and is consistent with that defined for *Graphium*.

Lee and Hanlin (1999) suggest that *Microascus* appears basal to the remainder of the family, but this study does not support their finding. The inclusion of more taxa results in a tree in which the *Microascus* clade is sister to the *Petriella/Kernia* clade (Fig. 7.1). In some additional analyses (data not shown), the *Petriella/Kernia* branch collapsed to a trichotomy, consisting of the *Microascus*, *Petriella* and *Kernia* clades, while in others the *Petriella* clade was sister to a *Kernia/Microascus* clade. *Microascus* did not appear basal in any variations of the analyses.

The sister group to the Microascaceae in this analysis is the Halosphaeriaceae. The Halosphaeriaceae are aquatic, primarily marine, ascomycetes and include a large number of taxa (Kohlmeyer 1972; Jones 1995). Relationships within the family are unclear and it is likely that similarity of morphology is a convergent feature with the family as currently circumscribed being polyphyletic (Jones 1995). Spatafora and Blackwell (1996) show that *Halosphaeriopsis* (based on the type species *H. mediosetigera*) forms a clade with the Microascaceae, and nests within the family in some analyses. Suh and Blackwell (1999) show that the Halosphaeriaceae (including *Halosphaeria appendiculata* and *Halosarpheia fibrosa*) is sister to the Microascaceae based on large subunit rDNA data. The

Microascales clade defined in the present analysis is well supported by bootrap value of 100% (Fig. 7.1) and contains three families: the Microascaceae, Halosphaeriaceae, and Ceratocystidaceae. Therefore, the Halosphaeriales (Jones 1995; Eriksson and Hawksworth 1998) is reduced to synonymy with Microascales. The Halosphaeriaceae (typified by *Halosphaeria appendicuata*) can be placed within the Microascales, but the appropriate disposition of genera and species is still required.

The Hypocreales appear to be the sister taxon to Microascales, supporting previous findings (Berbee and Taylor 1992; Wilmotte et al. 1993; Spatafora and Blackwell 1996; Okada et al. 1998; Suh and Blackwell 1999). All molecular evidence suggests that the morphological similarity between the anamorphs and teleomorphs of the Microascaceae and the Ophiostomataceae is a result of convergent evolution (Spatafora and Blackwell 1996), rather than an indication of relationship as previously supposed (Luttrell 1951; Barr 1990).

Benomyl tolerance is demonstrated to be a unifying feature of the Microascaceae (Table 7.2). Although other groups of ascomycetes are known to be benomyl tolerant, especially yeasts and loculoascomycetes with dematiaceous anamorphs (e.g., Summerbell 1993), this feature provides a clear means of delimiting the Microascaceae from others in the Microascales and from morphologically similar taxa in other orders, including the Ophiostomatales and Sordariales. Benomyl tolerance has evolved independently in several ascomycete lineages, but is a synapomorphy of the Microascaceae. By this means, a large number of taxa could be tested, and their relationship to the Microascaceae supported. Within the teleomorph or anamorph genera currently assigned to the Microascaceae by molecular analysis (Fig. 7.1), 55 species demonstrated benomyl tolerance (Table 7.2).

Extrafamilial taxa included in the Microascales (*Graphium penicillioides*, *Halosphaeria*, *Halosphaeriopsis*) were sensitive to benomyl with the exception of *Sphaeronaemella fimicola*. The relationship of *Sphaeronaemella* to *Ceratocystis* and *Microascus* was first suggested by Cain and Weresub (1957) based on morphology. *S. fimicola* forms a clade with *Ceratocystis* in Spatafora and Blackwell (1996), although bootstrap values for the Microascales clade were substantially higher with the exclusion of *S. fimicola* from their data set. For these reasons, and since conspecificity with the type species, *S. helvellae*, has not been conclusively demonstrated, *Sphaeronaemella* was excluded from molecular analyses in this study. The few representative taxa selected from other pyrenomycete orders, including the Sordariales, Ophiostomatales, and Xylariales, were uniformly sensitive to benomyl, exhibiting no growth at 2 μg/mL (Table 7.2).

Although many taxa were tolerant to cycloheximide, tolerance was less uniform throughout the family than benomyl tolerance (Table 7.2)(Hoog et al. 1994; April et al. 1998). Tolerance varied within genera, and occasionally among strains of a species (Table 7.2). Some generalizations can be made if we superimpose the cycloheximide test results onto the phylogram generated by molecular data. The species in the *Microascus* clade, containing *Microascus*, *Cephalotrichum*, *Wardomyces* and *Scopulariopsis*, generally demonstrated tolerance, although a few exceptions were seen. The *Petriella* clade showed

considerable variability between taxa and among strains, while the clade composed of *Lophotrichus* and *Kernia* species was predominantly sensitive to cycloheximide.

Other teleomorph genera suggested as possible relatives of the Microascaceae were not included within the family clade. Several taxa, including *Pidoplitchkoviella*, *Leuconeurospora* and *Chaetomium* were linked by Arx et al. (1984, 1988) based on dextrinoid immature ascospores, but appear distantly related (Fig. 7.1)(Lee and Hanlin 1999; Suh and Blackwell 1999). *Chaetomium*, *Pidoplitchkoviella*, *Emilmuelleria*, and *Faurelina* are benomyl sensitive, supporting their exclusion from the Microascaceae (Table 7.2).

Two species of *Scopulariopsis* with aberrant morphology were included in this study with the suspicion that they may be unrelated. The slow growing, white colonies and small (2.5-3 μm), globose conidia of *S. parva* were unique in the family. From sequence data, the type strain appears distantly related to the Microascaceae, and closest to *Leuconeurospora* among the taxa included in this analysis. *Leuconeurospora* was shown to belong with the Pseudeurotiaceae, outside the pyrenomycetes clade, in the molecular analyses of Suh and Blackwell (1999). *S. parva* was benomyl tolerant, and this physiological test did not provide a diagnostic character in this case. Benomyl sensitivity was useful in supporting the distant relationship of another morphologically aberrant species, *Scopulariopsis canadensis* (Abbott et al. 1998b). Detailed morphological examination and further molecular analyses including a greater number of taxa are required to determine the appropriate disposition of these species and to confirm the relatedness among species placed within the genera of Microascaceae accepted here.

Table 7.1. Source of fungal isolates and sequences used for 18S rDNA sequence analysis.

Name	Strain data	GenBank[a] number	Reference
Cephalotrichum cylindricum (= *Trichurus cylindricus*)	CBS[b] 646.70 (=UAMH[c] 9141)		this study
Cephalotrichum stemonitis (syn. *Echinobotryum atrum*)	UAMH 8623		this study
Ceratocystis fimbriata	not examined	U43777	Issakainen et al. 1997
Chaetomium globosum	not examined	U20379	Spatafora & Blackwell 1994
Daldinia concentrica	not examined	U32402	Spatafora & Blackwell 1994
Emericella nidulans	not examined	X78539	Melchers et al. 1994
Graphium penicillioides (A)	JCM 9331 (=UAMH 8495)	AB007682	Okada et al. 1998
Graphium penicillioides (B)	JCM 9300 (=UAMH 8494)	AB007653	Okada et al. 1998
Graphium cuneiferum (as *G. putredinus*)	JCM 7866 (=UAMH 8496)	AB007683	Okada et al. 1998
Graphium tectonae	CBS 127.84 (=UAMH 9401)[T]	U43907	Issakainen et al. 1997
Halosphaeria appendiculata	CBS 197.60 (=UAMH 9398)	U46872	GenBank
Halosphaeriopsis mediosetigera	CBS 245.62 (=UAMH 9399)	U32420	Spatafora & Blackwell 1994
Hypocrea schweinitzii	not examined	L36986	Spatafora & Blackwell 1994
Kernia nitida	UAMH 8396		this study
Leuconeurospora pulcherrima	CBS 343.76 (=UAMH 9397)	AF096178	Suh & Blackwell 1999
Lophotrichus ampullus	NRRL 2742[d] (=UAMH 9123)		this study
Melanospora zamiae	not examined	U78356	Wilmotte et al. 1993
Microascus brevicaulis (an. *Scopulariopsis brevicaulis*)	IMI[e] 49528 (=UAMH 644)		this study
Microascus cirrosus	NRRL 1689 (=UAMH 963)	M89994	Berbee & Taylor 1992
Microascus longirostris	NRRL 1717 (=UAMH 9329)		this study
Microascus nidicola (= *Pithoascus nidicola*)	NRRL A6894 (=UAMH 8979)[T]		this study
Microascus trigonosporus	not examined	L36987	Spatafora & Blackwell 1994
Nectria cinnabarina	not examined	U32412	Spatafora & Blackwell 1994
Ophiostoma ulmi	not examined	M83261	Berbee & Taylor 1992
Petriella setifera	not examined	U43908	Issakainen et al. 1997

Petriella sordida	DAOM[f] 162159 (=UAMH 8695)		this study
Pidoplitchkoviella terricola	CBS 180.77 (=UAMH 9395)[T]	AF096181	Suh & Blackwell 1999
Pseudallescheria boydii (an. *Scedosporium apiospermum*)	UAMH 4304	M89782	Berbee & Taylor 1992
Pseudallescheria ellipsoidea	CBS 418.73 (=UAMH 3987)[T]	U43911	Issakainen et al. 1997
Saccharomyces cerevisiae	not examined	J01353	Berbee & Taylor 1992
Scedosporium prolificans	CBS 467.74 (=UAMH 7149)[T]	U43909	Issakainen et al. 1997
Scopulariopsis parva	CBS 245.31 (=UAMH 9384)[T]		this study
Sordaria fimicola	not examined	X69851	Wilmotte et al. 1993
Wardomyces anomalus	UAMH 8275		this study

[a] GenBank accession number,
[b] University of Alberta Microfungus Collection and Herbarium, Edmonton, Alberta, Canada.
[c] Centraalbureau voor Schimmelcultures, Baarn, Netherlands.
[d] United States Department of Agriculture, Peoria, Illinois, USA.
[e] International Mycological Institute, Egham, Surrey, UK.
[f] Canadian Collection of Fungus Cultures, Ottawa, Ontario, Canada.
[T] Type strain.

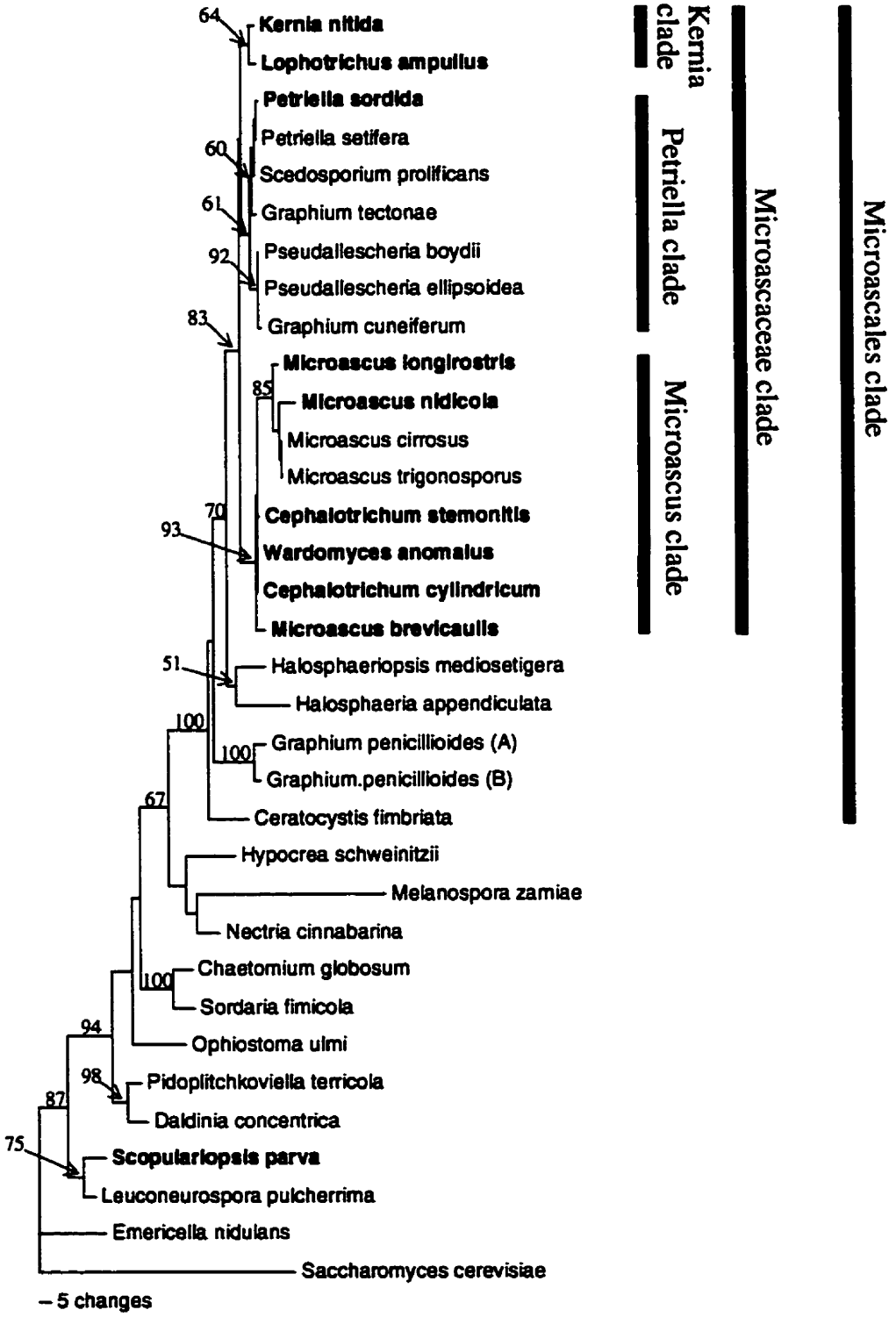
Table 7.2. Tolerance of species of Microascaceae and extrafamilial species to the antifungal compounds benomyl and cycloheximide. Results represent pooled data from all strains of the taxa tested. For cycloheximide tolerance, colony diam. on MYC of greater than 50% that of unamended PDA diam. was considered tolerant, and for benomyl, tolerance was determined by colony diam. greater than 90% that of the unamended medium.

Species	tolerance to benomyl (PDA amended with 2 µg/mL)	tolerance to cycloheximide (MYC containing 400 µg/mL)
MICROASCACEAE		
Cephalotrichum columnaris	+[a]	V[b]
Cephalotrichum cylindricum	+	+
Cephalotrichum dendrocephalum	+	NT[c]
Cephalotrichum nanum	+	+
Cephalotrichum purpureofuscum	+	+
Cephalotrichum putredinus	+	–[d]
Cephalotrichum spiralis	+	+
Cephalotrichum stemonitis	+	+
Graphium cuneiferum	+	+
Graphium tectonae	+	NT
Kernia hippocrepida	+	NT
Kernia hyalina	+	NT
Kernia nitida	+	V
Kernia pachypleura	+	–
Kernia retardata	+	–
Lophotrichus ampullus	+	–
Lophotrichus bartlettii	+	–
Lophotrichus macrospora	+	NT
Lophotrichus martinii	+	–
Lophotrichus plumbescens	+	NT
Microascus albonigrescens	+	V
Microascus brevicaulis	+	+
Microascus cinereus	+	+
Microascus cirrosus	+	+
Microascus giganteus	+	NT
Microascus intermedius	+	+
Microascus longirostris	+	+
Microascus manginii	+	+
Microascus microcordiformis	+	+
Microascus niger	+	+
Microascus pyramidus	+	NT
Microascus schumacheri	+	NT
Microascus senegalensis	+	NT
Microascus singularis	+	+
Microascus soppii	+	+
Microascus trigonosporus	+	+
Petriella guttulata	+	–
Petriella setifera	+	–
Petriella sordida	+	V

Pseudallescheria boydii	+	+
Pseudallescheria ellipsoidea	+	+
Scedosporium prolificans	+	–
Scopulariopsis acremonium	+	V
Scopulariopsis brumptii	+	+
Scopulariopsis carbonaria	+	+
Scopulariopsis fimicola	+	–
Scopulariopsis sphaerospora	+	NT
Wardomyces aggregatus	+	NT
Wardomyces anomalus	+	+
Wardomyces humicola	+	+
Wardomyces inflatus	+	+
Wardomyces moseri	+	NT
Wardomyces pulvinatus	+	+
Wardomyces simplex	+	+
Wardomycopsis humicola	+	+
EXTRAFAMILIAL TAXA		
Ceratocystis coerulescens	–	–
Chaetomium atrobrunneum	–	–
Chaetomium globosum	–	–
Chaetomium strumarium	–	–
Daldinia grandis	–	–
Doratomyces eichhorniae	+	–
Emilmuelleria spirotricha	–	NT
Faurelina fimigena	–	NT
Graphium penicillioides	–	–
Halosphaeria appendiculata	–	NT
Halosphaeriopsis mediosetigera	–	NT
Leuconeurospora pulcherrima	+	NT
Ophiostoma clavigerum	–	+
Ophiostoma crassivaginata	–	+
Ophiostoma ips	–	+
Ophiostoma minus	–	+
Ophiostoma stenoceras	–	+
Pidoplitchkoviella terricola	–	NT
Scopulariopsis canadensis	–	–
Scopulariopsis parva	+	NT
Sphaeronaemella fimicola	+	–

[a] + indicates tolerance to the antifungal compound.
[b] V indicates variable tolerance/ sensitivity for the antifungal compound among isolates tested.
[c] NT indicates this species not tested for this compound.
[d] – indicates sensitivity to the antifungal compound.

Figure 7.1. Phylogram of single most parsimonious tree for 34 taxa from 1019 bp fragment of 18S rDNA. Numbers above the branches indicate the percentage of bootstrap samplings of branches with 50% or higher support, bar = 5 bp changes.



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CHAPTER 8

A CONTRIBUTION TO THE NATURAL HISTORY OF THE MICROASCACEAE IN ALBERTA[3]

Introduction

The Microascaceae are saprobic fungi, which are important agents of decay on cellulose and protein-rich substrata (soil, plant litter, wood, dung, animal remains)(Barron et al. 1961a, b; Morton and Smith 1963; Domsch et al. 1980; Malloch and Hubart 1987). The family includes both sexually reproducing species as well as affiliated asexual species (e.g., Abbott et al. 1998; see also Chapters 3-7). They are extremely common molds in human environments, but their occurrence and habitat in nature are not well understood. Many species are molds which grow in indoor environments (homes, warehouses and office buildings), or are frequently associated with agricultural areas (stored seeds, pasture and crop-field soils, straw, manure and compost) and degradation of man-made substrata (textiles, paper). Some species of Microascaceae are opportunistic human pathogens that rarely invade compromised hosts.

The main goal of this project was to survey a broad selection of substrata in Alberta to 1) determine species richness, 2) assess substratum specificity, and 3) compare the fungal flora from boreal regions with that seen in urban and rural areas. Since natural substrata have rarely been targeted for isolation of Microascaceae, this study allows the opportunity to test the hypothesis that species which are prevalent in indoor environments are also common in nature.

Materials and Methods

Samples.— Over 400 substrata samples including soil, wood, litter, dung and fungal or animal remains from boreal, montane and parkland regions were collected in Alberta between 1996 and 1998. Soil and litter samples were plated directly onto agar media, or alternatively, residual soil particles from sterile water dilutions were spread across the plates (see Warcup 1950). All other samples were surface-sterilized by brief flaming, and plated onto six different media. Information regarding isolation of fungi from the human environment was available from urban air samples, building materials, clinical specimens and agricultural substrata collected in Alberta. These and other comparative isolates are maintained at the University of Alberta Microfungus Collection and Herbarium

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[3]Part of the data presented in this chapter is submitted for publication in a substantially different form as:
Lumley, T.C., S.P. Abbott, and R.S. Currah. Microscopic ascomycetes isolated from rotting wood in the boreal forest. Mycotaxon (accepted December 1999).
A summary of the findings presented in this chapter are published as:
Abbott, S.P. 1999. Diversity of decay fungi in boreal habitats. The bio-diversity grants program biennial report 1998/99, University of Alberta, Edmonton. Pp. 3.

(UAMH) (Sigler and Flis 1998).

Media.— Selective isolation media were developed to facilitate the isolation of Microascaceae. Primary isolation media included Mycosel (MYC; Becton Dickinson Microbiology Systems, Cockeysville, MD), Nobles malt agar (NMA; Nobles 1965), tap water agar (TWA; 1.5% agar), cornmeal agar (CMA; Difco Laboratories, Detroit, MI), potato dextrose agar (PDA; Difco Laboratories, Detroit, MI), and dichloran 18% glycerol agar (DG18; Pitt and Hocking 1985). Each of these media, with the exception of MYC, were supplemented with 2 μg/mL benomyl to inhibit many fast-growing hyphomycetes. Tetracycline (100 μg/mL) was added to all media to inhibit the growth of bacteria, including actinomycetes. Oatmeal salts agar (OAT; Weitzman and Silva-Hutner 1967) was routinely used for optimal sporulation of axenic cultures. Cellulose azure agar (Thorn 1993) and cellophane membrane degradation (Carmichael 1962) were used to determine cellulolytic ability.

Isolation and identification.— Primary isolation plates were incubated at room temperature (20-24°C) and examined at four weeks and subsequently every 2-6 months for new growth over 1-2.5 years. Species determinations were made from axenic cultures obtained by subsequent transfers maintained on CMA or OAT. Microscopic mounts were prepared in polyvinyl alcohol or lactofuchsin mounting medium (Sigler 1992). Ascospores were observed in squash mount preparations, and the slide culture technique was employed using cereal agar (Sigler 1992) to allow observation of sporulating conidial stages. In order to conserve the biodiversity of Microascaceae in Alberta, representative isolates of all taxa were preserved by lophilization and cryopreservation and maintained in the UAMH (Sigler 1994).

Results

The Microascaceae were found to comprise a diverse component of the fungal flora with over 350 isolates (252 accessioned in UAMH) representing 33 species occurring in Alberta. Occurrence in primary habitat types and abundance of each species are summarized in Table 8.1 and complete collection details for Alberta isolates are provided in Appendix 1. Of the 33 species found in Alberta, 30 were found in, and 10 were restricted to, urban or rural areas. Three species, *Microascus albonigrescens*, *M. singularis* and *M. soppii*, were only found in relatively undisturbed sites in the boreal forest. The different substrata were not sampled equally, and the urban/rural category is not necessary mutually exclusive with species potentially counted in more than one category (i.e., also dung, soil, etc.). The abundance ranking and list of number of isolates deposited in the UAMH provide a crude measure of relative frequency of occurrence of the Microascaceae species. Fourteen species were recovered from soil, 19 from wood, 6 from plant litter, and 14 from dung. Some species were abundant on a wide variety of substrata (e.g., *Cephalotrichum stemonitis*, *Microascus brevicaulis*, *Wardomyces humicola*, *Scopulariopsis brumptii*), while others exhibited substratum specificity. For example, *Microascus singularis* and *M. soppii* were recovered only from wood. Cellulose azure and cellophane membrane degradation tests confirm a moderate level of cellulolytic

ability among members of the family (data not shown).

Discussion

Methods employed in this study appear to have been more successful at recovering species of Microascaceae than traditional techniques designed for isolation of a broad spectrum of fungi from soil, and it is likely that their occurrence has been previously underestimated. Factors which have contributed to this success include: 1) the use of selective media to reduce or eliminate competitive molds, 2) prolonged incubation period, and 3) isolation techniques.

The media utilized were all inhibitory to some fungi and acted as highly selective media designed to target Microascaceae. All species of Microascaceae are resistant to benomyl (see Chapter 7), and its addition at 2 μg/mL eliminated many common molds allowing for greater recovery of target species. Many species of Microascaceae are resistant to cycloheximide, present in MYC at 400 μg/mL, which also inhibits many other fast growing molds, zygomycetes and basidiomycetes. The DG18 medium has low water availability and selects for xerotolerant fungi, including some Microascaceae such as *Microascus brevicaulis*. Tap water agar is nutrient deficient and slows all fungal growth, allowing easier isolation of desired strains. The primary food sources in CMA are complex carbohydrates (starch) and cellulose, while PDA and NMA have relatively simple carbohydrate sugars. The addition of tetracycline, a broad spectrum antibiotic, greatly increased the success of obtaining axenic cultures by reducing bacterial contamination. The combination of selective media achieved target isolation of Microascaceae in a manner not seen with routine mycological media.

Frequently, the microascaceous species did not appear for several months to over a year on the primary isolation plates, which were held for 18-30 months. This could account for these taxa being overlooked in many surveys which routinely hold plates only for several weeks. *Cephalotrichum* species were often the first to appear, producing synnemata on the inoculum pieces within four to eight weeks on the primary isolation plate.

Many soil surveys have utilized dilution plating, which biases results toward prolifically-sporulating species (Warcup 1950). Morrall and Vanterpool (1968) used dilution plating to isolate microfungi from soil in the boreal forest in Saskatchewan and, consequently, over 80% of their isolates were species of *Penicillium*, *Mortierella*, *Trichoderma*, or *Oidiodendron*. Crawford et al. (1990) also used dilution plating to isolate from rotted Douglas fir (*Pseudotsuga menziesii*) wood. Other techniques for assessing microfungi in soil, including the soil-washing method and direct observation technique, also yield predominantly fast-growing hyphomycetes and very few ascomycete species (Widden and Parkinson 1973). Direct examination of logs, branches, and twigs for superficially fruiting ascomycetes has been the traditional method for wood surveys, but the ascomycete flora detected in this manner (e.g., Ellis and Ellis 1985) is quite different from those isolated from the interior of decayed logs by plating the wood directly. None of

the above studies recovered any species of Microascaceae, although similar substrata were rich in this group in Alberta. Direct plating and flame-sterilization methods employed here appear to be effective in recovery of Microascaceae.

The Microascaceae (teleomorphs and anamorphs) are commonly reported from urban and agricultural areas, and are reported only infrequently from nature, with few reports of their occurrence in the boreal forest. Collections of this group come primarily from dung, litter, soil or as airborne spores (e.g., Morton and Smith 1963; Arx et al. 1988). Most microascaceous fungi are cellulolytic (Domsch et al. 1980) and proteolytic (Malloch and Hubart 1987) and presumably their role in fungal communities on substrata such as herbivore dung is the degradation of residual cellulose and proteins. Cellulolytic abilities for five of the *Microascus* species recovered (*Microascus albonigrescens, M. longirostris, M. manginii, M. soppii, M. singularis*) were tested using cellulose azure, and cellophane membrane degradation was monitored for all taxa (data not shown). All species were moderately to weakly cellulolytic, with some interspecific variation in capabilities. Based on the cellulose azure tests, *Microascus albonigrescens* was best able to degrade cellulose, while *Microascus longirostris* and *M. singularis* degraded cellulose only to a limited extent after prolonged incubation. *M. albonigrescens* is considered only moderately cellulolytic in comparison to the strong cellulolytic reaction of *Chaetomium globosum* used as a control. Interestingly, *M. albonigrescens* was by far the most frequently isolated species of *Microascus* from wood and plant litter. *Lophotrichus* species showed significant cellulolytic abilities as indicated by cellophane membrane degradation.

In addition to cellulose, other substrata are also available to microfungi in rotting wood and litter. These include lignin, xylan, insect frass and carcasses, keratinous animal remains, other fungi, and other residual proteinaceous material and organic compounds deposited by the action of other organisms. The diversity of additional substrates may help explain the diversity of microascaceous species, many of which have not previously been reported from rotting wood. Although some of these species are not strongly cellulolytic, they are able to utilize a variety of substrata and may be an integral part of the decay process.

The most common species isolated from wood were *Cephalotrichum nanum, Microascus albonigrescens, Scopulariopsis brumptii* and *Wardomyces humicola* (in descending order of frequency). While these species are also found on a variety of other substrata, two other moderately abundant species, *M. soppii* and *M. singularis* were found exclusively on wood. These common species were found on both gymnosperm and angiosperm wood, especially on wood in advanced stages of decay.

The majority of isolates recovered from soil were in agricultural and urban areas, with few isolates from soils in undisturbed areas (e.g., *Microascus brevicaulis*). Relatively few species are common in soil (Morton and Smith 1963; Domsch et al. 1980). Additionally, relatively few isolates were recovered from litter. Several species (*Microascus albonigrescens, Wardomyces humicola, Cephalotrichum stemonitis*) were recovered from coniferous litter, while others (*Kernia retardata, Scopulariopsis brumptii*)

were found on angiosperm leaves. Remains of fungi are known to be suitable substrata for a number of microascaceous taxa (Morton and Smith 1963; Udagawa and Horie 1971; Hammil 1977) and yielded *Scopulariopsis chartarum*, *Cephalotrichum spiralis* and several isolates of *Microascus brevicaulis* from Alberta.

A variety of substrata can be considered as animal-associated. The most prevalent and extensively studied is excrement, and dung provided a rich substratum in Alberta. The most abundant species was *Cephalotrichum nanum*, which occurred on a wide variety of herbivore and carnivore dung (rodent, lagomorph, ungulate, mustelid, canid). The long history of coprophilous studies in mycology has demonstrated that dung is a common source for species of *Cephalotrichum*, *Microascus*, *Lophotrichus*, *Kernia*, *Petriella* and *Pseudallescheria* (Massee and Salmon 1901; Barron et al. 1961a, b; Morton and Smith 1963; Seth 1970; Malloch and Cain 1971), and these genera (except *Petriella*) have been recorded on dung in Alberta. Although Morton and Smith (1963) state that no species of *Scopulariopsis* have been found on dung, several isolations of *Scopulariopsis brevicaulis* (=*Microascus brevicaulis*) and *Scopulariopsis asperula* (=*M. niger*) were made in this study. Interestingly, the common *S. brumptii* was never isolated from dung, but was found on all other types of substrata examined. The single, most species-rich substratum collected in this study was a sample of skunk dung collected in a farm yard, that yielded five species of Microascaceae (*Cephalotrichum putredimus*, *Kernia retardata*, *Lophotrichus bartlettii*, *Microascus brevicaulis*, and *M. niger*).

Several species were recovered from soil containing animal hair, and hair baiting techniques have occasionally recovered microascaceous species (e.g., Dominik 1970). One isolate of *Cephalotrichum nanum* (UAMH 8741) demonstrated synemata forming along hairs plated directly with soil particles onto the primary isolation plates. *C. purpureofuscum* and *C. stemonitis* were also isolated from rodent hair. No keratinolytic abilities were demonstrated by in-vitro hair degradation tests (Carmichael 1962) (data not shown). Several collections (*Microascus albonigrescens*, *Wardomyces humicola*) were made from squirrel middens, although no direct evidence of animal remains was detected. Two species (*Scopulariopsis brumptii*, *Microascus brevicaulis*) were recovered from fresh water snail shells. *Microascus brevicaulis* has been recorded several times from insect carcasses. Surveys of rodent lungs and organs have been conducted in Alberta periodically over the past 30 years, and have recorded *Cephalotrichum purpureofuscum*, *C. dendrocephalum*, *Microascus brevicaulis*, *M. longirostris*, *M. manginii*, *Scopulariopsis brumptii*, *S. fimicola*, *S. parva*, and *Wardomyces inflatus*.

Collections associated with agricultural environments included those from animal pens (*Cephalotrichum putredimus*, *Kernia retardata*, *Microascus niger*, *Pseudallescheria boydii*, *Scopulariopsis acremonium* and *S. parva*) and from manure or compost (*Cephalotrichum microsporum*, *C. spiralis*, *Pseudallescheria boydii*). Some species of Microascaceae have demonstrated the ability to utilize, and a preference for, urea-containing substrata (Horie and Udagawa 1983; Udagawa and Furuya 1988) and it is likely that the agricultural substrata listed above are highly suited to the species recovered. Species recovered from other agricultural sites (soil, buildings, etc.) include

Cephalotrichum columnaris, *C. nanum*, *C. stemonitis*, *Microascus brevicaulis*, *M. manginii*, *M. niger*, *Petriella sordida*, *Pseudallescheria boydii*, *Wardomyces anomalus* and *W. columbinus*.

Some Microascaceae are known as common molds in urban areas. Species encountered as airborne contaminants in Alberta include *Cephalotrichum microsporum*, *C. purpureofuscum*, *C. spiralis*, *Microascus brevicaulis*, *M. cinereus*, *M. manginii*, *M. niger*, and *Petriella setifera*. A few species of Microascaceae are opportunistic human pathogens (Rippon 1988), and confirmed cases of infection from *Pseudallescheria boydii* and *Scopulariopsis brevicaulis* (=*Microascus brevicaulis*) are reported from Alberta (Dowding 1935; Sekhon et al. 1974). A large number of additional species have also been recorded as probable contaminants in clinical specimens including *Cephalotrichum columnaris*, *C. microsporum*, *C. purpureofuscum*, *C. spiralis*, *Graphium cuneiferum*, *Microascus cinereus*, *M. cirrosus*, *M. intermedius*, *M. longirostris*, *M. manginii*, *M. niger*, *Scopulariopsis acremonium*, and *S. brumptii*. Additionally, *Microascus brevicaulis*, *M. manginii* and *Pseudallescheria boydii* were isolated from veterinary specimens.

Most of the species recovered from substrata in the boreal forest are also known to occur in urban or rural areas, but one rarely seen species, *Microascus albonigrescens*, was found only on wood, plant litter and dung. This poorly known species was originally described from Scandinavia (Sopp 1912), and reported from North America by Barron et al. (1961b). It has also been isolated from wood in Sweden and litter in Japan. It was most frequently isolated from decaying coniferous wood, and was additionally recovered from conifer litter in a squirrel (*Tamiasciurus hudsonicus*) midden under pine (*Pinus banksiana*), angiosperm leaf litter under hazelnut (*Corylus cornuta*) and aspen (*Populus tremuloides*), and carnivore dung. These are the first collections from Canada. The widespread occurrence in decayed logs sites provides further insight into the ecological role of this rarely recorded species.

Several other rare species were found in Alberta, including three new records for North America that represent the only collections known in addition to the type. *Kernia retardata* was originally described from soil in Japan (Udagawa and Muroi 1981). Four isolates were recovered from well rotted spruce wood, two isolates collected on decomposing leaves, one on live sphagnum moss, one on dung, and two from soil in animal pens. Many of these collections exhibited only the teleomorph state on natural substrata and on the primary isolation plates, but produced a *Scopulariopsis* state sparsely in axenic culture. *Cephalotrichum columnaris*, originally described from hare's dung in South Africa (Swart 1967, as *Doratomyces columnaris*), is also reported from two rural collections and a clinical specimen in Alberta. *Cephalotrichum dendrocephalum* is a distinctive synnematous fungus with undulate, branched appendages, originally described from soil in Iraq (Udagawa et al. 1985, as *Trichurus dendrocephalus*). A second collection is now known from a ground squirrel in Alberta. Abbott (unpublished, see Chapter 6) transferred these species to *Cephalotrichum*.

Results have shown that *Scopulariopsis brevicaulis*, which is an extremely

common mold in human environments in Alberta (Sigler et al. 1996; Abbott et al. 1998), is also very common in nature. It has been isolated from a variety of substrata including herbivore and carnivore dung, conifer and broad-leaved litter and wood, soil of forests and lake shores, and remains of fungi and animals. This supports my supposition that many of the species common in urban areas are not introduced 'weeds', but are widespread in nature, having moved in and colonized materials in our human environment.

Table 8.1 Occurrence of species of Microascaceae in primary substrata/habitat types in Alberta. Value in brackets after species name indicates the number of Alberta isolates in UAMH.

Species	substrata/habitat type					
	soil	wood	plant litter	animal/ fungal remains	dung	rural/ urban
Cephalotrichum columnaris (3)						+[a]
Cephalotrichum dendrocephalum (1)				+		+
Cephalotrichum microsporum (9)	+	+			+	++[b]
Cephalotrichum nanum (11)	+	++		+	++	+
Cephalotrichum purpureofuscum (9)	+			+		++
Cephalotrichum putredinus (10)	+				+	++
Cephalotrichum spiralis (5)				+		+
Cephalotrichum stemonitis (5)	+	++	+	+	+	+
Graphium cuneiferum (2)		+				+
Kernia retardata (8)	+	+	+		+	+
Lophotrichus bartletii (1)					+	+
Microascus albonigrescens (6)		++	+		+	
Microascus brevicaulis (55)	+	++	+	++	++	++
Microascus cinereus (5)		+			+	+
Microascus cirrosus (3)						+
Microascus intermedius (1)						+
Microascus longirostris (4)		+		+	+	+
Microascus manginii (12)		++		+		++
Microascus niger (13)	+	+			+	++
Microascus singularis (4)		++				
Microascus soppii (9)		++				
Petriella setifera (1)						+
Petriella sordida (2)		+				+
Pseudallescheria boydii (17)	+			+	+	++
Scopulariopsis acremonium (5)	+					+
Scopulariopsis brumptii (15)	+	++	+	+		++
Scopulariopsis chartarum (3)		+		+		+
Scopulariopsis fimicola (1)				+		+
Scopulariopsis parva (10)	+	+		++		++
Wardomyces anomalus (1)						+
Wardomyces columbinus (2)					+	+
Wardomyces humicola (6)	+	++	+		+	+
Wardomyces inflatus (4)	+	++		+		+

[a] + indicates 1-5 records.

[b] ++ 6 or more records.

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CHAPTER 9

SUMMARY

Historically, the ascomycetes have been classified at the genus and family level based on features of their sexual stage (teleomorph). This foundation for ascomycete systematics began in the early 1800's (e.g., Fries 1821-32) and remains the basis of classification today. Hypotheses concerning systematics of the time centred on grouping species and genera based on observed gross similarities of fruiting bodies and spores. Luttrell (1951) opened a new avenue for classification of ascomycetes by examination of the development of the ascomata, and especially the formation of asci within the ascomatal centrum. By this means, the first concept of the Microascaceae was envisioned.

Similarly, the common molds were observed during an early period in the field of mycology and it was soon recognized that the spores (conidia) of these organisms were not products of sexual reproduction. Classification of these anamorphs in form-class Hyphomycetes (filamentous molds) under the broad category of Fungi Imperfecti was separate from that of the sexually reproducing forms. One of the most influential systems of classification was outlined by Saccardo (1886) in which the anamorphic fungi were divided into broad morphological groups by the colour and septation of the conidia. Hughes (1953) revolutionized hyphomycete systematics with his pioneering work on conidium formation (conidiogenesis) by placing emphasis on the developmental process, leading to a less artificial system of classification.

The first realization of pleomorphism (the production of different states by a single species) came from observation of ascomycetes in pure culture, revealing that many possessed asexual, anamorphic stages (Tulasne and Tulasne 1861). This allowed a new understanding of the life histories of fungi and ushered in an era of observation of fungi in the laboratory. The piecing together of morphologically disparate elements in the life cycle of a fungus allowed for the recognition of what is now termed the fungal holomorph (Hennebert and Weresub 1977).

Modern studies of the Microascaceae have added to the body of knowledge available to Luttrell (1951) and have been primarily concerned with inclusion or exclusion of additional teleomorph taxa within the family typified by *Microascus*. Although the typical form of the ascoma in the family is a perithecium with a well defined opening (ostiole) from which a sticky column of ascospores is extruded (cirrus), it was realized that several taxa with closed, cleistothecial ascomata were also closely related based on similarities of ascus development and morphology of the anamorphic stages. This allowed a broadening of the family concept, as outlined by Malloch (1970) and accepted in modern classifications (Eriksson and Hawksworth 1998).

Throughout the taxonomic history of the Microascaceae, the morphology of associated asexual states has been closely observed and recorded. The similarity of these

stages to other anamorphic fungi for which no sexual states were known gave rise to a general acceptance of relationship based on morphological and developmental similarity. Nevertheless, these strictly asexual fungi have been excluded from circumscriptions of the family since their affinity with this group of ascomycetes was inferential and unproven.

The primary goal of the research presented in this dissertation was to provide sufficient evidence of relationship through studies of the fungal holomorph that the anamorphic taxa could be confidently integrated into the phylogenetic framework of the Microascaceae. Central to this was the hypothesis that the teleomorph and anamorph taxa of the Microascaceae form a monophyletic group.

The entire life history of a species, comprising the various spore-forming stages, constitutes the holomorph. Studies of fungal holomorphs were conducted in a number of ways throughout this research. Fundamental to these studies was the growth of all species in pure culture, providing a means of observing the development of both asexual and sexual stages. Thus, cultural studies allowed me to test taxonomic hypotheses of various taxa by comparing the observed morphological variation with the concept previously described in the literature.

Early in my investigations into the morphology of anamorph and teleomorph taxa, the discovery of a teleomorph for *Scopulariopsis brevicaulis*, in one of my isolates obtained from an air sample in an agricultural building in Alberta, afforded a valuable insight into the relationships within the family. The discovery of a sexually reproducing state consistent with other species of the genus *Microascus*, prompted a careful reexamination of over 100 strains of *Scopulariopsis brevicaulis* in a search for additional evidence of relatedness. Two additional isolations were recovered from Alberta air samples and another two fertile strains were found among strains in the UAMH culture collection. This finding was significant because it definitively linked *S. brevicaulis*, the type species of the form-genus *Scopulariopsis*, with the Microascaceae (Abbott et al. 1998).

Considering the long history, widespread distribution, and frequent isolation of *Scopulariopsis brevicaulis*, the discovery of five sexually reproducing isolates was remarkable and raised further questions regarding the life history of microascaceous species. From this initial discovery, I became interested in the mating system involved with ascomatal production in this group of ascomycetes. Although evidence suggested that some members of the family were homothallic (self-fertile)(Emmons and Dodge 1931), the rarity of sexual isolates known for this common mold suggested the possibility of heterothallism (self-incompatibility). Also, scattered reports of sexual stages and the presence of sterile stuctures which resembled perithecia in other taxa of the '*Scopulariopsis brevicaulis* Series' suggested potential teleomorph connections. Thus, this group presented an excellent opportunity to test the hypothesis of heterothallism and clarify holomorph concepts.

Heterothallism was observed in this group through the use of mating trials and is

the first report of this type of mating system in the Microascaceae. Strictly asexual strains were paired on agar medium and allowed to grow together for an extended period, eventually forming ascomata along the zone of contact. Homothallism was also confirmed in another species of *Microascus* by making single ascospore isolates, all of which produced fertile ascomata independently.

Recognition of pleomorphy and an understanding of holomorph concepts also aids in the accurate identification of species as they are recovered from the environment. The multiple spore states of *Pseudallescheria boydii* are an example. By connecting the *Scedosporium* state and its *Graphium* synanamorph to the sexual stage, a group of unidentified environmental isolates encountered in oil/ hydrocarbon contaminated sites were determined as potential agents of biodeterioration. The connections were made based on morphological evidence and supported with molecular data from RFLP banding patterns. Without recognition of conspecificity, the abundance of this single holomorphic species would have been greatly underestimated and its potential importance unnoticed. Further comparisons with isolates and reports from the literature revealed that other strains known to degrade hydrocarbons, variously reported as *Graphium* species, in fact are conspecific with *P. boydii*. This is the first time that degradation of oil has been attributed to this species, and its accurate identification has important implications for field trials of biodeterioration and environmental reclamation given that *P. boydii* is an opportunistic human pathogen (April et al. 1998).

Not all anamorphic genera could be linked to teleomorphs. One group of anamorphs with dry-spored conidia formed on complex, brush-like conidiophores (synnemata) and no proven affinity to the Microascaceae, was in need of reevaluation at the genus and species levels. The form-genus *Cephalotrichum* was shown to be the correct name for this group which showed remarkable similarity in conidiogenesis to *Scopulariopsis* anamorphs of *Microascus* species. Mating trials were unsuccessful in demonstrating a teleomorph for the type species, *C. stemonitis*, and additional means of inferring relationships were needed to help circumscribe the family.

Molecular and physiological data provided independent characters to support the hypothesis of monophyly in the Microascaceae. Sequences were obtained from the small subunit (18S) rDNA molecule for the type species of anamorph and teleomorph genera tentatively assigned to the Microascaceae. Additional species of Microascaceae and a sampling of pyrenomycete taxa from the Microascales and other orders were included to place these taxa in a phylogenetic framework. Molecular sequence analyses support the hypothesis that the taxa included in the Microascaceae by morphological characters form a phylogenetically related, monophyletic group. These data were crucial in placing anamorph genera, such as *Cephalotrichum* and *Wardomyces*, within the family because without a teleomorph, many of the characters required for phylogentic integration were not available from morphology.

Physiological differences between groups of fungi have been important indicators of relationships and have helped to establish modern systematic concepts. For instance,

among the ascomycetes responsible for blue stain of lumber, the tolerance to cycloheximide of *Ophiostoma* species versus the sensitivity of species of *Ceratocystis* was an important character leading to the recognition of convergence and eventual taxonomic separation of two groups (Harrington 1981). For species of Microascaceae, cycloheximide tolerance was variable and proved unreliable as a family level indicator of relationship, although trends were seen at the genus level. On the other hand, tolerance to the fungicide benomyl was demonstrated to be a uniform feature of the family. Although several lineages of ascomycetes demonstrate benomyl tolerance, it is a synapomorphy among the Microascaceae, allowing for separation of microascaceous taxa from superficially similar ones in other orders, such as the Ophiostomatales and Sordariales. Physiological tests provided a relatively simple method of testing a large number of isolates to determine support for relationship by checking for growth on media with and without the addition of the antifungal compounds.

Development of selective media incorporating the antifungal compounds discussed above allowed for the target isolation of microascaceous species. This resulted in the Microascaceae being detected at a level not previously seen in environmental surveys. Although many species are common molds in human environments, their occurrence and habitat in nature was not well understood. An intensive survey of a large number of diverse substrata, including wood, litter, soil, and animal and fungal remains, was undertaken in Alberta. The results show the Microascaceae comprise a diverse and integral component of natural ecosystems as well as a prominent component of the fungal diversity in urban and rural habitats.

Naming pleomorphic fungi remains problematic. Anamorphic form-genera are primarily artificial taxonomic entities based on morphological similarity serving as a practical means of identifying and naming asexual fungi (Gams 1995) and do not, by definition, imply relatedness, but many modern hyphomycete systematists have adopted a more natural approach and suggest that anamorph genera should reflect phylogeny (e.g., Seifert 1993). Form-genera are not strictly monophyletic units, especially when combined in a phylogenetic framework with teleomorphic taxa, but I have supported the view that unrelated and morphologically divergent taxa should be excluded where practicable. The International Code of Botanical Nomenclature (ICBN Article 59, Greuter et al. 1994) states that "in ascomycetous fungi with mitotic asexual morphs (anamorphs) as well as a meiotic sexual morph (teleomorph), the correct name covering the holomorph is the earliest name typified by an element representing the teleomorph." The holomorph concepts defined in this study allow species to be referred to a teleomorph genus, even though the ascomatal stage is rarely seen, and have simplified the taxonomy of this group. For example, in the '*Scopulariopsis brevicaulis* Series', over a dozen binomial names were applied to various stages and morphological extremes that we now know comprise only four holomorph taxa. Although very effective for demonstrating a more complete picture of the holomorph, mating trials are impractical for routine mycological identification since they are very slow to demonstrate the desired results, often taking over a year to produce fertile sexual structures. Thus, identification of isolates must still be based on asexual structures in many instances and names for asexual states remain useful.

In this study, the form-genera *Scopulariopsis*, *Cephalotrichum*, *Echinobotryum*, *Wardomyces*, and *Wardomycopsis* are directly connected to the Microascaceae, while the current concepts of *Graphium* and *Scedosporium* are applied at the ordinal level to members of the Microascales. Thus, if a holomorph concept is applied to the family level, species of these anamorphic taxa can be integrated into the Microascaceae, along with the teleomorphic genera *Microascus*, *Kernia*, *Lophotrichus*, *Petriella* and *Pseudallescheria*. The circumscription of the family provides the foundation for further investigations into the systematics of the Microascaceae. From this framework, a more complete understanding of the relationships among species in the various genera can be ascertained, and the strictly anamorphic species can be integrated into a phylogeny with their sexual relatives.

Literature Cited

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Tulasne, L.R. and C. Tulasne. 1861. Selecta fungorum carpologia, vol. 1 (Translated by W.B. Grove). Imperial Press, Paris. 241 pp. + plates.

APPENDIX 1

NOMENCLATOR OF MICROASCACEAE: TAXA AND STRAINS EXAMINED

Six hundred and forty five strains representing 87 species assigned to the Microascaceae were examined in this study and are deposited in the University of Alberta Microfungus Collection and Herbarium (UAMH). Nomenclatural citations and strain data are provided below.

Microascaceae Luttrell ex Malloch. 1970. Mycologia 62: 734.

≡ Microascaceae Luttrell. 1951. University of Missouri Studies 24: 108. (*nomen nudum*, ICBN Art. 36.1)

= Lophotrichaceae Seth. 1970. Nova Hedwigia 19: 592.

= Pithoascaceae Benny & Kimbrough. 1980. Mycotaxon 12: 45.

Type genus: *Microascus* Zukal. 1885. Verhandlungen. Zoologische-Botanische Gesellschaft in Wien 35: 339.

Cephalotrichum Link: Fries. 1829. Systema Mycologicum 3: 280.

≡ *Cephalotrichum* Link. 1809. Berlinische Magazin 3: 20.

= *Doratomyces* Corda. 1829. in Sturm, Deutschlands Flora, III (Pilze) 2: 65.

= *Stysanus* Corda. 1837. Icones Fungorum 1: 21.

= *Trichurus* Clements & Shear. 1896. in Clements and Pound, Botanical Survey of Nebraska 4: 7.

Type species: *Cephalotrichum stemonitis* (Persoon) Link : Fries. 1832. Systema Mycologicum 3: 280.

Cephalotrichum columnaris (H.J. Swart) S.P. Abbott, comb. nov.

≡ *Doratomyces columnaris* H.J. Swart. 1967. Acta Botanica Neerlandica 15: 521.

Collections Examined:

UAMH 8042 St. Lina, Alberta, Canada, indoor air ex RCS strip from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 111) 10 Dec 1993.

UAMH 8597 Vegreville, Alberta, Canada, nail, 60 yr old male, DE-. from Rennie, R. as MY 0750.

UAMH 9281 South Africa, dung of hare, H.J. Swart. from CBS as CBS 159.66 (=IMI 116691), ex-type of *Doratomyces columnaris*.

UAMH 9623 Brooks, Alberta, Canada, indoor air ex RCS strip from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 112) 13 Dec 1993.

Cephalotrichum cylindricum (Clements & Shear) S.P. Abbott comb. nov.

≡ *Trichurus cylindricus* Clements & Shear. 1896. in Clements and Pound, Botanical Survey of Nebraska 4: 7.

= *Trichurus terrophilus* Swift & Povah. 1929. Mycologia 21: 214.

Collections Examined:

UAMH 1348 Kansas, USA, seed of sorghum, C.T. Rogerson (S.129) 1955. from DAOM as DAOM 45913 (=IMI 96753).

UAMH 8848 South Africa, timber of eucalyptus (*Eucalyptus saligna*), TRL8-FPRL (S590) 1951. from Ito, T. as IFO 7660 *Trichurus terrophilus* (=IMI 46251, =LSHB BB344, =CBS 448.51).

UAMH 8912 Belem, PA, Brazil, soil under primary Amazonian forest, L. Pfenning Dec 1993. from Umino, C.Y. as CCT 3815 *Scopulariopsis carbonaria.*

UAMH 8976 Huron National Forest, Michigan, soil under white pine (*Pinus strobus*), NRRL isolate 19 Jul 1962. from NRRL as NRRL A-11628 *Doratomyces stemonitis.*

UAMH 9141 France, soil, A. Russo. from CBS as CBS 646.70 *Trichurus terrophilus.*

Cephalotrichum dendrocephalum (Udagawa, Horie & Abdullah) S.P. Abbott comb. nov.

≡ *Trichurus dendrocephalus* Udagawa, Horie & Abdullah. 1985. Mycotaxon 23: 253.

Collections Examined:

UAMH 1383 Edmonton, Alberta, Canada, Richardson's ground squirrel (*Spermophilus richardsonii*), J.W. Carmichael 8 Aug 1962.

UAMH 5372 Basrah City, Iraq, soil date palm plantation, S. Abdullah Jul 1983. from Udagawa, S.-I. as NHL 2927, ex-type of *Trichurus dendrocephalus.*

Cephalotrichum microsporum (Saccardo) P.M. Kirk. 1984. Kew Bulletin 38: 578.

≡ *Stysanus microsporus* Saccardo. 1878. Michelia 1: 274.

≡ *Doratomyces microsporus* (Saccardo) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 77.

= *Graphium graminum* Cooke. 1887. Grevillea 16: 11.

Collections Examined:

UAMH 2791 Cardston, Alberta, Canada, manure pile, D. Remington Jun 1967.

UAMH 4019 UAMH, Alberta, Canada, contaminant ex culture, Dec 1976.

UAMH 6751 Edmonton, Alberta, Canada, soil, L. Rosmus Sep 1990.

UAMH 8295 Alberta, Canada, bronchial wash, male 50 yr, Provincial Laboratory for Southern Alberta 29 Jun 1995. from Rennie, R. as MY 2217.

UAMH 8625 Edmonton, Alberta, Canada, bronchial washings, male, 59 yr, G. Man/N. Brown 27 May 1996. from Rennie, R. as MY 2296.

UAMH 8789 Mt. Albert, New Zealand, potato (*Solanum tuberosum*), F.J. Morton (H97) Jan 1962. from Young, J. as ICMP 1054.

UAMH 8845 Otoineppu, Nakagawa-gun, Hokkaido, Japan, decaying higher fungus (*Coriolus hirsutus*), S. Udagawa (NHL 2446) 6 Sep 1969. from Ito, T. as IFO 9383.

UAMH 9003 Edmonton, Alberta, Canada, right heel, female 35 yr, C. Sand (MY 148) 12 Jan 1995. from Rennie, R. as MY 148.

UAMH 9143 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S2A, 2-12A) 12 Feb 1997.

UAMH 9365 near Peace River, Alberta, Canada, indoor air of home ex chemical assessment filter, S.P. Abbott (SA-M270) 9 Sep 1998.

UAMH 9456 North Buck Lake near Lac La Biche, Alberta, Canada, dung of coyote (*Canis latrans*) in birch/pine woods (*Betula papyrifera/Pinus banksiana*), S.P. Abbott (SA-M277) 8 Jan 1999.

Cephalotrichum nanum (Ehrenberg) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Periconia nana* Ehrenberg 1818. Sylvae Mycol. Berol. pp. 13, 24.

≡ *Stilbum nanum* (Ehrenberg) Sprengel. 1827. Linn. Syst. Veg., Ed. 16, 4(1): 547.

≡ *Graphium nanum* (Ehrenberg) Saccardo. 1886. Sylloge Fungorum 4: 616.

≡ *Doratomyces nanus* (Ehrenberg) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 80.

= *Stysanus fimetarius* (Karsten) Massee & E.S. Salmon. 1902. Annals of Botany 16: 86.

≡ *Stysanus stemonitis* var. *fimetarius* Karsten. 1887. Meddelanden af Societas pro Fauna et Flora Fennica 14: 93.

= *Periconia phillipsii* Berkeley & Leighton. 1875. in Berkeley and Broome, Annals and Magazine of Natural History, Ser. 4, 15: 33.

≡ *Sporocybe phillipsii* (Berkeley & Leighton) Saccardo. 1886. Sylloge Fungorum 4: 609.

≡ *Stysanus phillipsii* (Berkeley & Leighton) E.W. Mason & M.B. Ellis. 1953. Mycological Papers 56: 40.

≡ *Cephalotrichum phillipsii* (Berkeley & Leighton) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Doratomyces phillipsii* (Berkeley & Leighton) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 82.

= *Doratomyces asperulus* auct. *sensu* Domsch et al. 1980.

≠ *Doratomyces asperulus* Wright & Marchand. 1972. Boletin de la Sociedad Argentina de Botánica 14: 308. (= *Cephalotrichum purpureofuscum*)

Collections Examined:

UAMH 4758 Michel Reservoir, southern Alberta, Canada, dung, R. Currah Mar 1983. from Currah, R.S.

as *Leightoniomyces phillipsii*.

UAMH 7755 Fairview, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 181) 31 Jan 1994.

UAMH 8485 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S2E) 14 Sep 1995.

UAMH 8486 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S3G) 04 Sep 1995.

UAMH 8620 Fish Lake near Nordegg, Alberta, Canada, deer (*Odocoileus* sp.) dung in spruce (*Picea glauca*) forest, S.P. Abbott (SA-M134) 14 Jun 1996.

UAMH 8621 Astoria River valley, Jasper National Park, Alberta, Canada, Marten (*Martes americana*) dung, S.P. Abbott (SA-M140) 28 Aug 1996.

UAMH 8622 near Moraine Lake, Jasper National Park, Alberta, Canada, hoary marmot (*Marmota caligata*) dung, S.P. Abbott (SA-M141) 28 Aug 1996.

UAMH 8740 Wagner Natural Area near Spruce Grove, Alberta, Canada, dung of snowshoe hare (*Lepus americanus*) in spruce/larch (*Picea mariana/Larix laricina*) forest, S.P. Abbott (SA-M168) 16 Dec 1996.

UAMH 8741 Wagner Natural Area near Spruce Grove, Alberta, Canada, soil of northern pocket gopher (*Thomomys talpoides*) mound in hay field, S.P. Abbott (SA-M167) 16 Dec 1996 (=IFO 33044).

UAMH 8742 Devonian Botanic Garden near Devon, Alberta, Canada, dung of porcupine (*Erethizon dorsatum*), S.P. Abbott (SA-M166) 17 Dec 1996.

UAMH 8854 England, UK, deer dung, J. Hawkins 1956. from Ito, T. as IFO 8180 *Doratomyces nanus* (=IMI 68394, =LSHB Sc. 142, =CBS 119.61).

UAMH 8855 Japan, soil, T. Yokoyama (R-1607-21) 1985. from Ito, T. as IFO 31957 *Doratomyces nanus*.

UAMH 9126 Elk Island National Park, Alberta, Canada, dung of bison (*Bison bison*) in white spruce (*Picea glauca*) and poplar (*Populus tremuloides/ P. balsamifera*) forest, S.P. Abbott (SA-M198) 18 Aug 1997.

UAMH 9128 Netherlands, sand dune soil. from CBS as CBS 187.78 *Doratomyces asperulus*.

Cephalotrichum purpureofuscum (Schweinitz) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Aspergillus purpureofuscus* Schweinitz. 1832. Transactions. American Philosophical Society, Ser. II, 4: 282.

≡ *Aspergillus purpureofuscus* Fries. 1832. Systema Mycologicum 3: 388.

≡ *Stysanus purpureofuscus* (Fries) S. Hughes. 1953. Canadian Journal of Botany 31: 744.

≡ *Doratomyces purpureofuscus* (Fries) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 74.

= *Periconia fusca* Corda. 1837. Icones Fungorum 1: 19.

≡ *Stysanus fuscus* (Corda) E.W. Mason & M.B. Ellis. 1953. Mycological Papers 56: 31.

= *Stysanus mandlii* Montagne. 1837. Annaes de Sciencias Naturaes, Sér. 3, 4: 345.

= *Stysanus medius* Saccardo. 1881. Michelia 2: 300.

≡ *Doratomyces medius* (Saccardo) Matsushima. 1980. Matsushima Mycological

Memoirs 1: 33.

≡ *Cephalotrichum medium* (Saccardo) S. Hughes. 1958. Canadian Journal of Botany 36: 744.

≡ *Stysanopsis media* (Saccardo) Ferr. 1909. Annales Mycologici 7: 281.

= *Stysanus asperulus* Wright & Marchand. 1972. Boletin de la Sociedad Argentina de Botánica 14: 308.

Collections Examined:

UAMH 989 Bittern Lake, Alberta, Canada, lung Richardson's ground squirrel (*Spermophilus richardsonii*), J.W. Carmichael May 1959.

UAMH 1299 Edmonton, Alberta, Canada, soil, J.W. Carmichael 7 Jul 1962.

UAMH 1416 San Diego, soil, G.F. Orr (217). from DAOM as DAOM 84432 O 217

UAMH 1767 Anastasiou, C.J. S55 (A20) as *Scopulariopsis* sp.

UAMH 2771 Cardston, Alberta, Canada, hair of Richardson's ground squirrel (*Spermophilus richardsonii*), D. Remington (1) 7 Jun 1967.

UAMH 2775 Cardston, Alberta, Canada, hair of Richardson's ground squirrel (*Spermophilus richardsonii*), D. Remington (1) 6 Jun 1967.

UAMH 4455 Spain, soil, Guarro, J. FFBA 217.

UAMH 7303 Edmonton, Alberta, Canada, ex nail, male 59 yr, C. Sand 11 Jan 1993. Rennie, R. MY 5858b

UAMH 7743 Calgary, Alberta, Canada, ex fingernail, female 35 yr, 8 Nov 1994. from Rennie, R. as MY 3483 *Scopulariopsis* sp.

UAMH 8237 Alberta, Canada, bronchial wash, male 65 yr, Provincial Laboratory for Southern Alberta 29 Jun 1995. from Rennie, R. as MY 2216.

UAMH 8739 Lord Howe Island, Australia, soil, banyan rhizosphere, A.D. Hocking 1977. from Hocking, A. as FRR 1903 *Doratomyces stemonitis.*

UAMH 8788 Mt. Albert, New Zealand, cave wall, F.J. Morton (H56) Nov. 1961. from Young, J. as ICMP 1165 *Trichurus terrophilus.*

UAMH 8790 Mt. Albert, New Zealand, leaf of swede (*Brassica napus* var. *napobrassica*), F.J. Morton (H286) July 1963. from Young, J. as ICMP 1094 *Doratomyces microsporus.*

UAMH 8844 Japan, leaves of needle-leaved tree, T. Ito (ISR 47-1) 1986. from Ito, T. as IFO 32040 *Doratomyces stemonitis.*

UAMH 8853 Germany, wheat field soil, K. Domsch 1963. frp, Ito, T. as IFO 31240 *Doratomyces purpureofuscus* (=CBS 523.63, =ATCC 16224).

UAMH 8892 Han-sur-Lesse, Belgium, wood of decaying furniture in underground laboratory cave, G.L. Hennebert (882-18) Sep 1959. from Untereiner, W. as MUCL 536 *Doratomyces purpureofuscus.*

UAMH 8910 Peruibe, São Paulo, Brazil, soil under primary Atlantic forest, A.B. Garlipp Oct 1994. from Umino, C.Y. as CCT 4299 *Doratomyces stemonitis.*

UAMH 9002 UAMH, plate contaminant in walk-in cooler (5 C), S.P. Abbott (SA-M3) 28 Apr 1993. (=IFO 33045).

UAMH 9127 Arroyo Las Viboras, Tordillo, Buenos Aires, Argentina, humus-rich soil, A.M. Godeas 1970. from CBS as CBS 582.71 *Doratomyces asperulus* ATCC 26885, ex-type of *Doratomyces asperulus.*

UAMH 9158 Alberta, Canada, bronchial wash, male 16 yr, Prov. Lab for Southern Alberta 1997. from Rennie, R. as MY 6111.

UAMH 9209 Pemberton, British Columbia, Canada, indoor air of school library ex Anderson sampler, S.P. Abbott (SA-M209) 18 Feb 1998.

Cephalotrichum putredinis (Corda) S.P. Abbott comb. nov.

≡ *Stysanus putredinis* Corda. 1839. Icones fungorum 3: 12.

≡ *Doratomyces putredinis* (Corda) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 83.

≠ *Graphium putredinus* (Corda) S. Hughes, auct. *sensu* Hughes 1958; Ellis 1971; Seifert et al. 1993. (= *Graphium cuneiferum* (Berkeley & Broome) E.W. Mason & M.B. Ellis)

= *Sympenicillium album* Costantin. 1888. Bulletin Societé Mycologique de France 4: 67.

≡ *Coremium album* (Costantin) Saccardo & Traverso. 1839. in Saccardo, Sylloge Fungorum 22: 1444.

≡ *Penicillium costantini* Bainier. 1906. Bulletin Societé Mycologique de France 22: 205. (*nomen novum*).

≡ *Scopulariopsis costantini* (Bainier) Dale. 1914. Annales Mycologici 12: 57.

= *Scopulariopsis alba* Szilvinyi. 1941. Zentralblatt fuer Bakteriologie, Parasitenkunde, Infektionskrankheiten, und Hygiene, Abteilung II, 103: 172.

≡ *Doratomyces albus* (Szilvinyi) Dominik. 1970. Zeszyty Naukowe Wyzszej Szkoly Rolniczej W Szczecinie 32: 89.

Collections Examined:

UAMH 637 Edmonton, Alberta, Canada, shavings ex rabbit cages, J.W. Carmichael May 1959.

UAMH 1145 Alberta Game Farm, Edmonton, Alberta, Canada, soil, cougar pen, J.W. Carmichael 8 Nov 1961.

UAMH 1290 Alberta Game Farm, Edmonton, Alberta, Canada, soil nursery paddock, J.W. Carmichael 7 Jul 1962.

UAMH 1301 Alberta Game Farm, Edmonton, Alberta, Canada, soil Guanaco's paddock, J.W. Carmichael 7 Jul 1962.

UAMH 1318 Alberta Game Farm, Edmonton, Alberta, Canada, soil cougar pen, J.W. Carmichael 7 Jul 1962.

UAMH 1321 Alberta Game Farm, Edmonton, Alberta, Canada, soil under falcon roost, J.W. Carmichael 7 Jul 1962.

UAMH 1331 Alberta Game Farm, Edmonton, Alberta, Canada, straw under bird roosts, J.W. Carmichael 7 Jul 1962.

UAMH 1332 Alberta Game Farm, Edmonton, Alberta, Canada, straw under bird roosts, J.W. Carmichael 7 Jul 1962.

UAMH 3238 Chino, California, USA, soil chicken pens, poultry ranch, J.W. Carmichael 17 Feb 1969.

UAMH 5623 Alberta, Canada, coyote (*Canis latrans*) dung, R. Currah (D-7).

UAMH 5739 North York, Ontario, Canada, ex air, mold-contaminated building, R.C. Summerbell 30 Jul 1986. from Summerbell, R.C. as FR 1395.86.

UAMH 8849 Sugadaira, Sanada-machi, Chiisagata-gun, Nagano Pref., Japan, decaying higher fungus (*Macrolepiota procera*), S. Udagawa (NHL 2440) 2 Oct 1969. from Ito, T. as IFO 9384 *Doratomyces putredinus*.

UAMH 8891 Innsbruck, Austria, culture contaminant, W. Gams 1960. from Untereiner, W. as MUCL

4039 *Doratomyces putredinus* (=IMI 86950, =LSHB Sc. 152, =CBS 192.62).

UAMH 8990 USA, wood treated with fungicide, D.T. Wicklow 16 May 1995. from NRRL as NRRL 25172 *Scopulariopsis candida.*

UAMH 9028 10 km south of Leduc, Alberta, Canada, dung of skunk (*Mephitis mephitis*) on ground in farm yard, S.P. Abbott (SA-M185) 10 Jun 1997. (=IFO 33046).

Cephalotrichum spiralis (Hasselbring) S.P. Abbott comb. nov.

≡ *Trichurus spiralis* Hasselbring. 1900. Botantical Gazette 29: 321.

= *Trichurus gorgonifer* Bainier. 1907. Bulletin Societé Mycologique de France 23: 230.

Collections Examined:

UAMH 3585 Spruce Grove, Alberta, Canada, steamed decomposing mushroom compost, L. Sigler 8 Mar 1973.

UAMH 4093 British Columbia, contaminant in tray sawdust and straw used for growing *Lentinus edodes*, R.J. Bandoni 2 Feb 1978.

UAMH 4094 Preston Lowe, basidiomycete detritis in moisture chamber. from Hammill, T.M. as 210-72 *Trichurus spiralis.*

UAMH 7259 Nisku, Alberta, Canada, ex growth pouch with alfalfa seeds in growth chamber, M. Matlock 25 Nov 1992.

UAMH 7892 New Zealand, ex nail, female 35 yr, DE-. from Woodgyer, A. as 94.600.

UAMH 8689 Ottawa, Ontario, Canada, airborne contaminant of wheat-straw agar plate, R.A. Shoemaker. from DAOM as DAOM 147400 *Trichurus spiralis.*

UAMH 8690 Ottawa, Ontario, Canada, egg of gypsy moth (*Lymantria dispar*), M.I. Timonin. from DAOM as DAOM 190434 *Trichurus spiralis.*

UAMH 8691 Ottawa, Ontario, Canada, air, M.E. Elliott (MEE 42-I-342B) 1942. from DAOM as DAOM 196858 *Trichurus spiralis.*

UAMH 8836 Alberta, Canada, sputum, male 63 years, Provincial Laboratory for Southern Alberta 11 Dec 1996. from Rennie, R. as MY 251.

UAMH 8843 Japan, soil, T. Ito (1726-7) 1989. from Ito, T. as IFO 32272 *Trichurus spiralis.*

UAMH 8882 Nicosia, Cyprus, soil, on roots of potato (*Solanum tuberosum*), R.M. Nattrass (285) Oct 1932. from Untereiner, W. as MUCL 9829 *Trichurus spiralis* (=CBS 336.32).

UAMH 8911 Bihar, India, paper, D.S. Attili Sept 1992. from Umino, C.Y. as CCT 3035 *Trichurus spiralis* (=IMI 145114).

UAMH 9319 Edmonton, Alberta, Canada, air, J.P. Tewari 1995. from Tewari, J.P. as *Trichurus spiralis.*

UAMH 9405 Alberta, Canada, finger nail, Provincial Laboratory for Southern Alberta, 21 Aug 1998. from Rennie, R. as MY 5540 *Trichurus spiralis.*

Cephalotrichum stemonitis (Persoon) Link : Fries. 1832. Systema Mycologicum 3: 280.

≡ *Cephalotrichum stemonitis* (Persoon) Link. 1809. Berlinische Magazin 3: 20.

≡ *Isaria stemonitis* Persoon. 1797. Commentarius Fungis Clavaeform. p 234.

≡ *Periconia stemonitis* (Persoon) Persoon. 1801. Synopsis Methodica Fungorum p 687.

≡ *Stysanus stemonitis* (Persoon) Corda. 1837. Icones Fungorum 1: 22.

≡ *Doratomyces stemonitis* (Persoon) F.J. Morton & G. Smith. 1963. Mycological

Papers 86: 70.

= *Doratomyces neesii* Corda. 1829. in Sturm, Deutschlands Flora, III (Pilze) 2: 65.

Synanamorph:

Echinobotryum atrum Corda. 1831. in Sturm, Deutschlands Flora, III (Pilze) 3: 51.

= *Dematium echinobotryum* Fries. 1832. Systema Mycologicum 3: 87.

Collections Examined:

UAMH 1532 G.L. Barron. from Barron, G.L. as 9503.

UAMH 4834 Slave Lake, Alberta, Canada, coyote (*Canis latrans*) dung, L. Sigler Sep 1983.

UAMH 7754 Girouxville, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 182) 30 Jan 1994.

UAMH 8502 Fallbrook, California, USA, rat dung, G.F. Orr (O-714) 09 Aug 1960. from NRRL as NRRL A-10079 *Echinobotryum* sp.

UAMH 8623 Fish Lake near Nordegg, Alberta, Canada, cone of white spruce (*Picea glauca*), S.P. Abbott (SA-M135) 14 Jun 1996.

UAMH 8624 North Buck Lake near Lac La Biche, Alberta, Canada, sandy soil with hair at entrance of woodchuck (*Marmota monax*) burrow in jack pine (*Pinus banksiana*) forest, S.P. Abbott (SA-M138) 16 Aug 1996.

UAMH 8913 near Guelph, Ontario, Canada, soil of elm (*Ulmus americanus*) woods, G.L. Barron (9504) 11 Dec 1961. from NRRL as NRRL A-11326 *Echinobotryum atrum*.

UAMH 8914 Iceland, agricultural soil, NRRL isolate (ss-831) 26 Oct 1966. from NRRL as NRRL A-14847 *Echinobotryum* sp.

UAMH 9142 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S6H, 4-15G) 15 Apr 1996. from Currah, R.S. as EI-02-S6H, 4-15G *Cephalotrichum stemonitis*.

Graphium Corda. 1837. Icones Fungorum 1: 18.

Type species: *Graphium penicillioides* Corda. 1837. Icones Fungorum 1:18. (Microascales)

Graphium penicillioides Corda. 1837. Icones Fungorum 1: 18. (Microascales)

Collections Examined:

UAMH 3644 Prague, ex *Populus italica*. from Crane, J.L. as ILLS 35467 *Graphium penicillioides* PR 155518, slide from type of *Graphium penicillioides*.

UAMH 8493 United Kingdom, elm (*Ulmus procera*), M.J. Wingfield. from Nakase, T. as JCM 7440 *Graphium penicillioides* (=CBS 506.86).

UAMH 8494 Solomon Islands, forest soil, T. Matsushima (MFC 2097). from Nakase, T. as JCM 9300 *Graphium penicillioides* (=CBS 320.72), ex-type of *Stilbum basitruncatum*.

UAMH 8495 South Africa, M.J. Wingfield. from Nakase, T. as JCM 9331 *Graphium penicillioides* (=CBS 781.85).

Graphium cuneiferum (Berkeley & Broome) E.W. Mason & M.B. Ellis. 1953. Mycological Papers 56: 41.

= *Stilbum cuneiferum* Berkeley & Broome. 1875. Annals and Magazine of Natural History, Ser. 4, 15: 33

≡ *Sporocybe cuneifera* (Berkeley & Broome) Saccardo. 1886. Sylloge Fungorum 4: 606.

= *Graphium putredinus* auct. sensu Ellis 1971, Siefert and Okada 1993.

≠ *Stysanus putredinus* Corda. 1839. (= *Cephalotrichum putredinus*).

Collections Examined:

UAMH 8496 Tsukuba, Ibaraki Pref., Japan, grass, G. Okada (OFC 1384). from Nakase, T. as JCM 7866 *Graphium putredinus*.

UAMH 8860 Alberta, Canada, sputum, female 38 yr, Provincial Laboratory for Southern Alberta, Canada 18 Dec 1996. from Rennie, R. as MY 250.

UAMH 9318 Edmonton, Alberta, Canada, elm (*Ulmus*) wood, J.P. Tewari (97M-100) 1997. from Tewari, J.P. as *Graphium putredinus*.

Graphium tectonae C. Booth. 1964. Mycological Papers 94:5.

Collections Examined:

UAMH 9401 Jamaica, seeds of teak (*Tectona grandis*), C. Booth. from CBS as CBS 127.84 *Graphium tectonae* (=IMI 95673d, =JCM 9753), ex-type of *Graphium tectonae*.

Kernia Nieuwland. 1916. American Midland Naturalist 4: 379.

= *Magnusia* Saccardo. 1878. Michelia 1: 123. (nom. invalid., later homonym; non *Magnusia* Klotsch)

Type species: *Kernia nitida* (Saccardo) Nieuwland. 1916. Amer. Midl. Natur. 4:379.

Kernia hippocrepida Malloch & Cain. 1971. Canadian Journal of Botany 49: 855-867.

Collections Examined:

UAMH 6796 Ontario, Canada, house plant soil, Summerbell, R.C. (W 1916).

UAMH 9254 east of Brockville, Leeds Co., Ontario, Canada, dung of porcupine (*Erethizon dorsatum*), J. Krug 5 Sep 1965. from CBS as CBS 774.70 *Kernia hippocrepida* (=IMI 151078, =ATCC 22154, =TRTC 43764), ex-type of *Kernia hippocrepida*.

UAMH 9255 Ontario, Canada, maize-field soil, G.C. Bhatt. from CBS as CBS 389.69 *Kernia hippocrepida*.

Kernia hyalina Malloch & Cain. 1971. Canadian Journal of Botany 49: 860.

Collections Examined:

UAMH 8393 Aurora, Ontario, Canada, horse dung, J. Scott (JS237) 10 Feb 1994. from Malloch, D. as *Kernia hyalina.*

UAMH 9129 Potter, Cheyenne Co., Nebraska, USA, dung of cow, R. Cain 16 Aug 1964. from CBS as CBS 766.70 *Kernia hyalina* (=TRTC 45422, =ATCC 22155, =IMI 151079, =CBS 766.70, =TRTC 45422 holotype), ex-type of *Kernia hyalina.*

Kernia nitida (Saccardo) Nieuwland. 1916. American Midland Naturalist 4: 379.

≡ *Magnusia nitida* Saccardo. 1878. Michelia 1: 123.

= *Kernia brachytricha* (Ames) Benjamin. 1956. El Aliso 3: 344.

= *Kernia geniculotricha* Seth. 1968. Acta Botanica Neerlandica 17: 481.

Collections Examined:

UAMH 3060 Benjamin, R.K. RSA 207 (=ATCC 11223, =CBS 281.52), ex-type of *Kernia brachytricha.*

UAMH 8396 Mount Pleasant, Brant Co., Ontario, Canada, bird/mouse dung mix, J. Scott (JS 105) 13 Feb 1991. from Malloch, D. as *Kernia nitida.*

UAMH 8397 near Pink Lake State Park, Victoria, Australia, sheep dung, J. Scott (JS 276) 9 Feb 1995. from Malloch, D. as *Kernia nitida.*

UAMH 9044 Aktau, Mangyschlak Peninsula, Kazakhstan, camel dung on sandy soil under shrubs (*Rhamnus sintenisii*), M. Schnittler (6922b) 30 Apr 1995. from Krug, J.C. as TRTC 52071 *Kernia nitida.*

UAMH 9119 from NRRL as NRRL 1298 *Kernia brachytricha.*

UAMH 9120 Little Lake, California, USA, cow dung, G.F. Orr. from NRRL as NRRL A-7642 *Kernia nitida.*

UAMH 9121 Hamburg, Germany, rabbit dung. from NRRL as NRRL A-24186 *Kernia geniculotricha* (=IMI 133118, =ATCC 18529, =CBS 599.68), ex-type of *Kernia geniculotricha.*

Kernia ovata (Booth) Malloch & Cain. 1973. Mycologia 65: 1075.

≡ *Thielavia ovata* Booth. 1964. Mycological Papers 94: 7.

Collections Examined:

UAMH 8859 Jamaica, calyx of teak (*Tectona grandis*) seed, J.A.N. Burra Jul 1962. from Ito, T. as IFO 8792 *Kernia ovata* (=IMI 95673), ex-type of *Thielavia ovata.*

Kernia pachypleura Malloch & Cain. 1971. Canadian Journal of Botany 49: 864.

Collections Examined:

UAMH 8857 Japan, wood panel, K. Tubaki (Kita 2A-1-3) 1973. from Ito, T. as IFO 9864 *Kernia pachypleura.*

UAMH 8858 Japan, soil of paddy field, T. Yokoyama (WIII-4-5-25) 1977. from Ito, T. as IFO 30413 *Kernia pachypleura.*

UAMH 9256 Venezuela, dung of goat, J. Krug. from CBS as CBS 410.78 *Kernia pachypleura.*
UAMH 9282 Uganda, dung of elephant, D. Malloch. from CBS as CBS 776.70 *Kernia pachypleura* (=ATCC 22142, =IMI 151091, =TRTC 662166g), ex-type of *Kernia pachypleura.*

Kernia peruviana Udagawa & Furuya. 1988. Mycotaxon 33: 291-301.

Collections Examined:
UAMH 6494 Tamshiyacu, Iquitos, Peru, urea-treated soil, T. Akiyama 9 Jul 1987. from Udagawa, S.-I. as NIH 2985, ex-type of *Kernia peruviana.*

Kernia retardata Udagawa & Muroi. 1981. Transactions Mycological Society of Japan 22: 18.

Collections Examined:
UAMH 1327 Alberta Game Farm, Edmonton, Canada, soil ex donkey paddock, J.W. Carmichael 7 Jul 1962.
UAMH 1385 Alberta Game Farm, Edmonton, Canada, soil ex Cougar pen, J.W. Carmichael 18 Jul 1962.
UAMH 9026 Devonian Botanic Garden near Devon, Alberta, Canada, leaves of aspen (*Populus tremuloides*) on lawn with snow mold, S.P. Abbott (SA-M182) 21 Apr 1997. (=IMI 377815, =IFO 33037).
UAMH 9027 10 km south of Leduc, Alberta, Canada, dung of striped skunk (*Mephitis mephitis*) on ground in farm yard, S.P. Abbott (SA-M184) 10 Jun 1997.
UAMH 9134 Nishinasuno-machi, Nasu-gun, Tochigi, Japan, rice (*Oryza sativa*) field soil, T. Muroi 28 May 1978. from CBS as CBS 707.82 *Kernia retardata* (=NHL 2879), ex-type of *Kernia retardata.*
UAMH 9420 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S5A) 28 Sep 1998.
UAMH 9454 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S6H) 9 Feb 1999.
UAMH 9455 Elk Island National Park, Alberta, Canada, leaf litter under hazelnut (*Corylus cornuta*) and aspen (*Populus tremuloides*), S.P. Abbott (SA-M281) 7 Jan 1999.
UAMH 9500 Slave Lake, Alberta, Canada, rotted wood of white spruce (*Picea glauca*) log, stage 3 decay, 30 year post-fire site, T. Lumley (F681-01-S3E) 19 Feb 1999.
UAMH 9613 Perryvale, Alberta, Canada, living *Sphagnum fuscum* in bog, M.N. Thormann 1 Sep 1997.

Lophotrichus R.K. Benjamin. 1949. Mycologia 41: 347.

Type species: *Lophotrichus ampullus* R.K. Benjamin. 1949. Mycologia 41: 347.

Lophotrichus ampullus R.K. Benjamin. 1949. Mycologia 41: 347.

Collections Examined:
UAMH 1762 dung. from Anastasiou, C.J. (A12) as RSA 779 *Lophotrichus ampullus.*
UAMH 3067 Champaign, Illinois, USA. from Benjamin, R.K. as RSA 43 *Lophotrichus ampullus.*
UAMH 8626 10 km W of Bidar, near Khanapure, Forest Conservation Area, Karnataka State, Bidar Dist., India, soil under wild almond tree (*Terminalia catappa*), R.S. Khan 19 Dec 1989. from Krug, J.C. as TRTC 51963 *Lophotrichus bartlettii.*

UAMH 9122 Tuscon, Arizona, USA, guano and soil from cave, G.F. Orr (O-124) 3 Dec 1958. from NRRL as NRRL 2741 *Lophotrichus ampullus.*
UAMH 9123 Tuscon, Arizona, USA, guano and soil from cave, G.F. Orr (O-128) 3 Dec 1958. from NRRL as NRRL 2742 *Lophotrichus ampullus.*

Lophotrichus bartlettii (Massee & E.S. Salmon) Malloch & Cain. 1971. Canadian Journal of Botany 49: 866.

≡ *Magnusia bartlettii* Massee & E.S. Salmon. 1901. Annals of Botany 15: 333.

≡ *Kernia bartlettii* (Massee & E.S. Salmon) Benjamin. 1956. El Aliso 3: 344.

= *Enterocarpus grenotii* Locquin-Linard. 1977. Revue de Mycologie 41: 515.

= *Kernia bifurcotricha* Saxena & Mukerji. 1970. Transactions of the British Mycological Society 54: 146.

= *Lophotrichus brevirostratus* Ames. 1961. A Monograph of the Chaetomiaceae p. 52.

Collections Examined:
UAMH 8395 Metro Zoo, Toronto, Ontario, Canada, bison (*Bison bison*) dung, J. Scott (JS 253) 7 Sep 1994. from Malloch, D. as *Lophotrichus bartlettii.*
UAMH 8694 Nashville, York County, Ontario, Canada, rabbit dung, R.F. Cain. from DAOM as DAOM 146082 *Lophotrichus bartlettii* (=ATCC 22153, =TRTC 43829, =CBS 775.70).
UAMH 9036 10 km S of Leduc, Alberta, Canada, dung of striped skunk (*Mephitis mephitis*) on ground in farm yard, S.P. Abbott (SA-M186) 10 Jun 1997. (=IFO 33038).
UAMH 9124 seed, D. Johns (DJ 38) 5 Jan 1984, from NRRL as NRRL A-27250 *Lophotrichus bartlettii.*
UAMH 9257 180 km from El Golea, central Sahara, dung of fox (*Vulpes ruppeli*), M. Locquin-Linard, from CBS as CBS 380.78 *Enterocarpus grenotii*, ex-type of *Enterocarpus grenotii.*
UAMH 9283 Egypt, desert soil, J. Mouchacca, from CBS as CBS 277.75 *Lophotrichus bartlettii.*
UAMH 9287 India, dung of kangaroo, K.G. Mukerji (DU/KS 80). from ATCC as ATCC 18523 *Kernia bifurcotricha* IMI 141564, ex-type of *Kernia bifurcotricha.*

Lophotrichus macrosporus (Faurel & Locquin-Linard) Arx, Figueras & Guarro. 1988. Beihefte zur Nova Hedwigia 94: 27.

= *Kernia macrospora* Faurel & Locquin-Linard. 1977. Revue de Mycologie 41: 519.

Collections Examined:
UAMH 8394 near Pink Lake State Park, Victoria, Australia, sheep dung, J. Scott (JS 273) 15 Oct 1994. from Malloch, D. as *Kernia macrospora.*
UAMH 9258 Plateau d'Edehi, Tassili des Ajjer, central Sahara, dung of goat, M. Locquin-Linard, from CBS as CBS 379.78 *Kernia macrospora*, ex-type of *Kernia macrospora.*

Lophotrichus martinii Benjamin. 1949. Mycologia 41: 349.

Collections Examined:

UAMH 3066 from Benjamin, R.K. (RSA 45) as *Lophotrichus martinii*.
UAMH 8692 near Talara, Peru, rabbit dung, G.W. Martin Sep 1945. from DAOM as DAOM 146075, ex-type of *Lophotrichus martinii*.
UAMH 8693 Barton County, Kansas, USA, rat dung, T.E. Brooks 24 May 1950. from DAOM as DAOM 146083 *Lophotrichus martinii* (=TRTC 45466).
UAMH 9125 Georgia, USA, mouse dung, Jun 1940., from NRRL as NRRL 1716 *Lophotrichus martinii*.

Lophotrichus plumbescens Morinaga, Minoura & Udagawa. 1978. Transactions of the Mycological Society of Japan 19: 140..

Collections Examined:
UAMH 8710 Bangkok, Thailand, soil, T. Morinaga (HUT 4163) 8 Apr 1976. from Ito, T. as IFO 30864 *Lophotrichus plumbescens* (=ATCC 38285), ex-type of *Lophotrichus plumbescens*.

Microascus Zukal. 1885. Verhandlungen. Zoologisch-Botanische Gesellschaft in Wien 35: 339.

Type species: *Microascus longirostris* Zukal. 1885. Verhandlungen. Zoologisch-Botanische Gesellschaft in Wien 35: 339.

Microascus albonigrescens (Sopp) Curzi. 1931. Bollettino. Stazione de Patologia Vegetale di Roma 11: 60.

≡ *Acaulium albonigrescens* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 70.

= *Petriella proteophila* Horie & Udagawa. 1983. Mycotaxon 17: 334.

status anamorphosis:

Scopulariopsis proteophila Horie & Udagawa. 1983. Mycotaxon 17: 334.

Collections Examined:
UAMH 3168 Ontario, California, USA, sandy soil and dung of cattle feeder lot, J.W. Carmichael 6 Feb 1969.
UAMH 4757 Fort McMurray, Alberta, Canada, carnivore dung, R. Currah (81-189) 1983.
UAMH 4953 Mt. Kyozumi, Japan, forest soil treated with urea, Horie, Y. (81-AU-727-HA) 27 Jul 1981. from Udagawa, S.-I. as NHL 2913, ex-type of *Petriella proteophila*.
UAMH 8487 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S1F, 1-18B) 13 Sep 1995.
UAMH 8490 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S5H) 13 Sep 1995.
UAMH 8753 North Buck Lake near Lac La Biche, Alberta, Canada, debris of red squirrel (*Tamiasciurus hudsonicus*) midden under jack pine (*Pinus banksiana*), S.P. Abbott (SA-M158) 21 Oct 1996. (=IMI 377814, =IFO 33039).
UAMH 8851 Japan, K. Tubaki 1968. from Ito, T. as IFO 8988 *Microascus albo-nigrescens*.
UAMH 9148 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S4B, 4-16A) 16 Apr 1996.
UAMH 9322 Massachusetts, USA, R. Thaxter, Harvard University (50), from NRRL as NRRL 1571

Microascus vesparius.

UAMH 9529 Slave Lake, Alberta, Canada, wood of aspen (*populus tremuloides*) log, stage 3 decay, 15 year post-fire site, T. Lumley (F822-03-S1E) 29 Jan 1999.

Microascus brevicaulis S.P. Abbott. 1998. Mycologia 90: 298.

status anamorphosis:

Scopulariopsis brevicaulis (Saccardo) Bainier. 1907. Bulletin Societé Mycologique de France 23: 99.

≡ *Penicillium brevicaule* Saccardo. 1881. Fungi Italici No. 893.

= *Scopulariopsis koningii* (Oudemans) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 143.

≡ *Monilia koningii* Oudemans. 1902. in Oudemans and Koning, Archives Néerlandaises des Sciences, Sér. 2, 7: 287.

Collections Examined:

UAMH 76 Edmonton, Alberta, Canada, contaminant ex vaginal swab, J.W. Carmichael 17 Nov 1954.
UAMH 200 Edmonton, Alberta, Canada, agar plate exposed in animal autopsy room, J.W. Carmichael Nov 1954.
UAMH 228 Edmonton, Alberta, Canada, contaminant ex skin crural region, J.W. Carmichael 1954.
UAMH 231 Edmonton, Alberta, Canada, contaminant skin ex feet, J.W. Carmichael 1954.
UAMH 345 Edmonton, Alberta, Canada, skin from neck, J.W. Carmichael 1955.
UAMH 351 Edmonton, Alberta, Canada, vaginal swab, J.W. Carmichael 1955.
UAMH 352 Edmonton, Alberta, Canada, skin, J.W. Carmichael 1955.
UAMH 363 Edmonton, Alberta, Canada, hairs ex neck, J.W. Carmichael 1955, (=LSHB Sc.114, =IMI 86929).
UAMH 384 Edmonton, Alberta, Canada, sputum, J.W. Carmichael 1955.
UAMH 414 Edmonton, Alberta, Canada, upper lip and nasal passages, J.W. Carmichael 1955.
UAMH 415 Edmonton, Alberta, Canada, upper lip and nasal passages, J.W. Carmichael 1955.
UAMH 437 Edmonton, Alberta, Canada, contaminant, J.W. Carmichael Aug 1955.
UAMH 644 Mount Hawa, Zaire, silk worm chrysalis, R.L. Steycurt 1952. from IMI as IMI 49528, (=ATCC 36840).
UAMH 827 Edmonton, Alberta, Canada, mouse dung, J.W.Carmichael, 1960.
UAMH 901 white plaster mold or flour mold, Kneebone, L.R. as *Scopulariopsis fimicola.*
UAMH 916 Edmonton, Alberta, Canada, J.W. Carmichael 1961.
UAMH 919 Edmonton, Alberta, Canada, J.W. Carmichael 1961.
UAMH 920 Edmonton, Alberta, Canada, hair research, J.W. Carmichael 1961.
UAMH 921 Edmonton, Alberta, Canada, soil under tree, J.W. Carmichael 19 Mar 1961.
UAMH 922 Edmonton, Alberta, Canada, rodent survey, J.W. Carmichael 1961.
UAMH 925 strain Roper. from CBS as *Scopulariopsis brevicaulis.*
UAMH 926 var. alba strain Thom. from CBS as *Scopulariopsis brevicaulis* var. *alba*
UAMH 939 from NRRL as NRRL 1110 *Scopulariopsis brevicaulis* var. *hominis.*
UAMH 943 Caracas, Venezuela, 1955. from NRRL as NRRL A6185 *Scopulariopsis* sp.
UAMH 952 elephant, Martin-Scott Nov 1951. from Smith as LSHB Sc.8 (BB 269) *Scopulariopsis* sp. (=CBS 208.61, =IMI 86926)
UAMH 967 Edmonton, Alberta, Canada, J.W. Carmichael 1961.
UAMH 1197 Alberta Game Farm, Edmonton, Alberta, Canada straw ex birdhouse roosts, J.W. Carmichael 8 Nov 1961.
UAMH 1654 Edmonton, Alberta, Canada, nail left great toe, J.W. Carmichael 19 Mar 1963.

UAMH 2378 Toronto, Ontario, Canada, white pine inside galvanized fire door, Mar 1965. from Shields, J.K. as 656-21 *Chrysosporium* sp.

UAMH 3328 Edmonton, Alberta, Canada, contaminant on mannitol salt agar, J.W. Carmichael 11 Feb 1970.

UAMH 3618 Edmonton, Alberta, Canada, chronic leg granulomas, A. Sekhon Oct 1973. from Sekhon, A.S. as MY 4280 *Scopulariopsis* sp.

UAMH 3753 Lethbridge, Alberta, Canada, dead housefly larvae, R.G. Bell.

UAMH 5636 Saskatchewan, Canada, ex equine fetus, H. Congly. from Congly, H. as 180M *Scopulariopsis* sp.

UAMH 6219 Edmonton, Alberta, Canada, reverse of cotton duck canvas & wooden frame, oil painting, L. Sigler 9 Aug 1988.

UAMH 6877 Lethbridge, Alberta, Canada, *Megachile rotundata* (alfalfa leafcutting bee) larvae, D. Inglis (MR 1024) Aug 1990.

UAMH 7020 Lethbridge, Alberta, Canada, frass ex *Megachile rotundata* (alfalfa leafcutting bee) cadavers, D. Inglis (HD 240) Aug 1990.

UAMH 7473 Houston, Texas, USA, mitral valve ring, St. Luke's Episcopal Hospital (M7163). from Rinaldi, M.G. as UTHSC 93-2196.

UAMH 7770 Scandia, Alberta, Canada, indoor air ex RCS strip, from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 428) 11 Mar 1994, (=IFO 33040, =IMI 377809), holoytpe and ex-type of *Microascus brevicaulis.*

UAMH 7771 Scandia, Alberta, Canada, indoor air ex RCS strip, from Honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 38) 13 Dec 1993.

UAMH 7774 St. Lina, Alberta, Canada, indoor air ex RCS strip, from Honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 41) 10 Dec 1993, (=IFO 33051, =IMI 377810).

UAMH 7880 Calgary, Alberta, Canada, indoor air of basement of home ex RCS strip, S.P. Abbott (SA-M26) 10 Jan 1995.

UAMH 7918 Edmonton, Alberta, Canada, mixed air, plenum, ex bacterial RCS strip @ 35 C, S.P. Abbott (SA-M70) 22 Feb 1995, (=IMI 377812, =IFO 33052).

UAMH 7919 Red Deer, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M72) 9 Mar 1995.

UAMH 8400 Toronto, Ontario, Canada, rabbit dung, J. Scott (JS 170) 28 May 91. from Malloch, D. as *Scopulariopsis brevicaulis.*

UAMH 8401 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (056-121.1) 24 Feb 1994. from Malloch, D. as *Scopulariopsis brevicaulis.*

UAMH 8454 Thaxter 1905 (=Thom 480-2). from NRRL as NRRL 1096 *Scopulariopsis brevicaulis* (=IMI 40026, =LSHB Sc. 1, =IMI 61534, =CBS 467.48, =ATCC 7903).

UAMH 8497 Chuncheon, Korea, Meju, Korean fermented soybeans, J.D. Lee (A-1-2). from Nakase, T. as JCM 2619 *Scopulariopsis brevicaulis.*

UAMH 8499 Florida, USA, bath towel, Weston (FLA IA186) Apr 1946. from NRRL as NRRL A-1671 *Scopulariopsis brevicaulis.*

UAMH 8500 Biourge (350) 02 May 1924 (=Thom 4733.112.1). from NRRL as NRRL 1112 *Scopulariopsis brevicaulis.*

UAMH 8627 Barrhead, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M76) 20-Mar-1996.

UAMH 8628 15 km north of Mariana Lake, Alberta, Canada, burnt wood of black spruce (*Picea mariana*), S.P. Abbott (SA-M137) 16-Aug-1996.

UAMH 8629 east of Spruce Grove, Alberta, Canada, ex ascocarp of *Peziza vesiculosa* on decayed straw, S.P. Abbott (SA-M139) 11-Jul-1996.

UAMH 8702 Innisfail, Queensland, Australia, atmosphere, cleared site, J. Upsher 1985. from Montelli, L. as AMRL 1675 *Scopulariopsis brevicaulis.*

UAMH 8703 Innisfail, Queensland, Australia, atmosphere, cleared site, J. Upsher 1985. from Montelli, L. as AMRL 1512 *Scopulariopsis* sp.

UAMH 8709 Barrhead, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M77) 20 Mar 1996.

UAMH 8737 Sydney, New South Wales, Australia, wine cork, C. Davis 1980. from Hocking, A. as FRR 2342 *Scopulariopsis koningii.*

UAMH 8745 North Buck Lake, Alberta, Canada, freshwater snail shells on lakeshore, S.P. Abbott (SA-

M161) 21 Oct 1996.

UAMH 8746 North Buck Lake, Alberta, Canada, dung of white-tailed deer (*Odocoileus virginianus*) in pine/birch (*Pinus banksiana/ Betula papyrifera*) woods, S.P. Abbott (SA-M164) 18 Dec 1996.

UAMH 8747 15 km north of Mariana Lake, Alberta, Canada, burnt cones of black spruce (*Picea mariana*), S.P. Abbott (SA-M159) 21 Oct 1996.

UAMH 8748 Goldeye Lake near Nordegg, Alberta, Canada, dung of red squirrel (*Tamiaciurus hudsonicus*) in lodgepole pine (*Pinus contorta*) forest, S.P. Abbott (SA-M155) 15 Nov 1996, (=IFO 33049).

UAMH 8749 Fish Lake near Nordegg, Alberta, Canada, soil of lakeshore under white spruce (*Picea glauca*), S.P. Abbott (SA-M154) 15 Nov 1996.

UAMH 8750 Fish Lake near Nordegg, Alberta, Canada, dung of snowshoe hare (*Lepus americanus*) in white spruce (*Picea glauca*) forest, S.P. Abbott (SA-M153) 14 Nov 1996.

UAMH 8751 Fish Lake near Nordegg, Alberta, Canada, old basidiocarps of *Hydnum repandum* in white spruce (*Picea glauca*) forest, S.P. Abbott (SA-M152) 14 Nov 1996.

UAMH 8785 Manchester, UK, NCTC/ BCIRA 1930. from IMI as IMI 61424 *Scopulariopsis brevicaulis*, (=LSHB Sc. 5).

UAMH 8786 Vienna, Austria, Pribram Feb 1926. from IMI as IMI 91946 *Scopulariopsis brevicaulis*, (=LSHB Sc. 3).

UAMH 8787 Wanganui, New Zealand, air, F.J. Morton (H74) Dec 1961. from Young, J. as ICMP 1044 *Scopulariopsis brevicaulis*.

UAMH 8981 Formosa, soil, NRRL isolate (13) Jun 1952. from NRRL as NRRL A-3865 *Scopulariopsis* sp.

UAMH 9038 Scandia, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (OHS 109) 13 Dec 1993.

UAMH 9039 Camp Creek, Alberta, Canada, indoor air ex RCS strip, honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 339) 24 Mar 1994.

UAMH 9040 Winnipeg, Manitoba, Canada, outside air ex RCS strip, S.P. Abbott (SA-M31) 21 Dec 1994.

UAMH 9041 Barrhead, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M85) 20 Mar 1996.

UAMH 9090 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 4) 5 May 1997, + mating type.

UAMH 9091 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 10) 5 May 1997, + mating type.

UAMH 9092 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 3) 5 May 1997, - mating type.

UAMH 9093 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 7) 5 May 1997, - mating type.

UAMH 9139 Netherlands, pupa of *Pteronus pini*, J. Rozsypal. from CBS as CBS 335.35 *Scopulariopsis flava*.

UAMH 9140 France, O. da Fonseca. from CBS as CBS 152.22 *Scopulariopsis flava* (=IMI 86928, =LSHB Sc. 62, =MUCL 9044).

UAMH 9145 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S1C-4-15B) 15 Apr 1997, (=DAOM 225611).

UAMH 9253 Gregoire Lake Provincial Park, Alberta, Canada, twig of aspen (*Populus tremuloides*), S.P. Abbott (SA-M229) 2 Mar 1998, (=DAOM 225612).

UAMH 9320 Sherwood Park, Alberta, Canada, decayed wood (2x4) in basement of home, S.P. Abbott (SA-M238) 24 Jul 1998.

UAMH 9367 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S1D) 28 Sep 1998.

UAMH 9406 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 1) 5 May 1997, - mating type.

UAMH 9407 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8627, S.P. Abbott (Mb 8) 5 May 1997, + mating type.

UAMH 9458 30 km east of Nordegg, Alberta, Canada, dung of moose (*Alces alces*) in black spruce (*Picea marianna*) forest, S.P. Abbott (SA-M136) 17 Jun 1996.

Microascus caviariformis Malloch & Hubart. 1987. Canadian Journal of Botany 65: 2384.

Collections Examined:

UAMH 5592 Prov. de Liege, Flemalle, Belgium, decaying meat in cave of Ramioul, J. Hubart Jun 1985. from Krug, J.C. as TRTC 50940 *Microascus caviariformis* (=CBS 536.87), ex-type of *Microascus caviariformis*.

UAMH 6112 Grotte de Rosee, Belgium, meat left in cave 6 months, J. Hubart Sep 1987. from Malloch, D. as *Microascus caviariformis*.

Microascus cinereus (Emile-Weil & Gaudin) Curzi. 1931. Bollettino. Stazione de Patologia Vegetale di Roma 11: 60.

≡ *Scopulariopsis cinerea* Emile-Weil & Gaudin. 1919. Archives de Medecine Experimentale et d'Anatomie Pathologique 28: 452.

= *Microascus griseus* Mathur et al. 1962. Sydowia 16: 47.

= *Microascus pedrosoi* Fuentes & Wolfe. 1956. Mycologia 48: 63.

Collections Examined:

UAMH 1581 Edmonton, Alberta, Canada., contaminant, J.W. Carmichael Feb 1963.

UAMH 5315 Takatori, K. 1011-2.

UAMH 7455 Tyler, Texas, USA, bronchial wash, male 81 yr. from Harris, J. as *Microascus* sp.

UAMH 8505 Kampala, Uganda, Kibuka-Serunkuma (808) 17 Feb 1971. from NRRL as NRRL A-18426 *Doratomyces putredinus*.

UAMH 8681 Edmonton, Alberta, Canada, toenail (DE+), C. Sand 31 Jul 1996. from Rennie, R. as MY 3499 *Scopulariopsis* sp.

UAMH 8842 Japan, paddy field soil, T. Yokoyama (YV-3-5-31) 1985. from Ito, T. as IFO 31841 *Microascus cinereus*.

UAMH 8889 Norwood Technical College, England, UK, soil, J.I. Mendy May 1959. from Untereiner, W. as MUCL 9048 *Microascus cinereus*, (=IMI 75542, =LSHB Sc. 35, =CBS 195.61).

UAMH 9094 Alberta, Canada, sputum, Provincial Laboratory for Southern Alberta F 43 yr, 12 Aug 1997. from Rennie, R. as MY 4894 *Scopulariopsis brumptii*.

UAMH 9323 Jamaica, coffee, D. Johns 11 Apr 1984. from NRRL as NRRL A-27373 *Microascus desmosporus*.

UAMH 9324 California, USA, soil, G. Orr (O-423) 29 Aug 1958. from NRRL as NRRL A-8020 *Microascus cinereus*, (=CBS 666.71).

UAMH 9366 Maqua Lake near Fort McMurray, Alberta, Canada, grouse dung in black spruce (*Picea mariana*) forest, S.P. Abbott (SA-M272) 15 Sep 1998.

UAMH 9390 California, USA, lung of man, G.F. Orr. from CBS as CBS 664.71 *Microascus cinereus*, ex-type of *Microascus reniformis*.

UAMH 9391 Maharashtra, India, soil, M.J. Thirumalachar (HACC 1252). from CBS as CBS 365.65 *Microascus cinereus*, (=ATCC 16204, =IMI 113680), ex-type of *Microascus griseus*.

UAMH 9392 A. Lechmère, from CBS as CBS 126.14 *Microascus cinereus*, (=LSHB Sc. 79, =IMI 86916), ex-type of *Peristomium desmosporum* v. *verticillium*.

UAMH 9486 Muskeg Road SW of Boyle, Alberta, Canada, wood of willow (*Salix discolor*) branches, intermediate stage decay, S.P. Abbott (SA-M282) 20 Jan 1999.

Microascus cirrosus Curzi. 1930.Bollettino. Stazione de Patologia Vegetale di Roma 10: 308.

Collections Examined:

UAMH 334 Edmonton, Alberta, Canada, skin from hand, J.W. Carmichael.

UAMH 963 Thom 5207, from NRRL as NRRL 1689 *Nephrospora microascus*, (=CBS 301.61, =GenBank M89993, =IMI 86914, =LSHB Sc.71).

UAMH 965 Italy, decayed *Prunus* leaves, M. Curzi 1930. from CBS as CBS 217.31 *Microascus cirrosus* (=UAMH 9389), ex-type of *Microascus cirrosus*.

UAMH 966 soil, K. Domsch, from CBS as CBS 240.58 *Microascus cirrosus*, (=IMI 86913).

UAMH 7322 Edmonton, Alberta, Canada, bronchial washing, female 69 yr, C. Sand 16 Dec 1992. from Rennie, R. as MY 5861.

UAMH 7456 ex Rt knee lesion, bone marrow transplant patient, male 12 yrs + mass in upper lobe of Rt lung. from Rinaldi, M.G. as UTHSC 92-780 *Microascus cinereus*.

UAMH 7580 Edmonton, Alberta, Canada, ex bronchial wash, female, 61 yr, Grey Nuns Hospital 17 Dec 1993. from Rennie, R. as MY 0255.

UAMH 8212 Pennsylvania, USA, ex bronchoalveolar lavage, female, Presbyterian University Hospital (F15666) 1995. from Rinaldi, M.G. as UTHSC 95-1180 *Microascus cirrosus*.

UAMH 8504 France, soil, J. Guillemat & J. Montegut (AS75) 1956. from NRRL as NRRL A-7373 *Microascus* sp.

UAMH 8887 Italy, root of grape (*Vitis vinifera*), M. Curzi. from Untereiner, W. as MUCL 9050 *Microascus cirrosus*, (=CBS 277.34).

UAMH 8888 Italy, ex man, G. Pollacci 1927. from Untereiner, W. as MUCL 7915 *Microascus cirrosus*, (=CBS 213.27, =LSHB Sc. 84, =IMI 36480), ex-type of *Torula paisii*.

UAMH 8978 ear, D. Fennell (E-7-16) 11 Oct 1972. from NRRL as NRRL A-20199 *Scopulariopsis constantini*.

UAMH 9325 California, USA, G. Orr (O-380) 29 Aug 1958. from NRRL as NRRL A-8023 *Microascus* sp.

UAMH 9326 Arizona, USA, G. Orr (O-381) 29 Aug 1958. from NRRL as NRRL A-8024 *Microascus* sp.

UAMH 9327 G. Orr (O-424) 29 Aug 1958. from NRRL as NRRL A-8021 *Microascus cirrosus*.

UAMH 9389 Italy, decayed leaf of *Prunus*, M. Curzi 1930. from CBS as CBS 217.31 *Microascus cirrosus*, (=UAMH 965), ex-type of *Microascus cirrosus*.

Microascus exsertus Skou. 1973. Antonie van Leeuwenhoek 39: 529.

≡ *Pithoascus exsertus* (Skou) Arx. 1973. Persoonia 7: 373.

Collections Examined:

UAMH 8698 Denmark, cocoon of leaf-cutting bee (*Megachile willoughbiella*), J.P. Skou (825). from DAOM as DAOM 146087, (=CBS 819.70, =ATCC 28361), ex-type of *Pithoascus exsertus*.

Microascus giganteus Malloch. 1970. Mycologia 62: 731.

Collections Examined:

UAMH 9425 South of Coldwater, Simcoe Co., Ontario, Canada, insect frass in dead log, D. Malloch 12 Oct 1968. from CBS as CBS 746.69 *Microascus giganteus*, (=TRTC 45434, =ATCC

18771), ex-type of *Microascus giganteus*.

Microascus intermedius Emmons & Dodge. 1931. Mycologia 23: 324.

≡ *Pithoascus intermedius* (Emmons and Dodge) Arx. 1973. Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, Series C, 76: 292.

Collections Examined:

UAMH 656 Charlborn, North Carolina, USA, diseased roots strawberry (*Fragaria vesca*), Emmons and Dodge 1930. from CBS as CBS 217.32, (=IMI 86917), ex-type of *Microascus intermedius*.

UAMH 2469 Edmonton, Alberta, Canada, hair ex scalp, J.W. Carmichael 1 Mar 1965.

UAMH 6954 Bidar, Karnataka State, India, field soil, R. Khan 18 Dec 1989. from Khan, R. as TRTC 51200 *Microascus intermedius*.

UAMH 8697 Kentville, Nova Scotia, Canada, seed of lowbush blueberry (*Vaccinium angustifolium*), C.O. Gourley (KP 3080a) June 1978. from DAOM as DAOM 169158 *Pithoascus intermedius*, (=ATCC 38876).

UAMH 8840 Japan, soil, T. Ito (1724-E3) 1989. from Ito, T. as IFO 32232 *Pithoascus intermedius*.

UAMH 9043 3 km north of Bidar, Bidar Dist., Karnataka State, India, soil from interior building of ruins of Bidar Fort, R.S. Khan 18 Dec 1989. from Krug, J.C. as TRTC 52054 *Microascus* sp.

UAMH 9136 Germany, ex man, tinea plantaris, H. Listemann. from CBS as CBS 103.85 *Pithoascus nidicola*.

UAMH 9328 Georgia, USA, soil, C. Emmons (5916) Oct 1956. from NRRL as NRRL A-6904 *Microascus* sp.

Microascus longirostris Zukal. 1885. Verhandlungen. Zoologisch-Botanische Gesellschaft in Wien 35: 339.

= *Microascus variabilis* Massee & E.S. Salmon. 1901. Annals of Botany 15: 349.

Collections Examined:

UAMH 408 Edmonton, Alberta, Canada, ex finger nails, J.W. Carmichael 1955.

UAMH 4833 Slave Lake, Alberta, Canada, coyote (*Canis latrans*) dung, L. Sigler 1 Sep 1983.

UAMH 7957 New Britain, Connecticut, USA, ex bronchial wash. from Rinaldi, M. as UTHSC 95-696 *Microascus cirrosus*.

UAMH 8354 Prince Albert, Saskatchewan, Canada, indoor air of woodroom ex RCS strip, S.P. Abbott (SA-M52) 8-Dec-1995. (=IFO 33041).

UAMH 8841 Netherlands, skin of squirrel (*Sciurus vulgaris*), 1949. from Ito, T. as IFO 7029 *Microascus longitostris*, (=CBS 267.49).

UAMH 9042 north of Lac La Biche, Alberta, Canada, lung of northern flying squirrel (*Glaucomys sabrina*), J. Csotonyi 31 Jan 1997. from Currah, R.S. as J31/21-1BT *Microascus longirostris*.

UAMH 9151 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen log with hollow core (*Populus tremuloides*), T. Lumley (EI-13-S5C, 8-14I) 14 Aug 1996.

UAMH 9329 Kittery Point, Maine, USA, wasp nest, Harvard University (51) Jun 1940. from NRRL as NRRL 1717 *Microascus longirostris*, (=IMI 86908, =LSHB Sc. 43, =CBS 196.61, =MUCL 9058).

UAMH 9432 C. Emmons (5701) Jan 1947. from NRRL as NRRL A-2018 *Microascus lunasporus*.

Microascus manginii (Loubière) Curzi. 1931. Bollettino. Stazione di Patologia Vegetale di Roma 11: 60.

≡ *Nephrospora manginii* Loubière. 1923. Comptes Rendus. Academie des Sciences (Paris) 177: 209.

= *Scopulariopsis alboflavescens* Zach. 1934. Österreichische Botanische Zeitschrift 83: 177.

status anamorphosis:

Scopulariopsis candida Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 143.

≡ *Monilia candida* auct, sensu Guéguen. 1899. Bulletin Societé Mycologique de France 15: 271. (non Persoon; non Bonorden).

≠ *Monilia candida* Persoon. 1801. Synopsis methodica fungorum. (=*Aspergillus* fide Vuillemin 1911).

≠ *Monilia candida* Bonorden. 1851. Handbuch der allgemeinen mykologie. (=*Monilia bonordenii* Vuillemin 1911).

= *Chrysosporium keratinophilum* var. *denticolum* Moreau. 1969. Mycopathologia et Mycologia Applicata 37: 37. (nom invalid, ICBN Art. 36).

Collections Examined:

UAMH 238 Edmonton, Alberta, Canada, skin from chin, J.W. Carmichael 1954.
UAMH 931 from CBS as *Scopulariopsis rufulus*.
UAMH 934 Austria, diseased skin of man, F. Zach. from CBS as CBS 399.34 *Scopulariopsis alboflavescens*, ex-type of *Scopulariopsis alboflavescens*.
UAMH 937 Biourge (372) 1924. from NRRL as NRRL 1106 *Penicillium brevicaule* var. *album*, (=LSHB Sc.103).
UAMH 938 Bureau of Dairy Industry, USDA, abnormal cheese, L.A. Rogers June 1938. from NRRL as NRRL 1109 *Scopulariopsis brevicaulis* var. *glabra*, (=LSHB Sc.106).
UAMH 940 France, L. Mangin 1927. from NRRL as NRRL 2157 *Scopulariopsis brevicaulis* var. *glabra*, (=LSHB Sc.107).
UAMH 944 from NRRL as NRRL 1107 *Penicillium brevicaule* var. *album*, (=LSHB Sc.104).
UAMH 945 from NRRL as NRRL 1108 *Penicillium brevicaule* var. *album*, (=LSHB Sc.105).
UAMH 957 U.K., toenail, Feb 1959. from Smith as LSHB Sc.33 *Scopulariopsis candida*.
UAMH 958 human lesion, Nov 1959. from Smith as LSHB Sc.36 *Scopulariopsis candida*, (=IMI 73030).
UAMH 959 from Smith as LSHB Sc.55 *Scopulariopsis candelabrum*.
UAMH 961 soil, 1952. from Smith as LSHB Sc.12 (BB 299) *Acaulium* sp.
UAMH 1242 Toronto, Ontario, Canada, cedar cooling tower, J.W. Carmichael 1962.
UAMH 1923 Burma, milled rice, 1954. from Udagawa, S.-I. as NHL 2278 *Microascus manginii* (=CBS 250.64, =IFO 7555).
UAMH 2044 Italy, soil, Varsavsky EV I-7(2). from Orr, G.F. as *Chrysosporium*.
UAMH 2470 Edmonton, Alberta, Canada, rash ex neck, J.W. Carmichael 9 Apr 1965.
UAMH 2642 Guelph, Ontario, Canada, chicken litter, G.L. Barron (10490) Jan 1966, (=ATCC 16685, =CBS 506.66).
UAMH 2710 Edmonton, Alberta, Canada, head lesions ex chicken, J.W. Carmichael 1967.
UAMH 3568 Chile, soil, Zaror, L. (T59), (=DAOM 225613).

UAMH 4065 Edmonton, Alberta, Canada, spruce lumber, A. Jobson.
UAMH 4367 lymphatic lesions on horse, from CDC as CDC B-3390, (=CDC 81-003005).
UAMH 4975 Katowice, Poland, aerobically digested sewage sludge, K. Ulfig (14) 1984.
UAMH 7882 Grimshaw, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 173) 30 Jan 1994.
UAMH 7902 New Zealand, ex Lt great toenail, female 74 yr, DE+, D. Parr (268).
UAMH 7921 Red Deer, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M73) 9 Mar 1995, (=IMI 377813, =IFO 33042).
UAMH 7924 Edmonton, Alberta, Canada, ex nail, Rt great toe, male 63 yr, DE+, C. Sand 20 Feb 1995. from Rennie, R. as MY 0563.
UAMH 7930 Edmonton, Alberta, Canada, ex nail, male 72 yr, Fielding, J. (F5188 8) Feb 1995.
UAMH 8359 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (128-121.2) 13 Apr 1994. from Malloch, D. as *Scopulariopsis candida*.
UAMH 8360 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (322-120.2) 16 Jun 1994. from Malloch, D. as *Scopulariopsis candida*.
UAMH 8361 Ottawa, Ontario, Canada, swab from home, D. Malloch (M22-2C) Dec 1995. from Malloch, D. as *Scopulariopsis* sp.
UAMH 8404 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (138-110.1) 14 Mar 1994. from Malloch, D. as *Scopulariopsis candida*.
UAMH 8405 Wallaceburg, Ontario, carpet dust from home, D. Malloch (139-121.2) 14 Apr 1994. from Malloch, D. as *Scopulariopsis candida*.
UAMH 8683 NRRL isolate, USA, ammoniated corn, R.J. Boothast 16 Jun 1976. from NRRL as NRRL A-22796 *Microascus* sp.
UAMH 8708 Winnipeg, Manitoba, Canada, indoor air ex RCS strip, S.P. Abbott (SA-M37) 31 Aug 1995.
UAMH 8796 Lucknow, India, J.N. Rai 1967. from IMI as IMI 128461 *Microascus manginii*.
UAMH 8797 UK, buckwheat chaff, A. Donnelly 1974. from IMI as IMI 182498 *Microascus manginii*.
UAMH 8798 France, C. Moreau 1969. from IMI as IMI 139629 *Scopulariopsis candida*, ex-type of *Chrysosporium keratinophilum* var. *denticola*.
UAMH 8944 Lac La Biche, Alberta, Canada, lung, northern flying squirrel (*Glaucomys sabrina*), J. Csotonyi 24 Apr 1997. from Currah, R.S. as A24/107/1MT/1c.
UAMH 8977 Arizona, USA, dung, G.F. Orr (O-425) 29 Aug 1958. from NRRL as NRRL A-8022 *Microascus manginii*.
UAMH 9004 Chilliwak, British Columbia, Canada, indoor air of office building ex Andersen sampler, S.P. Abbott (SA-M175) 27 Mar 1997, (=DAOM 225614, =IFO 33043).
UAMH 9135 France, L. Mangin. from CBS as CBS 170.27 *Microascus manginii*, (=IMI 86931, =LSHB Sc. 83), ex-type of *Microascus manginii*.
UAMH 9146 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen log with hollow core (*Populus tremuloides*), T. Lumley (EI-13-S5C, 6-26H) 26 Jun 1996.
UAMH 9147 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3E, 2-11A) 11 Feb 1997.
UAMH 9174 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3B, 2-11A) 11 Feb 1997.
UAMH 9293 Alberta, Canada, sputum, male 50 yr, Provincial Laboratory for Southern Alberta Jun 1998. from Rennie, R. as MY 3408.98.

Microascus microcordiformis T. Matsushima. 1996. Matushima. Mycological Memoirs 9: 16.

Collections Examined:

UAMH 9176 Pella Mission Station, South Africa, soil, T. Matsushima (MFC-6K057) 09 Sep 1995. from Matsushima, T. as MFC-6K057 *Microascus microcordiformis*, ex-type of *Microascus microcordiformis*.

Microascus nidicola Massee and E.S. Salmon. 1901. Annals of Botany 15: 313.

≡ *Pithoascus nidicola* (Massee and E.S. Salmon) Arx. 1973. Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, Series C, 76: 292.

Collections Examined:

UAMH 8979 Utah, USA, kangaroo rat (*Dipodomys merriami*), C.W. Emmons (A 1671) Oct 1956. from NRRL as NRRL A-6894 *Microascus nidicola*, (=CBS 197.61, =IMI 86918, =LSHB Sc. 44).

UAMH 8980 Utah, USA, soil, C.W. Emmons (A 1836) Oct 1956. from NRRL as NRRL A-6913 *Microascus nidicola*.

UAMH 9487 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8979, S.P. Abbott (Mn-4) 10 Jul 1998.

UAMH 9488 UAMH, Alberta, Canada, single ascospore isolate ex UAMH 8979, S.P. Abbott (Mn-8) 10 Jul 1998.

Microascus niger (Sopp) Curzi. 1931. Bollettino. Stazione di Patologia Vegetale di Roma 11: 60.

≡ *Acaulium nigrum* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 47.

status anamorphosis:

Scopulariopsis asperula (Saccardo) S. Hughes. 1958. Canadian Journal of Botany 36: 803.

≡ *Torula asperula* Saccardo 1882. Michelia 2: 560.

= *Scopulariopsis fusca* Castellani. 1930. British Journal of Dermatology and Syphilis 42: 365.

= *Scopulariopsis bestae* (Pollacci) Nannizzi. 1934. Trattato di micopatologia umana 4: 254.

≡ *Torula bestae* Pollacci. 1922. Riv. Biol. 4: 317.

= *Scopulariopsis arnoldii* (Mangin & Patouillard) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 148.

≡ *Monilia arnoldii* Mangin & Patouillard. 1908. Bulletin Societé Mycologique de France 24: 164.

= *Scopulariopsis roseola* Inagaki. 1962. Transactions of the Mycological Society of Japan 4: 1.

Collections Examined:

UAMH 216 Edmonton, Alberta, Canada, skin from foot, J.W. Carmichael 1955, (=LSHB Sc.109).

UAMH 347 Edmonton, Alberta, Canada, skin ex upper lip, J.W. Carmichael 1955, (=LSHB Sc.112).

UAMH 355 Edmonton, Alberta, Canada, skin ex face & chest, J.W. Carmichael 1955, (=LSHB Sc.113).

UAMH 440 Edmonton, Alberta, Canada, skin ex foot, J.W. Carmichael 1955, (=LSHB Sc.115).

UAMH 460 Edmonton, Alberta, Canada, skin ex neck, J.W. Carmichael 6 Dec 1955, (=LSHB Sc.116).

UAMH 917 Edmonton, Alberta, Canada, routine mycology, J.W. Carmichael 1961, (=LSHB Sc.120).
UAMH 923 strain Magnin. from CBS as *Scopulariopsis arnoldi*, (=LSHB Sc. 49).
UAMH 924 strain Pollacci. from CBS as CBS 289.38 *Scopulariopsis bestae*, (=LSHB Sc.51, =IMI 86927), ex-type of *Torula bestae*.
UAMH 930 Austria, carcass of rabbit, strain Zach. from CBS as CBS 401.34 *Scopulariopsis fusca*, (=IMI 86934, =LSHB Sc.58), ex-type of *Scopulariopsis fusca*
UAMH 941 from NRRL as NRRL 1111 *Scopulariopsis casei*.
UAMH 949 U.K., moldy packing straw, Smith Feb 1956. from Smith as LSHB Sc.16 (BB 315) *Scopulariopsis arnoldi*, (=IMI 63214).
UAMH 950 Perranporth, U.K., garden soil, Jun 1952. from Smith as LSHB Sc.37 *Scopulariopsis arnoldi*.
UAMH 951 London, U.K., moldy carmine, Mar 1937. from Smith as LSHB Sc.13 *Scopulariopsis arnoldi*, (=IMI 86932).
UAMH 955 strain Lab. Crypt., Paris. from Smith as LSHB Sc. 61 *Scopulariopsis rubellus*, (=IMI 86924).
UAMH 1322 Alberta Game Farm, Edmonton, Alberta, Canada, soil cougar pen, J.W. Carmichael 7 Jul 1962.
UAMH 7879 Girouxville, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 207) 30 Jan 1994, (=IFO 33047, =IMI 377811).
UAMH 8362 Ottawa, Ontario, Canada, swab from home, D. Malloch (M22-2C) Dec 1995. from Malloch, D. as *Scopulariopsis* sp.
UAMH 8682 Valley of the Five Lakes, Jasper National Park, Alberta, Canada, Marten (*Martes americana*) dung, S.P. Abbott (SA-M142) 13 May 1996.
UAMH 8706 Barrhead, Alberta, Canada, indoor air of office ex RCS strip, S.P. Abbott (SA-M78) 28 Mar 1996.
UAMH 8847 Japan, wheat flour, N. Inagaki (I-391) 1962. from Ito, T. as IFO 7564 *Scopulariopsis roseola*, ex-type of *Scopulariopsis roseola*.
UAMH 8984 Missouri, hay, D.T. Wicklow (DTW-001) 12 Feb 1992. from NRRL as NRRL A-28654 *Scopulariopsis fusca*.
UAMH 9029 10 km south of Leduc, Alberta, Canada, dung of striped skunk (*Mephitis mephitis*) on ground in farm yard, S.P. Abbott (SA-M183) 10 Jun 1997, (=IMI 377816, =IFO 33048).
UAMH 9037 Saskatoon, Saskatchewan, Canada, outside air ex RCS strip, S.P. Abbott (SA-M24) 28 Nov 1994.
UAMH 9095 Alberta, Canada, right great toe, male 54 yr, Provincial Laboratory for Southern Alberta 18 Aug 1997. from Rennie, R. as MY 4135 *Scopulariopsis fusca*.
UAMH 9144 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3G, 2-11D) 11 Feb 1997.
UAMH 9489 UAMH, Alberta, Canada, mating cross UAMH 8362 X 9037, S.P. Abbott 17 Apr 98, neotype of *Microascus niger*.
UAMH 9490 UAMH, Alberta, Canada, mating cross UAMH 7879 X 9037, S.P. Abbott 17 Apr 98.
UAMH 9491 UAMH, Alberta, Canada, mating cross UAMH 8847 X 9037, S.P. Abbott 17 Apr 1998.

Microascus pyramidus G.L. Barron & J.C. Gilman. 1961. Canadian Journal of Botany 39: 1618.

Collections Examined:
UAMH 9400 California, USA, desert soil, G.F. Orr. from CBS as CBS 212.65 *Microascus pyramidus*, (=ATCC 36763, =IMI 109887), ex-type of *Microascus pyramidus*.

Microascus schumacheri (Hansen) Curzi. 1931. Bollettino. Stazione di Patologia Vegetale di Roma 11: 60.

≡ *Sphaerella schumacheri* Hansen. 1877. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i Khobenhavn, p. 37.

≡ *Rosellinia schumacheri* (Hansen) Saccardo. 1882. Sylloge Fungorum 1: 276.

≡ *Pithoascus schumacheri* (Hansen) Arx. 1973. Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, Series C, 76: 292.

Collections Examined:

UAMH 9137 Peurto de la Quesera, Spain, soil, A. Martinez 1985. from CBS as CBS 435.86 *Pithoascus schumacheri*.

Microascus senegalensis Arx. 1975. Persoonia 8: 194.

Collections Examined:

UAMH 8799 Venezuela, stored grains, C. Mazzani (7-1C) 1982. from IMI as IMI 269128 *Microascus senegalensis*.

UAMH 9388 Senegal, mangrove soil, J.A. von Arx. from CBS as CBS 277.74 *Microascus senegalensis*, ex-type of *Microascus senegalensis*.

Microascus singularis (Saccardo) Malloch & Cain. 1971. Canadian Journal of Botany 49: 859.

≡ *Fairmania singularis* Saccardo. 1906. Annales Mycologici 4: 276.

= *Microascus doguetii* Moreau. 1953. Revue de Mycologie 18: 177.

Collections Examined:

UAMH 1938 Tokyo, Japan, laboratory contaminant, S. Udagawa 1962. from Udagawa, S.-I. as NHL 2297 *Microascus doguetii*.

UAMH 2637 Cambridge, Massachusetts, USA, barrel bottom, Thaxter (Harvard Univ. 47) 1904. from Barron, G.L. as OAC 10484 *Microascus doguetti*, (=ATCC 16684, =CBS 505.66, =IMI 86909).

UAMH 8618 Elk Island National Park, AB, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3G, 8-8F) 08 Aug 1996.

UAMH 9152 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S1C, 4-29C) 29 Apr 1996.

UAMH 9153 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S4F-2-11B) 11 Feb 1997.

UAMH 9175 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen log with hollow core (*Populus tremuloides*), T. Lumley (EI-13-S3D, 5-30A) 30 May 1996.

UAMH 9330 Tokyo, Japan, laboratory contaminant, S. Udagawa 1962. from NRRL as NRRL A-13013 *Microascus doguettii*, (=UAMH 1938, =NHL 2297, =CBS 414.64).

Microascus soppii S.P. Abbott, sp. nov.

status anamorphosis:

Scopulariopsis flava (Sopp) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 43.

≡ *Acaulium flavum* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 53.

= *Blastomycoides lanuginosus* Castellani. 1930. British Journal of Dermatology and Syphilis 42: 365.

≡ *Glenospora lanuginosa* (Castellani) Agostini. 1931. Atti. Instituto Botanico e Laboratorio Crittogamico. Universita di Pavia. III (Ser. IV): 67.

Collections Examined:

UAMH 831 strain Castellani, from CBS as CBS 187.33 *Glenospora lanuginosa*, ex-type of *Glenospora lanuginosa*.

UAMH 942 Pacific Grove, California, USA, sandy loam, A.L. Cohen. from NRRL as NRRL 1848 *Scopulariopsis* sp., (=LSHB Sc.68, =IMI 86923).

UAMH 8895 United Dairies, England, UK, cheese, G. Smith (LSHB BB230) 1948. from Untereiner, W. as MUCL 9031 *Scopulariopsis flava*, (=IMI 86921, =LSHB Sc. 7, =CBS 207.61).

UAMH 9167 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3E) 09 Jan 1997.

UAMH 9168 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3F, 2-11B1) 11 Feb 1997.

UAMH 9169 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen log with hollow core (*Populus tremuloides*), T. Lumley (EI-13-S4G) 09 Jun 1997.

UAMH 9170 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3D, 8-9E) 09 Aug 1996.

UAMH 9171 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3G, 2-11E) 11 Feb 1997.

UAMH 9172 Elk Island National Park, Alberta, Canada, decayed wood (stage 2 decay), white spruce log (*Picea glauca*), T. Lumley (EI-09-S3J, 7-5B) 05 Jul 1996.

UAMH 9201 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S3A, 11-26B) 26 Nov 1996.

UAMH 9202 Slave Lake, Alberta, Canada, dry, rotted wood (stage 3 decay), aspen log (*Populus tremuloides*) in 25 yr post-harvest site, T. Lumley (H681-01-S2F, 2-25A) 25 Feb 1997.

UAMH 9492 Elk Island National Park, Alberta, Canada, rotted wood of aspen (*Populus tremuloides*) log, intemediate stage decay, T. Lumley (EI-13-S3G, 12-6A) Dec 6 1997.

Microascus stoveri (Arx) S.P. Abbott, comb. nov.

≡ *Pithoascus stoveri* Arx. 1973. Persoonia 7: 373.

status anamorphosis:

Papulaspora stoveri Warren. 1948. Mycologia 40: 400.

Collections Examined:

UAMH 9138 Ohio, USA, root of sugar beet (*Beta vulgaris*) seedling, W.L. White. from CBS as CBS

176.71 *Pithoascus stoveri*, (=ATCC 11173), ex-type of *Pithoascus stoveri*.

Microascus trigonosporus Emmons & Dodge. 1931. Mycologia 23: 317.

= *Microascus trigonosporus* var. *terreus* Kamyschko. 1966. Novosti Sistematiki Nizshikh Rastenii, p. 175.

= *Microascus trigonosporus* var. *macrosporus* Orr. 1961. in Barron, Cain, and Gilman, Canadian Journal of Botany 39: 1617.

status anamorphosis:

Scopulariopsis trigonospora Emmons & Dodge. 1931. Mycologia 23: 317.

Collections Examined:

UAMH 655 oats (*Avena sativa*), M. Whitehead (3). from CBS as CBS 272.49.

UAMH 7922 Kuwait, soil, C. Sand 17 Mar 1995. from Rennie, R. as MY 0676L.

UAMH 7943 Danville, Pennsylvania, USA, ex sputum, immunosuppressed male. from Rinaldi, M. as UTHSC 95-467 *Microascus trigonosporus*.

UAMH 8398 near Soquel, California, USA, deer dung, J. Scott (JS 164) 3 May 1991. from Malloch, D. as *Microascus trigonosporus*.

UAMH 8503 Arizona, USA, soil at base of Saguarro cactus, NRRL isolate Feb 1957. from NRRL as NRRL A-7078 *Microascus trigonosporus*.

UAMH 8850 Burma, milled rice, S. Udagawa (NHL 2265) 1957. from Ito, T. as IFO 7027 *Microascus trigonosporus*, (=IMI 86912, =LSHB Sc. 132, =CBS 199.61).

UAMH 9331 Palo Verde, California, USA, lung of pocket mouse, H. Kuehn 2 Aug 1960. from NRRL as NRRL A-10058 *Microascus trigonosporus*, (=O-745).

UAMH 9332 Utah, USA, kangaroo rat (*Dipodomys merriami*), C. Emmons (U675) Oct 1956. from NRRL as NRRL A-6898 *Microascus trigonosporus*.

UAMH 9333 California, USA, soil, G. Orr (O-382) 29 Aug 1958. from NRRL as NRRL A-8019 *Microascus trigonosporus* (=CBS 665.71).

UAMH 9334 Puerto Rico, B.O. Dodge, Harvard University (48). from NRRL as NRRL 1570 *Microascus trigonosporus*, (=IMI 86911, =LSHB Sc. 40, =CBS 198.61).

UAMH 9335 USSR, soil, I.A. Beljakova (VKM F-1144). from NRRL as NRRL A-18283 *Microascus trigonosporus*, (=O-2502, =CBS 601.67, =ATCC 22360), ex-type of *Microascus trigonosporus* var. *terreus*.

UAMH 9336 California, USA, soil, G. Orr (O-12) 29 Aug 1958. from NRRL as NRRL A-8018 *Microascus trigonosporus* var. *macrosporus*, (=CBS 662.71).

UAMH 9387 USA, C. Emmons. from CBS as CBS 218.31 *Microascus trigonosporus*, ex-type of *Microascus trigonosporus*.

UAMH 9579 Texas, USA, blood, male 30 yr, 1999. from Harris, J. as BY99 1529 *Microascus* sp.

Microascus sp.

Collections Examined:

UAMH 8852 G.F. Orr (O-461). from Ito, T. as IFO 9813 *Microascus staurosporus*.

Petriella Curzi. 1930. Bollettino. Stazione di Patologia Vegetale di Roma 10: 384.

Type species: *Petriella sordida*(Zukal) G.L. Barron & J.C. Gilman. 1961. Canadian Journal of Botany 39: 839.

Petriella boulangeri Curzi. 1930. Bollettino. Stazione di Patologia Vegetale di Roma 10: 402.

Collections Examined:

UAMH 8696 Saskatchewan, Canada, lesions on leaves of *Vicia faba* in growth chamber, R.A.A. Morrall. from DAOM as DAOM 145233 *Petriella boulangeri*.

UAMH 8890 Hamburg, Germany, manganese plates in soil, R. Schweisfurth (P29) 1965. from Untereiner, W. as MUCL 8206 *Graphium eumorphum*.

Petriella guttulata G.L. Barron & Cain. 1961. Canadian Journal of Botany 39: 841.

Collections Examined:

UAMH 3996 Bei Tamsel, Germany, partridge dung, P. Vogel 14 Dec 1935. from CBS as CBS 362.61, (=TRTC 33049, =MUCL 9886).

UAMH 8399 Toronto, Ontario, Canada, rabbit dung, J. Scott (JS 173) 11 Jun 1991. from Malloch, D. as *Petriella guttulata*.

UAMH 9564 Toronto, Ontario, Canada, dung, R.F. Cain Dec 1935. from NRRL as NRRL 2901 *Petriella guttulata*, (=TRTC 33048).

Petriella musispora Malloch. 1970. Mycologia 62: 728.

Collections Examined:

UAMH 3986 south of Dorset, Haliburton Co., Ontario, Canada, inner layers of decaying wood of poplar (*Populus grandidentata*), D. Malloch 14 Sep 1968. from CBS as CBS 745.69 *Petriella musispora*, (=ATCC 18772, =TRTC 45435), ex-type of *Petriella musispora*.

Petriella setifera (Schmidt) Curzi. 1930. Bollettino. Stazione di Patologia Vegetale di Roma 10: 411.

≡ *Microascus setifer* Schmidt. 1912. Dissertation Breslau, Germany, W.C. Korn. pp. 81.

Collections Examined:

UAMH 805 from CBS as *Rhinocladium lesnei*, ex-type of *Rhinocladium lesnei*.

UAMH 1662 Edmonton, Alberta, Canada, contaminant ex UAMH 1620, J.W. Carmichael 22 Apr 1963.

UAMH 1924 Tokyo, Japan, soil, 1962. from Udagawa, S.-I. as NHL 2279 *Petriella setifera*, (=CBS 265.64).

UAMH 2174 from Martin, P. (1588) as *Rhinotrichum lesnei*.

UAMH 2702 Waterloo, Ontario, Canada, soil ex corn field, G.C. Bhatt 1966. from Bhatt, G.C. as CR 15, (=IMI 149503, =CBS 395.69).

UAMH 3999 from CBS as CBS 352.59 *Petriella lindforsii*, (=IMI 89336).
UAMH 5170 Wooster, Ohio, USA, wooden pot labels in mix of Canadian peat-perlite, G. Kuter 1985. from Kuter, G. as 1949E *Petriella setifera*.
UAMH 5945 Toronto, Ontario, Canada, soil of houseplant (*Chlorophyton comosum*) in hospital, R.C. Summerbell 15 Sep 1986. from Summerbell, R.C. as W 1791, (=TRTC RCS W1791).
UAMH 8575 Singapur, soil, J. Guarro Mar 1994. from Guarro, J. as FMR 5550 *Petriella setifera*.
UAMH 9565 West Virginia, USA, wilted oak (*Quercus*) tree, A.L. Shigo (924-a-8; =Barron 2310) 1957. from NRRL as NRRL 2907 *Petriella setifera*.

Petriella sordida (Zukal) G.L. Barron & J.C. Gilman. 1961. Canadian Journal of Botany 39: 839.

= *Microascus sordidus* Zukal. 1890. Berichte. Deutsche Botanische Gesellschaft 8: 295.

= *Petriella asymmetrica* Curzi. 1930. Bollettino. Stazione di Patologia Vegetale di Roma 10: 384.

≡ *Petriella asymmetrica* var. *cypria* Nattrass. 1937. First list of Cyprus fungi, p. 5.

Collections Examined:
UAMH 1410 Ottawa, Ontario, Canada, ex *Chrysanthemum*, H.S. Thompson 1958. from DAOM as DAOM 60250.
UAMH 3983 Italy, dry branch ex *Pyrus communis*, M. Curzi. from CBS as CBS 258.31 *Petriella asymmetrica*, (=IMI 38601), ex-type of *Petriella asymmetrica*.
UAMH 3985 Canada, soil ex mixed wood, G.L. Barron. from CBS as CBS 180.65 *Petriella sordida*, (=MUCL 8228).
UAMH 4754 Brooks, Alberta, Canada, cucumber, R.J. Howard (BR82-GH30A) 1982. from DAOM as DAOM 185713 *Sporothrix*.
UAMH 7493 Whitefish Lake Algonquin Provincial Park, Ontario, Canada, porcupine (*Erethizon dorsatum*) dung, J. Scott (JS 154) 4 Apr 1991. from Malloch, D. as *Petriella sordida*.
UAMH 8695 Kentville, Nova Scotia, Canada, twigs/wood of apple (*Malus* cv. Robusta 5), C.O. Gourley. from DAOM as DAOM 162159 Petriella sordida
UAMH 8893 Nicosia, Cyprus, bark of poplar (*Populus nigra*), R.M. Nattrass (367) Sep 1933. from Untereiner, W. as MUCL 9888 *Petriella asymmetrica* var. *cypria*, (=CBS 238.38, =IMI 62756), ex-type of *Petriella asymmetrica* var. *cypria*.
UAMH 9457 Wizard Lake near Calmar, Alberta, Canada, wood from poplar (*Populus* sp.) stump, early stage decay, S.P. Abbott (SA-M276) 8 Jan 1999.
UAMH 9566 Ottawa, Ontario, Canada, pepper seed, J.W. Groves 28 Dec 1944. from NRRL as NRRL 1659 *Petriella sordida*, (=TRTC 33042).
UAMH 9567 mouse dung, G.F. Orr (O-891) 1960. from NRRL as NRRL A-10406 *Petriella sordida*.

***Petriella* sp.**

Collections Examined:
UAMH 9568 Kilbourne, Illinois, USA, nitidulid beetles, D.T. Wicklow (NIT 29) 1989. from NRRL as NRRL A-28297 *Petriella* sp.

Pseudallescheria Negroni & I. Fischer. 1943. Prensa Medica Argentina 30: 2398.

= *Petriellidium* Malloch. 1970. Mycologia 62: 738.

Type species: *Pseudallescheria boydii* (Shear) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 97.

Pseudallescheria africana (Arx & G. Franz) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 97.

≡ *Petriellidium africanum* Arx & G. Franz. 1973. Persoonia 7: 370.

Collections Examined:

UAMH 4000 Tsiutsabis, South West Africa, sandy soil, G. Franz (105). from CBS as CBS 311.72 *Petriellidium africanum*, ex-type of *Petriellidium africanum*.

Pseudallescheria angusta (Malloch & Cain) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 97.

≡ *Petriellidium angustum* Malloch & Cain. 1972. Canadian Journal of Botany 50: 66.

Collections Examined:

UAMH 3984 Dayton, Ohio, USA, sewage in half-digestion tank, D. Malloch. from CBS as CBS 254.72 *Petriellidium angustum*, (=ATCC 22956, =DAOM 146023, =DAOM 146085, =TRTC 45321), ex-type of *Petriellidium angustum*.

Pseudallescheria boydii (Shear) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 97.

≡ *Allescheria boydii* Shear. 1922. Mycologia 14: 242.

≡ *Petriellidium boydii* (Shear) Malloch. 1970. Mycologia 62: 739.

= *Pseudallescheria shearii* Negroni & I. Fischer. 1943. Prensa Medica Argentina 30: 2398.

status anamorphosis:

Scedosporium apiospermum (Saccardo) Castellani & Chalmers. 1919. Manual of Tropical Medicine Ed. 3, p 1122.

≡ *Monosporium apiospermum* Saccardo. 1911. Annales Mycologici 9: 254.

= *Cephalosporium boydii* Shear. 1922. Mycologia 14: 242.

≡ *Glenospora boydii* (Shear) Pollacci & Nannizzi. 1936. Trattato di micopatologia umana 4: 246.

Synanamorph:

Graphium eumorphum Saccardo. 1881. Michelia 2: 560.

= *Dendrostilbella boydii* Shear. 1922. Mycologia 14: 242.

Collections Examined:

UAMH 0002 Alberta, Canada, mycetoma, E.S. Keeping 9 May 1934.
UAMH 0153 N.F. Conant.
UAMH 0800 strain Ciferri. from CBS as *Glenspora graphii.*
UAMH 1099 California, USA, mycetoma. from Orr, G.F. as UCLAB-M-55.
UAMH 1101 California, USA, brazil nut. from Orr, G.F. as UCLAB-M-148.
UAMH 1265 St. Albert, Alberta, Canada, swab ex ear canal, J.W. Carmichael 6 Apr 1962.
UAMH 1865 from Orr, G.F. as PV 1.
UAMH 2217 High Prairie, Alberta, Canada, pus ex ear of male, J.W. Carmichael Nov 1964.
UAMH 2324 white grained mycetoma pedis. from Borelli, D. as *Monosporium apiospermum*
UAMH 2507 Orr (O-3024) 1963.
UAMH 2975 Edmonton, Alberta, Canada, bronchial washing, J.W. Carmichael 2 Jul 1968.
UAMH 3230 Chino, California, USA, surface litter ex turkey corrals, J.W. Carmichael 17 Feb 1969.
UAMH 3239 Chino, California, USA, ex chicken pens, J.W. Carmichael 17 Feb 1969.
UAMH 3437 Los Angeles, California, USA, sputum, D.H. Howard 1971. from Orr, G.F. as 0-3673 *Chrysosporium*?
UAMH 3746 Lethbridge, Alberta, Canada, fresh manure ex beef feedlot, Sep 1974. from Bell, R.G. as 25M *Chrysosporium* sp.
UAMH 3749 Lethbridge, Alberta, Canada, manure, 28 Oct 1974. from Bell, R.G. as TM.
UAMH 3750 Lethbridge, Alberta, Canada, manure, 16 Sep 1974. from Bell, R.G. as M37.
UAMH 3872 Lethbridge, Alberta, Canada, cattle manure, 20 Jan 1975. from Bell, R.G. as 1CF1.
UAMH 3873 Lethbridge, Alberta, Canada, cattle manure, 21 May 1975. from Bell, R.G. as 3CF1 *Petirellidium boydii.*
UAMH 3904 fungus ball ex human. from Rippon, J.W.
UAMH 3905 sputum. from Rippon, J.W.
UAMH 3973 Pabellon II del Hosp. Rawson, Argentina, aspirate of pus ex Rt knee, I. Fischer. from Negroni, P. as 5163 *Pseudallescheria sheari,* (=CBS 101.22), ex-type of *Pseudallescheria sheari.*
UAMH 3981 ex man. from CBS as CBS 316.54 *Petriellidium boydii.*
UAMH 3982 Texas, USA, mycetoma ex man, C.L. Shear. from CBS as CBS 101.22 *Petriellidium boydii,* ex-type of *Petriellidium boydii.*
UAMH 3990 nasal cavity ex swine, A.A. Milko. from CBS as CBS 695.70 *Petriellidium boydii,* ex-type of *Acremonium suis.*
UAMH 3991 soil, D. Muecke. from CBS as CBS 114.59 *Petriellidium boydii.*
UAMH 3992 Surinam, soil under *Elaeis guineensis,* J.H. van Emden. from CBS as CBS 593.73 *Petriellidium boydii.*
UAMH 3995 Abidjan, Africa, savannah soil, J.L. Renard. from CBS as CBS 254.66 *Petriellidium boydii.*
UAMH 4218 Chicago, Illinois, USA, eye and chest wall biopsy, J. Rippon 1979.
UAMH 4301 sputum. from Kane, J. as OMH-1 *Petriellidium boydii.*
UAMH 4302 sputum. from Kane, J. as OMH-1159 *Petriellidium boydii.*
UAMH 4303 Ontario, Canada, sputum. from Kane, J. as FR 676 *Petriellidium boydii.*
UAMH 4304 sputum. from Kane, J. as FR 642 *Petriellidium boydii* GenBank M89994
UAMH 4310 ear sample. from Kane, J. as FR 806-80 *Petriellidium boydii.*
UAMH 4408 Sunnyside, Alberta, Canada, farm soil, V. Mann 25 May 1980.
UAMH 4409 Sunnyside, Alberta, Canada, farm soil, V. Mann 25 May 1980.
UAMH 4410 Sunnyside, Alberta, Canada, farm soil, V. Mann 25 May 1980.
UAMH 4604 Chicago, Illinois, USA, tracheal suction spec. ex male, May 1982. from Rippon, J.W. as E28182 *Pseudallescheria boydii.*
UAMH 4855 anaerobically digested sewage sludge. from Ulfig, K. as 8 Sporotrichum sp.

UAMH 4947 sputum. from Hnatko, S. as 45613, F5.
UAMH 5326 Japan, exudate and debris in nasal lesions, thoroughbred horse, K. Takatori (M1008-11) Aug 1985.
UAMH 5707 Consort, Alberta, Canada, bovine fetus aborted ex Hereford 5 yrs, H. Sissons (CM87-750-DB) 3 Feb 1987.
UAMH 5862 Saskatchewan, Canada, bronchial washings, H. Congly (1821M) 1987.
UAMH 6137 Edmonton, Alberta, Canada, black stained vinyl pool liner, A. Flis (4) Jun 1988.
UAMH 7272 La Selva, Heredia Prov., Costa Rica, ex roots of epiphytic orchid (*Encyclia fragrans*) growing on *Naucleopsis naga* (Moraceae), K. Richardson (K8b) 1 Mar 1991.
UAMH 7273 La Selva, Heredia Prov., Costa Rica, ex roots of orchid (*Sobralia mucronata*), K. Richardson (K59b) 6 Mar 1991.
UAMH 7904 New Zealand, ex large chronic wound secondary to severe tear from rose thorn, female 70 yr DE+, A. Woodgyer 1994. from Woodgyer, A. as 94.447 *Scedosporium apiospermum.*
UAMH 8598 London, Ontario, Canada, raw sewage, J.E. Zajic 1969. from ATCC as ATCC 58400 *Graphium* sp., (=NRRL 3915, =QM 9375, =UWO 27), [This strain has been cited in a US or other patent and should not be used to infringe patent claims].
UAMH 8791 Willesden Green northeast of Rocky Mountain House, Alberta, Canada, hydrocarbon contaminated flare-pit soil, C. Zelmer 13 Apr 1994.
UAMH 8792 Willesden Green northeast of Rocky Mountain House, Alberta, Canada, hydrocarbon contaminated flare-pit soil, T. April (18-FP4) 16 Aug 1995.
UAMH 8793 Cynthia west of Drayton Valley, Alberta, Canada, hydrocarbon contaminated flare-pit soil, T. April (DV-4-2A) 16 Aug 1995.
UAMH 8794 Boundary Lake, British Columbia, Canada, hydrocarbon contaminated flare-pit soil, T. April (S-BL1-2-1) 21 Jun 96.
UAMH 8897 Lethbridge, Alberta, Canada, fresh faeces of beef cattle, R.G. Bell Jan 1975. from DAOM as DAOM 148868 *Pseudallescheria boydii.*
UAMH 9018 Ontario, Canada, atypical isolate, right lung, female, 03 Oct 1996. from Summerbell, R.C. as FR 3309 *Humicola* sp.
UAMH 9285 Victoria, British Columbia, Canada, synovial fluid, R knee, immunocompetent male 17 yr, after fall from trail bike into dirt, Greater Victoria Hospital 22 May 1998. from Kibsey, P. as 26570 *Scedosporum apiospermum.*

Pseudallescheria desertorum (Arx & Mustafa) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 98.

≡ *Petriellidium desertorum* Arx & Moustafa. 1973. Persoonia 7: 371.

Collections Examined:
UAMH 3993 Kuwait, salt marsh soil, A.F. Moustafa (44). from CBS as CBS 489.72 , ex-type of *Petriellidium desertorum.*

Pseudallescheria ellipsoidea (Arx & Fassatiová) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14:98.

≡ *Petriellidium ellipsoideum* Arx & Fassatiová. 1973. Persoonia 7: 370.

= *Thielavia pallidospora* Pidoplichko et al. 1973. Mikrobiolohichnyi Zhurnal (Kiev) 35: 723.

Collections Examined:

UAMH 3987 Tadzhikistan, USSR, soil, O. Fassatiová (T11). from CBS as CBS 418.73 *Petriellidium ellipsoideum*, (=GenBank U43911), ex-type of *Petriellidium ellipsoideum*.

UAMH 9386 Ukraine, sandy soil, VKM F-1923. from CBS as CBS 332.75 *Pseudallescheria ellipsoidea*, ex-type of *Thielavia pallidospora*.

Pseudallescheria fimeti (Arx, Mukerji, & N. Singh) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 98.

≡ *Petriellidium fimeti* Arx, Mukerji, & N. Singh. 1978. Persoonia 10: 26.

Collections Examined:

UAMH 4257 Dehli Zoo, India, dung of nilgai, K.G. Mukerji. from CBS as CBS 129.78, ex-type of *Petriellidium fimeti*.

Pseudallescheria fusoidea (Arx) McGinnis, Padhye, & Ajello. 1982. Mycotaxon 14: 98.

≡ *Petriellidium fusoideum* Arx. 1973. Persoonia 7: 371.

Collections Examined:

UAMH 3997 Panama, soil, 1953. from CBS as CBS 106.53 *Petriellidium fusoideum*, (=ATCC 11657), ex-type of *Petriellidium fusoideum*.

UAMH 8795 Seychelles, palm rhinoceros beetle (*Orycetes monoceros*), G. Kingsland 1982. from IMI as IMI 271728 *Pseudallescheria fusoidea*.

Scedosporium Saccardo ex Castellani & Chalmers. 1919. in Castellani, Manual of Tropical Medicine, Ed. 3, p 1122.

= *Lomentospora* Hennebert & Desai. 1974. Mycotaxon 1: 45.

Type species: *Scedosporium apiospermum* (Saccardo) Castellani & Chalmers. 1919. in Castellani, Manual of Tropical Medicine, Ed. 3, p 1122.

Scedosporium prolificans (Hennebert & Desai) Guého & de Hoog. 1991. Journal de Mycologie Médicale 118: 8.

≡ *Lomentospora prolificans* Hennebert & Desai. 1974. Mycotaxon 1: 47.

= *Scedosporium inflatum* Malloch & Salkin. 1984. Mycotaxon 21: 249.

Collections Examined:

UAMH 4238 UCLA Med. School, California, USA, ex immunosuppressed patient, D. Howard (8373) May 1979. from Howard, D. as *Petriellidium boydii*.

UAMH 4248 Los Angelos, California, USA, ex patient with widespread disseminated disease, D. Howard (3382). from Howard, D. as *Scedosporium* sp.

UAMH 4421 Paris, France, ex boy 9 yrs, with acute knee arthritis, injured in Paris forest region (isol. 5 times), E. Drouhet (1307 IP).

UAMH 5517 Farmington, Maine, USA, human bone biopsy specimen ex male, 6 yr, Sep 1981. from Malloch, D. as CC222 *Scedosporium inflatum*, (=CBS 114.90, =GenBank U43910), ex-

type of *Scedosporium inflatum*.

UAMH 5735 Toronto, Ontario, Canada, soil of potted *Schefflera*, R.C. Summerbell 15 Sep 1986. from Summerbell, R.C. as RCS-W1801 *Scedosporium inflatum*.

UAMH 5736 Toronto, Ontario, Canada, soil of potted *Schefflera*, R.C. Summerbell 15 Sep 1986. from Summerbell, R.C. as RCS-W1802 *Scedosporium inflatum*.

UAMH 5819 New York, USA, foot wound boy 6 yr, stepped on nail, I. Salkin (M134-87) 1987. from Mallcoh, D. as *Scedosporium inflatum*.

UAMH 7149 Heverlee, Belgium, greenhouse soil prepared from mixed forest litter, G. Hennebert. from CBS as CBS 467.74 *Lomentospora prolificans*, (=MUCL 18141, =GenBank U43909), ex-type of *Lomentospora prolificans*.

UAMH 8524 Victoria, British Columbia, Canada, corneal scraping, male 40 yr with corneal ulcer after debris flew in eye following "weed eater" accident, Royal Jubilee Hospital Jun 1996. from Kibsey, P. as RJH 38754 *Scedosporium prolificans*.

UAMH 9404 Victoria, British Columbia, Canada, bronchial wash, LUL, male 76 yr with lung cavity, DE -, Victoria General Hospital 21 Sep 1998. from Kibsey, P. as 96227 *Scedosporium prolificans*.

Scedosporium sp.

Collections Examined:

UAMH 9532 CDC, Atlanta, Georgia, USA, clinical isolate, L.D. Haley (1-8222) 1 Aug 1985. from NRRL as NRRL A-26514 *Wardomyces* sp.

Scopulariopsis Bainer. 1907. Bulletin Societé Mycologique de France 23: 98.

= *Acaulium* Sopp. 1912. Videnskaps Selskapets Skrifter. 1. Mat.-Naturv. Klasse 11: 42.

= *Phaeoscopulariopsis* Ota. 1928. Japanese Journal of Dermatology and Urology 28: 405. (invalid, provisional genus, ICBN Art. 34).

= *Masoniella* (G. Smith) G. Smith. 1952. Transactions of the British Mycological Society 35: 237.

≡ *Masonia* G. Smith. 1952. Transactions of the British Mycological Society 35: 149. (illegitimate later homonym, ICBN Art. 53.1, non *Masonia* Hansford).

Type species: *Scopulariopsis brevicaulis* (Saccardo) Bainier. 1907. Bulletin Societé Mycologique de France 23: 99.

Scopulariopsis acremonium (Delacroix) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 148.

≡ *Monilia acremonium* Delacroix. 1897. Bulletin Societé Mycologique de France 13: 114.

Collections Examined:

UAMH 461 Edmonton, Alberta, Canada, skin ex wrist, J.W. Carmichael 1956.

UAMH 541 Edmonton, Alberta, Canada, soil chicken house, J.W. Carmichael Jul 1956, (=ATCC 58636).
UAMH 543 Edmonton, Alberta, Canada, soil chicken house, J.W. Carmichael 1956.
UAMH 927 strain Thom. from CBS as *S. brevicaulis var glabra.*
UAMH 928 strain v. Beyma. from CBS as *Scopulariopsis danica.*
UAMH 1157 Alberta Game Farm, Edmonton, Alberta, Canada, soil cougar pen, J.W. Carmichael 8 Nov 1961.
UAMH 1317 Alberta Game Farm, Edmonton, Alberta, Canada, soil cougar pen, J.W. Carmichael 7 Jul 1962.
UAMH 2903 Edmonton, Alberta, Canada, toe nail, J.W. Carmichael 15 Mar 1968.
UAMH 8885 Kiel, Kitzeberg, Schleswig-Holstein, Germany, soil, W. Gams (C-1372) 1966. from Untereiner, W. as MUCL 8999 *Scopulariopsis canadensis.*
UAMH 8982 Germany, wheat field soil, W. Gams (C656) 30 Apr 1980. from NRRL as NRRL 6517 *Scopulariopsis acremonium,* (=CBS 104.65, =ATCC 16282, =MUCL 8274).
UAMH 9251 Germany, wheat-field soil, K.H. Domsch. from CBS as CBS 892.68 *Scopulariopsis canadensis.*

Scopulariopsis atra Zach. 1934. Österreichische Botanische Zeitschrift 83: 184.

Collections Examined:
UAMH 936 F. Zach. from CBS as *Scopulariopsis atra,* (=UAMH 9385), ex-type of *Scopulariopsis atra.*
UAMH 9385 F. Zach. from CBS as CBS 400.34 *Scopulariopsis atra,* (=UAMH 936), ex-type of *Scopulariopsis atra.*

Scopulariopsis brumptii Salvanet-Duval. 1935. These Fac. Pharm. Paris 23: 58.

= *Masonia grisea* G. Smith. 1952. Canadian Journal of Botany 35: 149.

≡ *Masoniella grisea* (G. Smith) G. Smith. 1952. Canadian Journal of Botany 35: 237.

= *Masonia tertia* Batista, Lima & Vasconcelos. 1960. Publ. Inst. Mic. Univ. Recife 263: 14.

= *Scopulariopsis melanospora* Udagawa. 1959. Journal of Agricultural Science. Tokyo Nogyo Daigaku 5: 18.

Collections Examined:
UAMH 946 Edmonton, Alberta, Canada, soil under tree, J.W. Carmichael 19 Mar 1959.
UAMH 1415 Iowa, USA, culture contaminant, Orr (771). from DAOM as DAOM 84429.
UAMH 1454 Alberta, Canada, spleen Richardson's ground squirrel (*Spermophilus richardsonii*), J.W. Carmichael 3 Oct 1962.
UAMH 1477 USA, milled rice, S. Udagawa 1955. from IMI as IMI 78256 *Scopulariopsis melanospora,* (=CBS 272.60, =Herb. NHL 6045), ex-type of *Scopulariopsis melanospora.*
UAMH 7367 Edmonton, Alberta, Canada, indoor air of warehouse ex RCS strip, S.P. Abbott (SA-M256) 26 May 1993.
UAMH 7881 Calgary, Alberta, Canada, indoor air from basement of home ex RCS strip, S.P. Abbott (SA-M27) 10 Jan 1995.
UAMH 7920 Red Deer, Alberta, Canada, outside air ex RCS strip, S.P. Abbott (SA-M71) 9 Mar 1995.
UAMH 8065 Alberta, Canada, ex BAL, female 49 yr, Provincial Laboratory for Southern Alberta 3 May 1995. from Rennie, R. as MY 1865.

UAMH 8402 Creighton Mine, Sudbury Co., Ontario, Canada, contaminant ex agaric basidiocarp, D. Malloch (DM 308) 20 Sep 1981. from Mallcoh, D. as *Scopulariopsis brumptii*.

UAMH 8619 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen log with hollow core (*Populus tremuloides*), T. Lumley (EI-13-S2C, 1-29A) 29 Jan 1996.

UAMH 8699 Alberta, Canada, bronchial wash, male 70 yr, Provincial Laboratory for Southern Alberta 11 Apr 1996. from Rennie, R. as MY 1635 *Scopulariopsis* sp.

UAMH 8707 Prince Albert, Saskatchewan, Canada, indoor air of pulp and paper woodroom ex RCS strip, S.P. Abbott (SA- M50) 13 Dec 1996.

UAMH 8738 Australia, hay, toxic to animals, I.G. Pascoe 1983. from Hocking, A. as FRR 2578 *Scopulariopsis brumptii*.

UAMH 8743 North Buck Lake near Lac La Biche, Alberta, Canada, birch (*Betula papyrifera*) leaf litter, S.P. Abbott (SA-M165) 20 Dec 1996, (=IFO 33050).

UAMH 8744 North Buck Lake near Lac La Biche, Alberta, Canada, freshwater snail shells on lakeshore, S.P. Abbott (SA- M160) 21 Oct 1996.

UAMH 8856 London, England, UK, culture contaminant, G. Smith (BB 211). from Ito, T. as IFO 6795 *Scopulariopsis brumptii*, (=IMI 49908, =LSHB Sc. 144, =CBS 295.52), ex-type of *Masonia grisea*.

UAMH 8874 Lac La Biche, Alberta, Canada, lung of northern flying squirrel (*Glaucomys sabrina*), J. Csotonyi (F5/107-1BT/1M) 08 Feb 1997.

UAMH 8886 Recife, Brazil, air, A.C. Batista (IMUR 1550) 1952. from Untereiner, W. as MUCL 9005 *Scopulariopsis brumptii*, (=IMI 109550, =CBS 296.61), ex-type of *Masoniella tertia*.

UAMH 8983 Arizona, USA, kangaroo rat burrow, D.T. Wicklow (546) 14 Feb 1983. from NRRL as NRRL A-27019 *Scopulariopsis brumptii*.

UAMH 9289 Edmonton, Alberta, Canada, bronchial wash, RLL Male 51Y, C. Sand 8 Mar 1998. from Rennie, R. as MY 1467 *Scopulariopsis* sp.

UAMH 9321 Sherwood Park, Alberta, Canada, decayed wood (2x4) in basement of home, S.P. Abbott (SA-M239) 24 Jul 1998.

UAMH 9460 Edmonton, Alberta, Canada, indoor air of arena dressing room ex RCS strip, S.P. Abbott (SA-M284) 17 Dec 1998.

UAMH 9462 Edmonton, Alberta, Canada, sputum, male 51 yr, C. Sand 6 Nov 1998. from Rennie, R. as MY 6605.

Scopulariopsis carbonaria F.J. Morton & G. Smith. 1963. Mycological Papers 86: 59.

Collections Examined:

UAMH 948 Canary Islands, dust, R.R. Davis Mar 1958. from Smith, G. as LSHB Sc.14 (BB 368) *Scopulariopsis* sp., (=IMI 86940).

UAMH 8896 Kiel, Kitzeberg, Schleswig-Holstein, Germany, soil, W. Gams (C-1372) 1966. from Untereiner, W. as MUCL 8992 *Scopulariopsis carbonaria*.

UAMH 8985 Panama, soil, B. Coghill (H4) June 1942. from NRRL as NRRL 1860 *Scopulariopsis* sp., (=IMI 86941, =LSHB Sc. 66, =ATCC 46517), ex-type of *Scopulariopsis carbonaria*.

UAMH 8986 soil, C.W. Emmons (6568) Feb 1950. from NRRL as NRRL A-3013 *Scopulariopsis constantini*.

UAMH 8987 Florida, USA, soil, D. Fennell Nov 1954. from NRRL as NRRL A-5852 *Scopulariopsis* sp.

UAMH 8988 Formosa, soil, NRRL isolate (49) Jun 1952. from NRRL as NRRL A-3884 *Scopulariopsis constantini*.

UAMH 8989 Gold Coast, Africa, soil, NRRL isolate May 1950. from NRRL as NRRL A-3166 *Scopulariopsis constantini*.

Scopulariopsis chartarum (G. Smith) F.J. Morton & G. Smith. 1963. Mycological Papers 86: 64.

= *Masonia chartarum* G. Smith. 1952. Transactions of the British Mycological Society 35: 150.

= *Masoniella chartarum* (G. Smith) G. Smith. 1952. Transactions of the British Mycological Society 35: 237.

Collections Examined:

UAMH 1479 London, UK, wall-paper, K. Maunsell, G. Smith (BB 256) 1950. from IMI as IMI 49909 *Masoniella chartarum*, (=CBS 294.52, =LSHB Sc.146), ex-type of *Masoniella chartarum*.

UAMH 8202 Alberta, Canada, BAL fluid ex Lt. lingular lobe, female 49 yr, Provincial Laboratory for Southern Alberta May 1995. from Rennie, R. as MY 2290.

UAMH 8355 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (153-120.1) 16 Jun 1994. from Mallcoh, D. as *Scopulariopsis* cf. *fusca*.

UAMH 8356 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (029-220.1) 17 Feb 1994. from Mallcoh, D. as *Scopulariopsis chartarum*.

UAMH 8357 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (128-221.1) 11 Apr 1994. from Mallcoh, D. as *Scopulariopsis chartarum*.

UAMH 8358 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (178-211.1) 20 Apr 1994. from Mallcoh, D. as *Scopulariopsis chartarum*.

UAMH 8406 Wallaceburg, Ontario, Canada, carpet dust from home, D. Malloch (029-221.1) 17 Feb 1994. from Mallcoh, D. as *Scopulariopsis fusca*.

UAMH 8846 Germany, wheat field soil, K. Domsch 1968. from Ito, T. as IFO 31245 *Scopulariopsis chartarum*, (=ATCC 16279, =CBS 897.68, =MUCL 8993).

UAMH 9173 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S1H, 11-19C) 19 Nov 1996.

UAMH 9461 10 km south of Leduc, Alberta, Canada, decaying mushroom (*Pholiota squarrosa*) at base of Manitoba maple (*Acer negundo*) in rural shelterbelt, S.P. Abbott (SA-M285) 11 Jan 1999.

UAMH 9485 Gregoire Lake Provincial Park, Alberta, Canada, bark of aspen (*Populus tremuloides*), S.P. Abbott (SA-M296) 17 Feb 1999.

Scopulariopsis croci van Beyma. 1944. Leeuwenhoek Nederlandsch Tijdschrift 10: 53.

Collections Examined:

UAMH 932 from CBS as *Scopulariopsis sphaerospora*.

UAMH 933 *Crocus* sp., van Beyma. from CBS as CBS 158.44 *Scopulariopsis croci*, (=IMI 78261), ex-type of *Scopulariopsis croci*.

Scopulariopsis fimicola (Costantin & Matruchot) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 143.

= *Monilia fimicola* Costantin & Matruchot 1894. Revue Generale de Botanique 6: 292.

Collections Examined:

UAMH 954 Mushroom Growers Association, white plaster mold, C.A. la Touche (BB212) Jul 1946. from Smith, G. as LSHB Sc.9 *Scopulariopsis fimicola*, (=IMI 86944, =CBS 206.61).

UAMH 1017 Daysland, Alberta, Canada, lung of Richardson's ground squirrel (*Spermophilus richardsonii*), J.W. Carmichael Jun 1960.

Scopulariopsis gracilis Samson. 1972. Archiv fuer Mikrobiologie 85: 179. (nomen novum)

≡ *Paecilomyces fuscatum* Inagaki. 1962. Transactions of the Mycological Society of Japan 4: 4. (illegitimate later homonym, ICBN Art. 53.3; non *Scopulariopsis fusca* Zach).

Collections Examined:

UAMH 9536 Japan, wheat flour, N. Inagaki Aug 1959. from NRRL as NRRL 5822 *Scopulariopsis gracilis*, (=CBS 369.70, =IFO 7561), ex-type of *Paecilomyces fuscatum*.

Scopulariopsis hibernica Mangan. 1965. Transactions of the British Mycological Society 48: 617.

Collections Examined:

UAMH 2643 strain Mangan. from Barron, G.L. as 10465 *Scopulariopsis hibernica*, (=ATCC 16690), ex-type of *Scopulariopsis hibernica*.

Scopulariopsis murina Samson & Klopotek. 1972. Archiv fuer Mikrobiologie 85: 175.

Collections Examined:

UAMH 9537 Baden-Baden, Germany, domestic refuse compound, A. von Klopotek (P-27) 1970. from NRRL as NRRL 5823 *Scopulariopsis murina*, (=CBS 830.70, =IMI 161540), ex-type of *Scopulariopsis murina*.

Scopulariopsis sphaerospora Zach. 1934. Österreichische Botanische Zeitschrift 83: 180.

Collections Examined:

UAMH 5964 Austria, F. Zach. from CBS as CBS 402.34 *Scopulariopsis sphaerospora*, (=MUCL 9045), ex-type of *Scopulariopsis sphaerospora*.

UAMH 8883 Heverlee, Belgium, greenhouse soil, B.G. Desai Sep 1971. from Untereiner, W. as MUCL 18261 *Scopulariopsis sphaerospora*.

UAMH 9383 G. Smith (P. 10) 1955. from CBS as CBS 210.61 *Scopulariopsis sphaerospora*, (=LSHB Sc. 134, =IMI 86939).

***Scopulariopsis* sp.**

Collections Examined:

UAMH 5803 Nashville, Tennessee, USA, right lung washing, male, 1987. from CDC as CDC 87-017572 *Wardomycopsis* sp.

UAMH 6313 Edmonton, Alberta, Canada, soil, J. Newton Sep 1988.

UAMH 6315 Whitemud Equine Centre, Edmonton, Alberta, Canada, soil mixed with straw and horse dung, L. Sigler Sep 1988.

UAMH 7850 Calgary, Alberta, Canada, ex sputum, male, 6 Oct 1994. from Rennie, R. as MY 4304 [4305].

UAMH 7862 Scandia, Alberta, Canada, indoor air ex RCS strips. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (EW2-2-1A) 13 Dec 1993.

UAMH 7883 Clyde Corner, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 189) 21 Jan 1994, (=IFO 33053).

UAMH 7884 Girouxville, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 427) 21 Mar 1994.

UAMH 7885 Scandia, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 174) 24 Jan 1994.

UAMH 8501 South Africa, soil, NRRL isolate Mar 1949. from NRRL as NRRL A-2715 *Scopulariopsis constantini*.

UAMH 8700 Alberta, Canada, sputum, male 66 yr, Provincial Laboratory for Southern Alberta 28 Aug 1996. from Rennie, R. as MY 4846 *Scopulariopsis* sp.

UAMH 9252 Grimshaw, Alberta, Canada, indoor air of honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 446) 30 Jan 1994.

Wardomyces Brooks & Hansford. 1923. Transactions of the British Mycological Society 8: 137.

= *Hennebertia* Morelet. 1969. Annales. Societé des Sciences Naturelles et d'Archéologie de Toulon et du Var 21: 104.

= *Gamsia* Morelet. 1969. Annales. Societé des Sciences Naturelles et d'Archéologie de Toulon et du Var 21: 105.

Type species: *Wardomyces anomalus* Brooks & Hansford. 1923. Transactions of the British Mycological Society 8: 137.

Wardomyces aggregatus Malloch. 1970. Canadian Journal of Botany 48: 883.

Collections Examined:

UAMH 9394 Wycamp Lake, Emmet Co., Michigan, USA, dung of carnivore, D. Malloch 3 Aug 1967. from CBS as CBS 251.69 *Wardomyces aggregatus*, (=TRTC 45325), ex-type of *Wardomyces aggregatus*.

Wardomyces anomalus Brooks & Hansford. 1923. Transactions of the British Mycological Society 8: 137.

≡ *Wardomyces anomala* Brooks & Hansford. 1923. Transactions of the British Mycological Society 8: 137. (orthographic variant).

Collections Examined:

UAMH 1397 Ottawa, air cell of egg, W.I. Illman 1947. from DAOM as DAOM 75633 *Wardomyces anomala*, (=IMI 32064, =ATCC 15229, =CBS 299.61).
UAMH 1547 from Barron, G.L. as 10405 *Wardomyces anomalus*.
UAMH 8275 Grimshaw, Alberta, Canada, indoor air ex RCS strip from honeybee (*Apis mellifera*) overwintering facility, S.P. Abbott (OHS 309) 21 Mar 1994, (=IFO 33054).
UAMH 9533 Guelph, Ontario, Canada, soil, mixed woods, G. Barron (10404) 11 Dec 1961. from NRRL as NRRL A-11322 *Wardomyces anomala*, (=DAOM 84673).

Wardomyces columbinus (Demelius) Hennebert. 1968. Transactions of the British Mycological Society 51: 753.

≡ *Trichosporium columbinus* Demelius. 1923. Verhandlungen. Zoologisch-Botanische Gesellschaft in Wien 71: 105.

≡ *Hennebertia columbina* (Demelius) Morelet. 1969. Annales. Societé des Sciences Naturelles et d'Archéologie de Toulon et du Var 21: 104.

Collections Examined:
UAMH 4443 Elkwater, Alberta, Canada, coyote (*Canis latrans*) dung, R. Currah (116) Sep 1980.
UAMH 7847 Scandia, Alberta, Canada, indoor air ex RCS strip. from honeybee (*Apis mellifera*) overwintering facility, S. Abbott (OHS 209) 24 Jan 1994, (=IFO 33055).
UAMH 7888 Poczesna, Poland, ex soil, municipal landfill site, K. Ulfig 30 May 1994. from Ulfig, K. as IEIA 752 *Wardomyces columbinus*.
UAMH 8881 Germany, decaying wood, K. Kuhlwein (308-1) 1963. from Untereiner, W. as MUCL 4052 *Wardomyces columbinus*, (=MUCL 3198, =CBS 449.63).

Wardomyces humicola Hennebert & G.L. Barron. 1962. Canadian Journal of Botany 40: 1209.

Collections Examined:
UAMH 1527 Guelph, Ontario, Canada, greenhouse soil, G.L.Barron Apr 1961. from Barron, G.L. as 10403 *Wardomyces humicola*, (=ATCC 15232, =CBS 369.62, =DAOM 75655, =IMI 98886, =UAMH 3085), ex-type of *Wardomyces humicola*.
UAMH 3085 Guelph, Ontario, Canada, greenhouse soil, G.L.Barron 1961. from IMI as IMI 98886 *Wardomyces humicola*, (=ATCC 15232, =CBS 369.62, =DAOM 75655, =UAMH 1527), ex-type of *Wardomyces humicola*.
UAMH 7311 Edmonton, Alberta, Canada, soil, R. Sandre 16 Oct 1992.
UAMH 8489 Elk Island National Park, Alberta, Canada, well decayed wood (stage 4 decay), white spruce log (*Picea glauca*), T. Lumley (EI-01-S4F, 1-22B) 13 Sep 1995.
UAMH 8630 Fish Lake near Nordegg, Alberta, Canada, horse dung in spruce (*Picea glaucal P. mariana*) forest, S.P. Abbott (SA-M133) 14 Jun 1996.
UAMH 8752 Fish Lake near Nordegg, Alberta, Canada, debris of red squirrel (*Tamiasciurus hudsonicus*) midden under white spruce (*Picea glauca*), S.P. Abbott (SA-M151) 14 Nov 1996, (=IFO 33056).
UAMH 9368 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S5A) 19 Sep 1998.
UAMH 9459 Elk Island National Park, Alberta, Canada, dung of bison (*Bison bison*) in spruce (*Picea glauca*) forest, S.P. Abbott (SA-M283) 7 Jan 1999.

Wardomyces inflatus (Marchal) Hennebert. 1968. Transactions of the British Mycological Society 51: 755.

≡ *Trichosporium inflatum* Marchal. 1895. Bulletin. Societe Royale de Botanique de Belgique 34: 142.

= *Wardomyces hughesii* Hennebert. 1962. Canadian Journal of Botany 40: 1027.

Collections Examined:

UAMH 1528 Guelph, Ontario, Canada, soil, mixed wood, G.L. Barron Nov 1960. from Barron, G.L. as 10401, (=DAOM 75502).

UAMH 8488 Elk Island National Park, Alberta, Canada, dry, rotted wood (stage 2 decay), aspen (*Populus tremuloides*) log with hollow core, T. Lumley (EI-13-S3D) 19 Aug 1995.

UAMH 8875 Lac La Biche, Alberta, Canada, lung of northern flying squirrel (*Glaucomys sabrina*), J. Csotonyi 31 Jan 1997. from Currah, R.S. as J31/21-1MT *Wardomyces inflatus.*

UAMH 8879 Heverlee, Belgium, humic soil under tomato (*Lycopersicon esculentum*) in greenhouse, G.L. Hennebert (GHL 669) and E. Delvaux Jan 1959. from Untereiner, W. as MUCL 669 *Wardomyces inflatus,* (=CBS 367.62, =DAOM 84715), ex-neotype of *Trichosporium inflatum.*

UAMH 8880 Heverlee, Belgium, soil under tomato (*Lycopersicon esculentum*) in greenhouse, G.L. Hennebert and E. Delvaux Nov 1958. from Untereiner, W. as MUCL 668 *Wardomyces inflatus,* (=IMI 99752, =ATCC 15230, =CBS 448.63, =DAOM 84714).

UAMH 9215 Elk Island National Park, Alberta, Canada, roots of white spruce (*Picea glauca*) seedling on nurse log, T. Lumley (EIS-19-1, 1-29A) 29 Jan 1997.

UAMH 9433 Edmonton, Alberta, Canada, soil, M. Piercey 22 Oct 1998.

UAMH 9534 near Portal, Arizona, USA, soil of kangaroo rat burrow, D.T. Wicklow (143) 17 Sep 1987. from NRRL as NRRL A-28069 *Wardomyces inflatus.*

UAMH 9535 Quebec, Canada, rotten wood of maple (*Acer* sp.), (#1645) 1961. from NRRL as NRRL A-12177 *Wardomyces inflatus,* (=IMI 98885, =ATCC 15231, =CBS 216.61, =DAOM 74593), ex-type of *Wardomyces hughesii.*

Wardomyces moseri W. Gams. 1995. Beihefte. Sydowia 10: 67.

Collections Examined:

UAMH 9393 east of Villavicencio, Dep. Meta, Colombia, dead petiole of palm (*Mauritia minor*), W. Gams 1980. from CBS as CBS 164.80 *Wardomyces moseri*, ex-type of *Wardomyces moseri.*

Wardomyces ovalis W. Gams. 1968. Canadian Journal of Botany 51: 798.

≡ *Hennebertia ovalis* (W. Gams) Morelet. 1969. Annales. Societé des Sciences Naturelles et d'Archéologie de Toulon et du Var 21: 105.

Collections Examined:

UAMH 8800 UK, horse nasal swab, M.T. Archer 1978. from IMI as IMI 217208 *Wardomyces ovalis.*

UAMH 8894 Kiel, Kitzeberg, Schleswig-Holstein, Germany, wheat field soil, K. Domsch Mar 1963. from Untereiner, W. as MUCL 6031 *Wardomyces ovalis,* (=CBS 234.66, =IMI 117372), ex-type of *Wardomyces ovalis.*

Wardomyces pulvinatus (Marchal) Dickinson. 1966. Canadian Journal of Botany 49: 521.

≡ *Wardomyces pulvinata* (Marchal) Dickinson. 1966. Transactions of the British Mycological Society 49: 521. (orthographic variant).

≡ *Echinobotryum pulvinatum* Marchal. 1895. Bulletin. Societe Royale de Botanique de Belgique 34: 139.

= *Wardomyces papillatus* Dickinson. 1964. Transactions of the British Mycological Society 47: 322.

≡ *Wardomyces papillata* Dickinson. 1964. Transactions of the British Mycological Society 47: 322. (orthographic variant).

Collections Examined:

UAMH 8492 Japan, TI 159. from Nakase, T. as JCM 1939 *Wardomyces pulvinatus*, (=IFO 8908, =DAOM 107465).

UAMH 8877 Nancy, France, decaying wood, O. Reisinger 1965. from Untereiner, W. as MUCL 7886 *Wardomyces pulvinata*.

UAMH 8878 County Carlow, Ireland, wheat field soil, C. Dickinson (D-274) May 1962. from Untereiner, W. as MUCL 6081 *Wardomyces pulvinata*, (=IMI 98294), ex-paratype of *Wardomyces papillata*.

Wardomyces simplex Sugiyama et.al.. 1968. Botanical Magazine (Tokyo) 81: 243.

= *Wardomyces dimerus* W. Gams. 1968. Transactions of the British Mycological Society 51: 800.

≡ *Gamsia dimera* (W. Gams) Morelet. 1969. Annales. Societé des Sciences Naturelles et d'Archéologie de Toulon et du Var 21: 105.

Collections Examined:

UAMH 1259 Bradford Marsh, Ontario, Canada, peat soil, G.L. Barron 1960. from DAOM as DAOM 75752 *Echinobotryum* sp.

UAMH 8491 Japan, milled rice (*Oryza sativa*), J. Sugiyama (MR-329-1). from Nakase, T. as JCM 1937 *Wardomyces simplex*, (=ATCC 22254, =CBS 546.69, =IMI 141555, =IFO 8909), ex-type of *Wardomyces simplex*.

UAMH 8876 Kiel, Kitzeberg, Schleswig-Holstein, Germany, wheat field soil, W. Gams (C-908) May 1964. from Untereiner, W. as MUCL 6388 *Wardomyces simplex*, ex-type of *Wardomyces dimerus*.

Wardomycopsis Udagawa & Furuya. 1978. Mycotaxon 7: 92.

Type species: *Wardomycopsis inopinatua* Udagawa & Furuya. 1978. Mycotaxon 7: 92.

Wardomycopsis humicola (G.L. Barron) Udagawa & Furuya. 1978. Mycotaxon 7: 96.

≡ *Scopulariopsis humicola* G.L. Barron. 1966. Antonie van Leeuwenhoek 32: 294.

Collections Examined:

UAMH 2641 Guelph, Ontario, Canada, soil, Aug 1964. from Barron, G.L. as OAC 10260 *Scopulariopsis humicola*, (=ATCC 16691, =CBS 487.66), ex-type of *Scopulariopsis humicola*.

UAMH 4960 sand ex Tyrrhenian sea, L. Volterra. from CDC as CDC 84-032086.

UAMH 4961 sand ex Tyrrhenian sea, L. Volterra. from CDC as CDC 84-032091.

UAMH 8403 Mahale Mountains, Tanzania, clay soil of termite mound, D. Malloch (#4 clay) Dec 1995. from Mallcoh, D. as *Scopulariopsis* sp.

UAMH 8884 Potchefstroom, South Africa, litter of *Acacia karoo*, M.C. Papendorf (224) 1966. from Untereiner, W. as MUCL 8802 *Scopulariopsis humicola*.

EXCLUDED AND UNCERTAIN TAXA

Doratomyces eichhorniae Conway & Kimbrough. 1975. Mycotaxon 2: 128.

≡ *Doratomyces eichhornius* Conway & Kimbrough. 1975. Mycotaxon 2: 128. (orthographic variant)

Collections Examined:

UAMH 9288 Lake Alice, Gainesville, Florida, decaying laminae of water hyacinth (*Eichhornia crassipes*), F.W. Zettler (WH 47) Feb 1974. from ATCC as ATCC 28418 *Doratomyces eichhornius* (=FLAS F 50399, holotype), ex type of *Doratomyces eichhorniae*.

Pithoascus platysporus Arx & Veenbaas-Rijks. 1973. Persoonia 7: 374.

Collections Examined:

UAMH 9259 Wageningen, Netherlands, agricultural soil, J.H. van Emden. from CBS as CBS 419.73 *Pithoascus platysporus*, ex-type of *Pithoascus platysporus*.

Scopulariopsis blochii (Matruchot) Vuillemin. 1911. Bulletin Societé Mycologique de France 27: 148.

Collections Examined:

UAMH 960 from Smith as LSHB Sc. 52 *Scopulariopsis blochii*.

Scopulariopsis canadensis F.J. Morton & G. Smith. 1963. Mycological Papers 86: 55.

Collections Examined:

UAMH 956 Agassiz, British Columbia, Canada, ex seed of beet (*Beta vulgaris*), S.J. Hughes Jan 1958. from Smith as LSHB Sc.15 *Scopulariopsis canadensis*, (=DAOM 56303, =IMI 86938, =CBS 204.61, =UAMH 8498), ex-type of *Scopulariopsis canadensis*.

UAMH 8498 Agassiz, British Columbia, Canada, seed of beet (*Beta vulgaris*), S.J. Hughes Jan 1958. from NRRL as NRRL 2991 *Scopulariopsis canadensis*, (=UAMH 956, =LSHB Sc. 15, =DAOM 56303, =CBS 204.61, =IMI 86398), ex-type of *Scopulariopsis canadensis*.

Scopulariopsis parva (Brown & Smith) Samson. 1974. Studies in Mycology 6: 102.

≡ *Paecilomyces parvus* Brown & Smith. 1957. Transactions of the British Mycological Society 40: 58.

= *Scopulariopsis parvula* F.J. Morton & G. Smith. 1963. Mycological Papers 86: 65.

Collections Examined:

UAMH 743 Edmonton, Alberta, Canada, soil under tree frequented by sparrows, J.W. Carmichael 19 Mar 1959.

UAMH 918 Edmonton, Alberta, Canada, soil under tree frequented by sparrows, J.W. Carmichael 19 Mar 1959, (=ATCC 58635, =CBS 209.61, =IMI 86943), ex-type of *Scopulariopsis parvula*.

UAMH 1146 Alberta Game Farm, Edmonton, Alberta, Canada, soil and quills porcupine paddock, J.W. Carmichael 8 Nov 1961.

UAMH 1151 Alberta Game Farm, Edmonton, Alberta, Canada, soil and quills porcupine paddock, J.W. Carmichael 8 Nov 1961.

UAMH 1159 Alberta Game Farm, Edmonton, Alberta, Canada, soil and quills porcupine paddock, J.W. Carmichael 8 Nov 1961.

UAMH 1195 Alberta Game Farm, Edmonton, Alberta, Canada, soil and quills porcupine paddock, J.W. Carmichael 8 Nov 1961.

UAMH 1196 Alberta Game Farm, Edmonton, Alberta, Canada, sandy soil badger paddock, J.W. Carmichael 8 Nov 1961.

UAMH 1329 Alberta Game Farm, Edmonton, Alberta, Canada, sandy soil badger paddock, J.W. Carmichael 7 Jul 1962.

UAMH 1657 Slave Lake, Alberta, Canada, woodchuck (*Marmota monax*), J.W. Carmichael 9 Aug 1960.

UAMH 9154 Elk Island National Park, Alberta, Canada, extremely well decayed wood (stage 5 decay), white spruce log (*Picea glauca*), T. Lumley (EI-02-S1E, 4-23D) 23 Apr 1997.

UAMH 9384 skin infection ex man, A. Stuhmer. from CBS as CBS 245.31 *Scopulariopsis parva*, ex-type of *Paecilomyces parvus*.

APPENDIX 2

SMALL SUBUNIT (18S) rDNA ALIGNED SEQUENCE MATRIX

The matrix below was used to generate the inferred phylogenetic reconstruction shown in Figure 7.1. Nucleotide positions of the 1019 bp fragment are shown above the data matrix. "N" denotes missing data and "." indicates spaces introduced for alignment purposes. Source of strains is provided in Table 7.1.

```
[                    10        20        30        40        50        60        70        80        90       100]
[                    .         .         .         .         .         .         .         .         .        .]
Kernia.nitida                TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATTTACCTACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Lophotrichus.ampullus        TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATTTACCTACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Microascus.longirostris      TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACTTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Cephalotrichum.stemonitis    TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Microascus.nidicola          TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACGTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Wardomyces.anomalus          TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Scopulariopsis.parva         TATACCGTGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Petriella.sordida            TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Microascus.brevicaulis       TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Cephalotrichum.cylindricum   TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Pseudallescheria.boydii      TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Pseudallescheria.ellipsoidea TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Graphium.penicillioides (A)  TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATAGTTTATTTGATAGCACCTT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAAAACA
Graphium.penicillioides (B)  TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATAGTTTATTTGATAGCACCTT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAAAACA
Graphium.tectonae            TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATC.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Scedosporium.prolificans     TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Microascus.cirrosus          TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACGTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Microascus.trigonosporus     TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACGTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Petriella.setifera           TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Graphium.cuneiferum          TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACATGG.ATAACTGTGGTAATTCTAGAGCTAATACA
Ceratocystis.fimbriata       TATACAGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Halosphaeriopsis.mediosetigera TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACATT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Chaetomium.globosum          TATACCGCGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACATGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Pidoplitchkoviella.terricola TATACAGCGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Daldinia.concentrica         TATACTGCGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGTTAGTACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Halosphaeria.appendiculata   TATACAGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGCACCTT.GA.TACTCGG.ATAACTGTGGTAATTCTAGAGCTAATACG
Hypocrea.schweinitzii        TATACCGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAATACTTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Melanospora.zamiae           TATACAGCGAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGTGCCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Leuconeurospora.pulcherrima  TATACAGTGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Nectria.cinnabarina          NNNNNNNNNAAACTGCGAATGGCTCATTATATAAGTTATCGTTTATTTGATAGTACCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Ophiostoma.ulmi              TATACGGCGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGCCCCTT.AC.TACTTGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Sordaria.fimicola            TAAACCGCGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACATGG.ATAACCGTGGTAATTCTAGAGCTAATACA
Emericella.nidulans          TATACTGTGAAACTGCGAATGGCTCATTAAATCAGTTATCGTTTATTTGATAGTACCTT.AC.TACATGG.ATACCTGTGGTAATTCTAGAGCTAATACA
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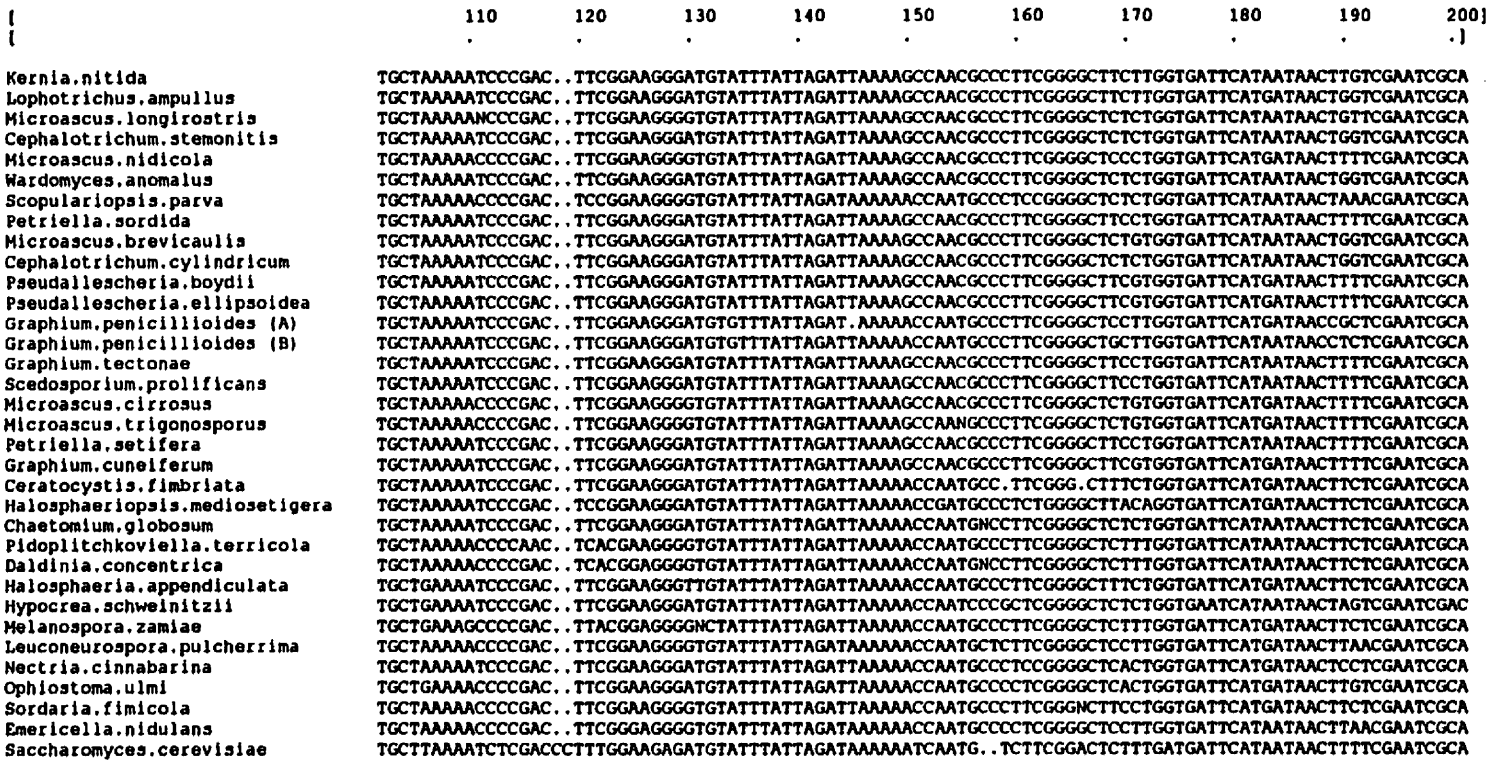
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Wardomyces.anomalus TGCTAAAAATCCCGAC..TTCGGAAGGGATGTATTTATTAGATTAAAAGCCAACGCCCTTCGGGGCTCTCTGGTGATTCATAATAACTGGTCGAATCGCA
Scopulariopsis.parva TGCTAAAAACCCCGAC..TCCGGAAGGGGTGTATTTATTAGATAAAAAACCAATGCCCTCCGGGGCTCTCTGGTGATTCATAATAACTAAACGAATCGCA
Petriella.sordida TGCTAAAAATCCCGAC..TTCGGAAGGGATGTATTTATTAGATTAAAAGCCAACGCCCTTCGGGGCTTCCTGGTGATTCATAATAACTTTTCGAATCGCA
Microascus.brevicaulis TGCTAAAAATCCCGAC..TTCGGAAGGGATGTATTTATTAGATTAAAAGCCAACGCCCTTCGGGGCTCTGTGGTGATTCATAATAACTGGTCGAATCGCA
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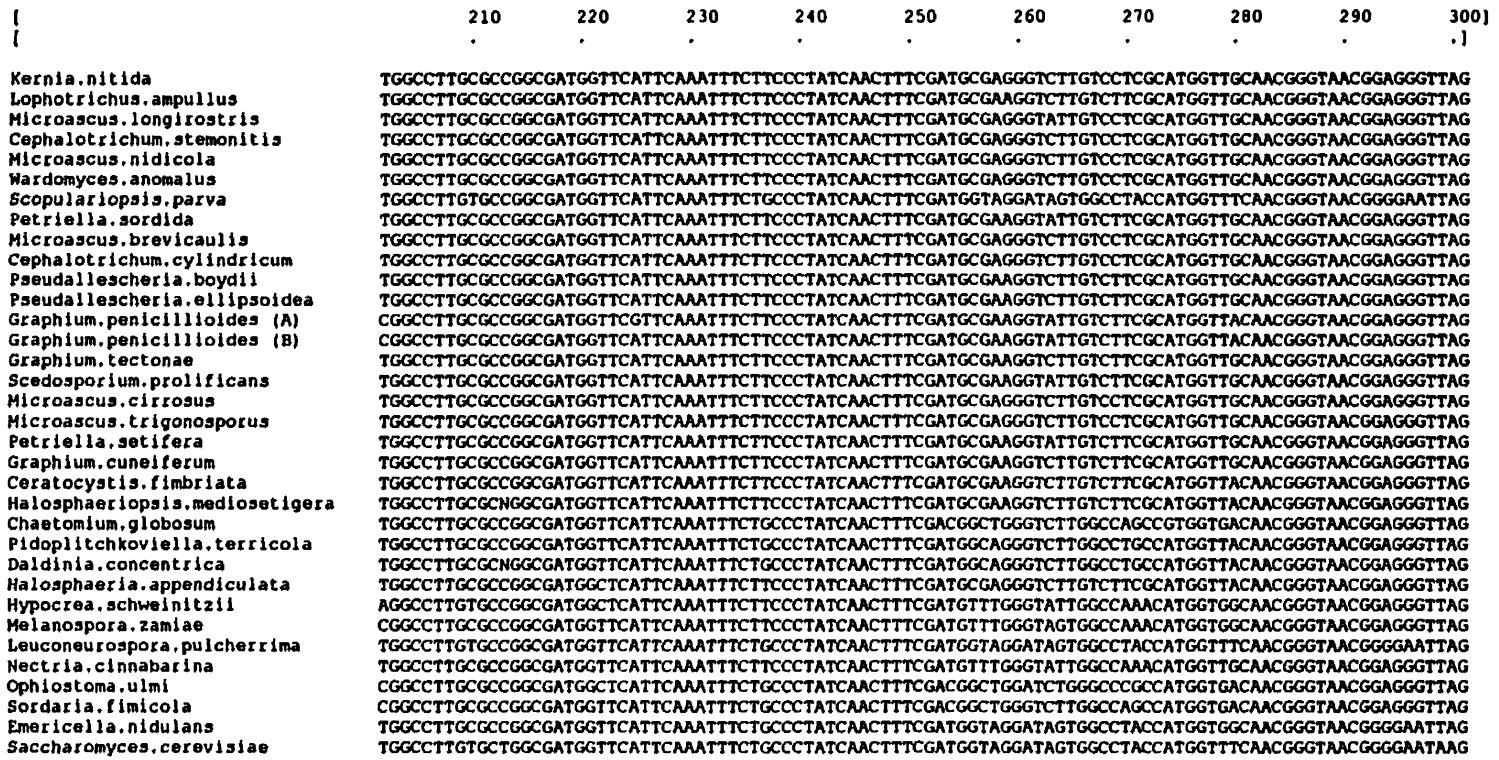
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Wardomyces.anomalus TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAGGGTCTTGTCCTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
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Cephalotrichum.cylindricum TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAGGGTCTTGTCCTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
Pseudallescheria.boydii TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTCTTGTCTTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
Pseudallescheria.ellipsoidea TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTCTTGTCTTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
Graphium.penicillioides (A) CGGCCTTGCGCCGGCGATGGTTCGTTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTATTGTCTTCGCATGGTTACAACGGGTAACGGAGGGTTAG
Graphium.penicillioides (B) CGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTATTGTCTTCGCATGGTTACAACGGGTAACGGAGGGTTAG
Graphium.tectonae TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTCTTGTCTTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
Scedosporium.prolificans TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAAGGTATTGTCTTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
Microascus.cirrosus TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGCGAGGGTCTTGTCCTCGCATGGTTGCAACGGGTAACGGAGGGTTAG
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Pidoplitchkoviella.terricola TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTGCCCTATCAACTTTCGATGGCAGGGTCTTGGCCTGCCATGGTTACAACGGGTAACGGAGGGTTAG
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Nectria.cinnabarina TGGCCTTGCGCCGGCGATGGTTCATTCAAATTTCTTCCCTATCAACTTTCGATGTTTGGGTATTGGCCAAACATGGTTGCAACGGGTAACGGAGGGTTAG
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[                                310       320       330       340       350       360       370       380       390       400]
(                                .         .         .         .         .         .         .         .         .         .]

Kernia.nitida                    GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Lophotrichus.ampullus            GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Microascus.longirostris          GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Cephalotrichum.stemonitis        GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Microascus.nidicola              GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Wardomyces.anomalus              GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Scopulariopsis.parva             GGTTCTATTCCGGAGAGGGAGCCTGAGAAACG CTACCACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Petriella.sordida                GGCTCGACCCCGGAGAAGGAGCCTGAGAAACG CTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Microascus.brevicaulis           GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Cephalotrichum.cylindricum       GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
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Scedosporium.prolificans         GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Microascus.cirrosus              GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
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Hypocrea.schweinitzii            GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Melanospora.zamiae               GNCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTCCTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCTCAACTCGAGGAGGTAGTATA
Leuconeurospora.pulcherrima      GGTTCTATTCCGGAGAGGGAGCCTGAGAAACGGCTACCACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
Nectria.cinnabarina              GGCTCGACCCCGGAGAAGGAGCCTGAGAAACGGCTACTACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAATCCCGACACGGGGAGGTAGTGACA
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Emericella.nidulans              GGTTCGATTCCGGAGAGGGAGCCTGAGAAACGGCTACCACATC.CAAGGAAGGCAGCAGGCGCGCAAATTACCCAA..CCGACACGGGGAGGTAGTGACA
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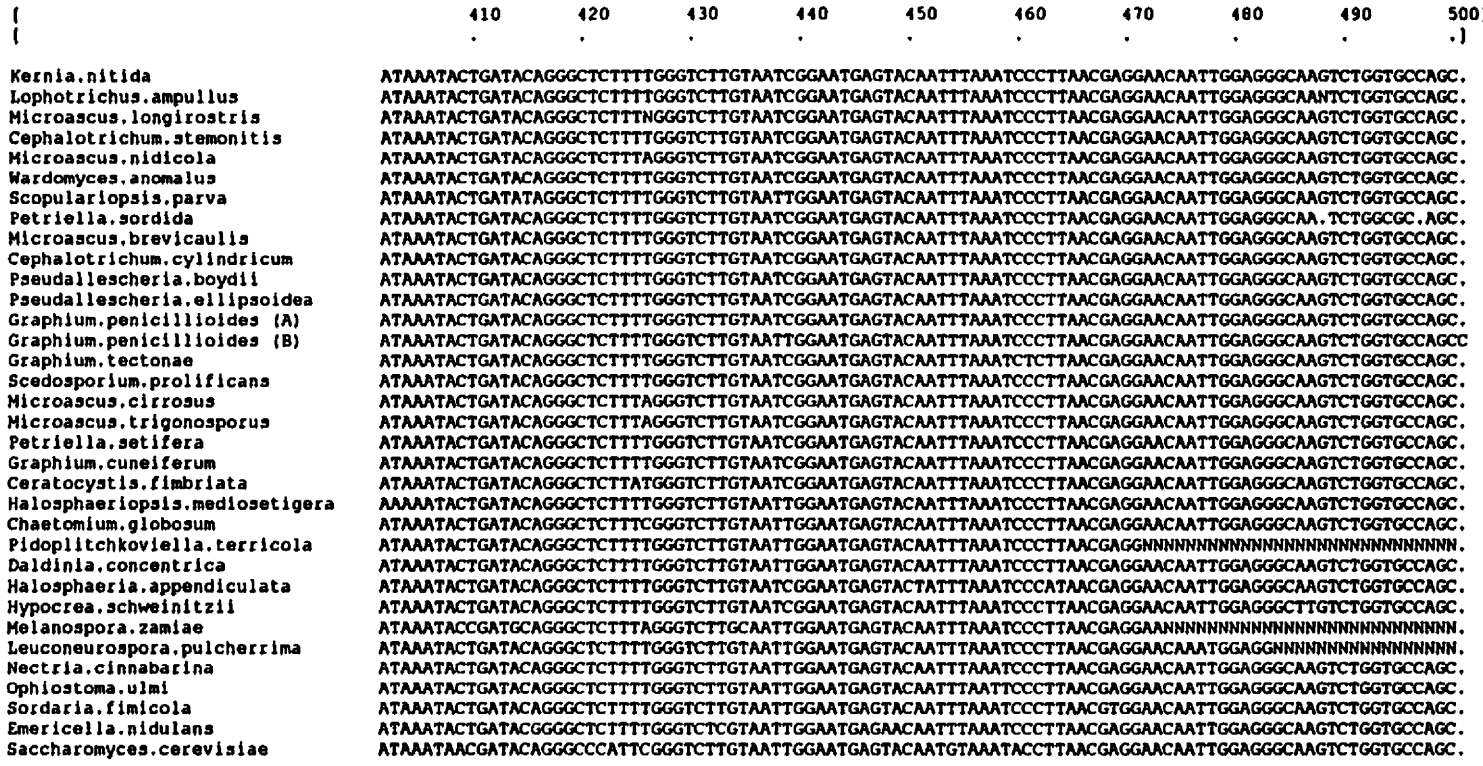
[410 420 430 440 450 460 470 480 490 500]
[. . . . .]
Kernia.nitida ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Lophotrichus.ampullus ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAANTCTGGTGCCAGC.
Microascus.longirostris ATAAATACTGATACAGGGCTCTTTNGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Cephalotrichum.stemonitis ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Microascus.nidicola ATAAATACTGATACAGGGCTCTTTAGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Wardomyces.anomalus ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Scopulariopsis.parva ATAAATACTGATATAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Petriella.sordida ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAA.TCTGGCGC.AGC.
Microascus.brevicaulis ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
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Pseudallescheria.boydii ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Pseudallescheria.ellipsoidea ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Graphium.penicillioides (A) ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Graphium.penicillioides (B) ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGCC
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Microascus.trigonosporus ATAAATACTGATACAGGGCTCTTTAGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Petriella.setifera ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Graphium.cuneiferum ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
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Halosphaeriopsis.mediosetigera AAAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Chaetomium.globosum ATAAATACTGATACAGGGCTCTTTCGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Pidoplitchkoviella.terricola ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGNNNNNNNNNNNNNNNNNNNNNNNNNNN.
Daldinia.concentrica ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Halosphaeria.appendiculata ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACTATTTAAATCCCATAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Hypocrea.schweinitzii ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATCGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCTTGTCTGGTGCCAGC.
Melanospora.zamiae ATAAATACCGATGCAGGGCTCTTTAGGGTCTTGCAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAANNNNNNNNNNNNNNNNNNNNNNNNNN.
Leuconeurospora.pulcherrima ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAAATGGAGGNNNNNNNNNNNNNNNN.
Nectria.cinnabarina ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
Ophiostoma.ulmi ATAAATACTGATACAGGGCTCTTTTGGGTCTTGTAATTGGAATGAGTACAATTTAATTCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
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Emericella.nidulans ATAAATACTGATACGGGGCTCTTTTGGGTCTCGTAATTGGAATGAGAACAATTTAAATCCCTTAACGAGGAACAATTGGAGGGCAAGTCTGGTGCCAGC.
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Lophotrichus.ampullus                      AACCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
Microascus.longirostris                    AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTCGAACCTTGGGCCTGGCCGGCCGGTCCCCCTCACCGG
Cephalotrichum.stemonitis                  AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTCGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
Microascus.nidicola                        AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTCGAACCTTGGGCCTGGCCGGCCGGTCCCCCTCACCGG
Wardomyces.anomalus                        AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTCGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
Scopulariopsis.parva                       AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTAGCTGGCCGGTCCGCCTCACCGC
Petriella.sordida                          ...CGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
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Pseudallescheria.boydii                    AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
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Halosphaeriopsis.mediosetigera             AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCCCCTCACCGG
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Pidoplitchkoviella.terricola               NNNNNNNNNNNNNNNNNNNNNNNTAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCGCCTCACCGC
Daldinia.concentrica                       AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGACGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCTGGTCCGCCTCACCGC
Halosphaeria.appendiculata                 AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTTGTCAGTCCCCCTCACCGG
Hypocrea.schweinitzii                      AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGTGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCGCCTCACCGC
Melanospora.zamiae                         NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCCGCCTAACAGC
Leuconeurospora.pulcherrima                NNNNGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCGCCTCACCGC
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Ophiostoma.ulmi                            AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACCTTGGGCCTGGCTGGCCGGTCCGCCTCACCGC
Sordaria.fimicola                          AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGAGGTTAAAAAGCTCGTAGTTGAACCTTGGGCCCAGCCGGCCGGTCCGCCTCACCGC
Emericella.nidulans                        AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACCTTGGGTCTGGCTGGCCGGTCCGCCTCACCGC
Saccharomyces.cerevisiae                   AGCCGCGGTAATTCCAGCTCCAATAGCGTATATTAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAACTTTGGGCCCGGTTGGCCGGTCCGATTTTTTCG
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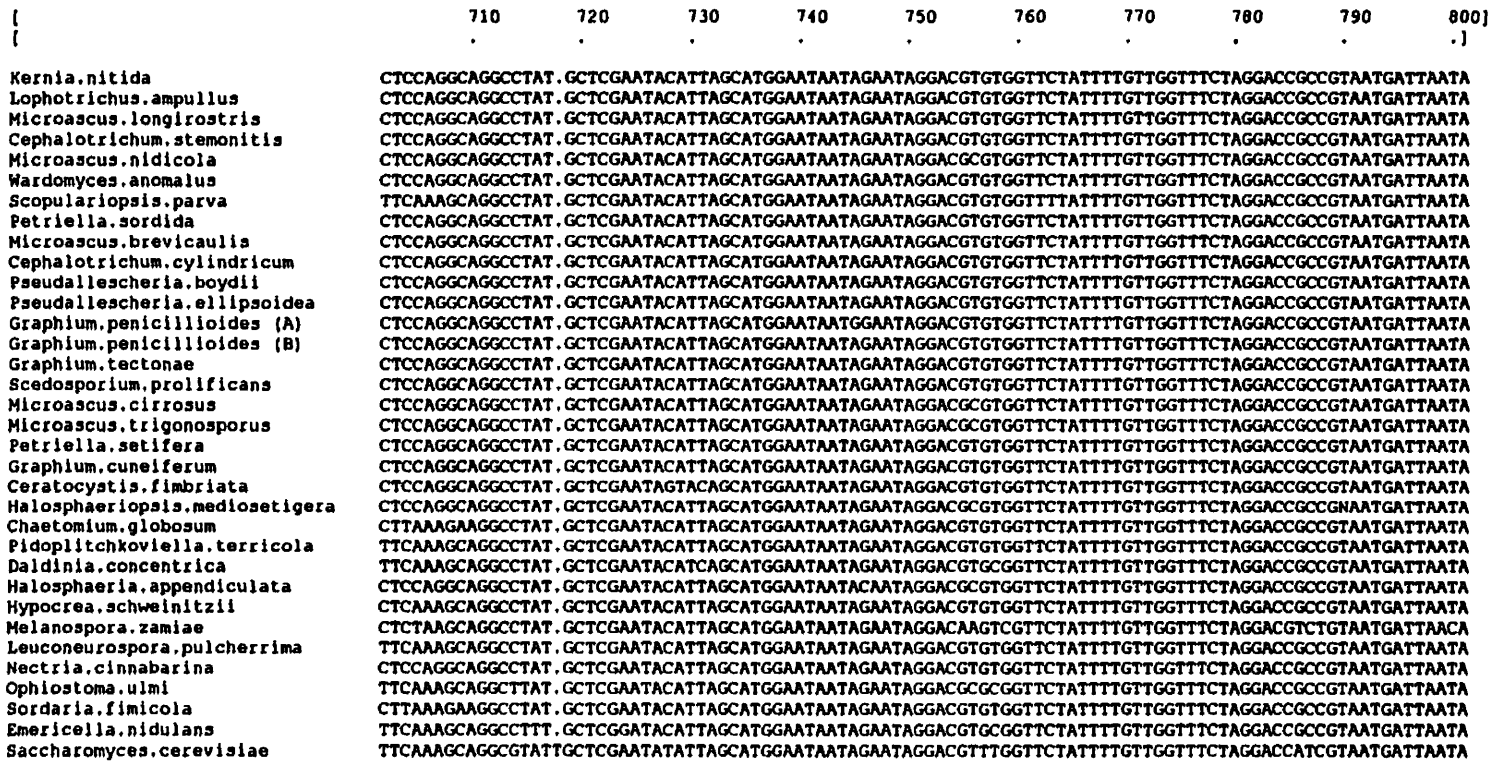
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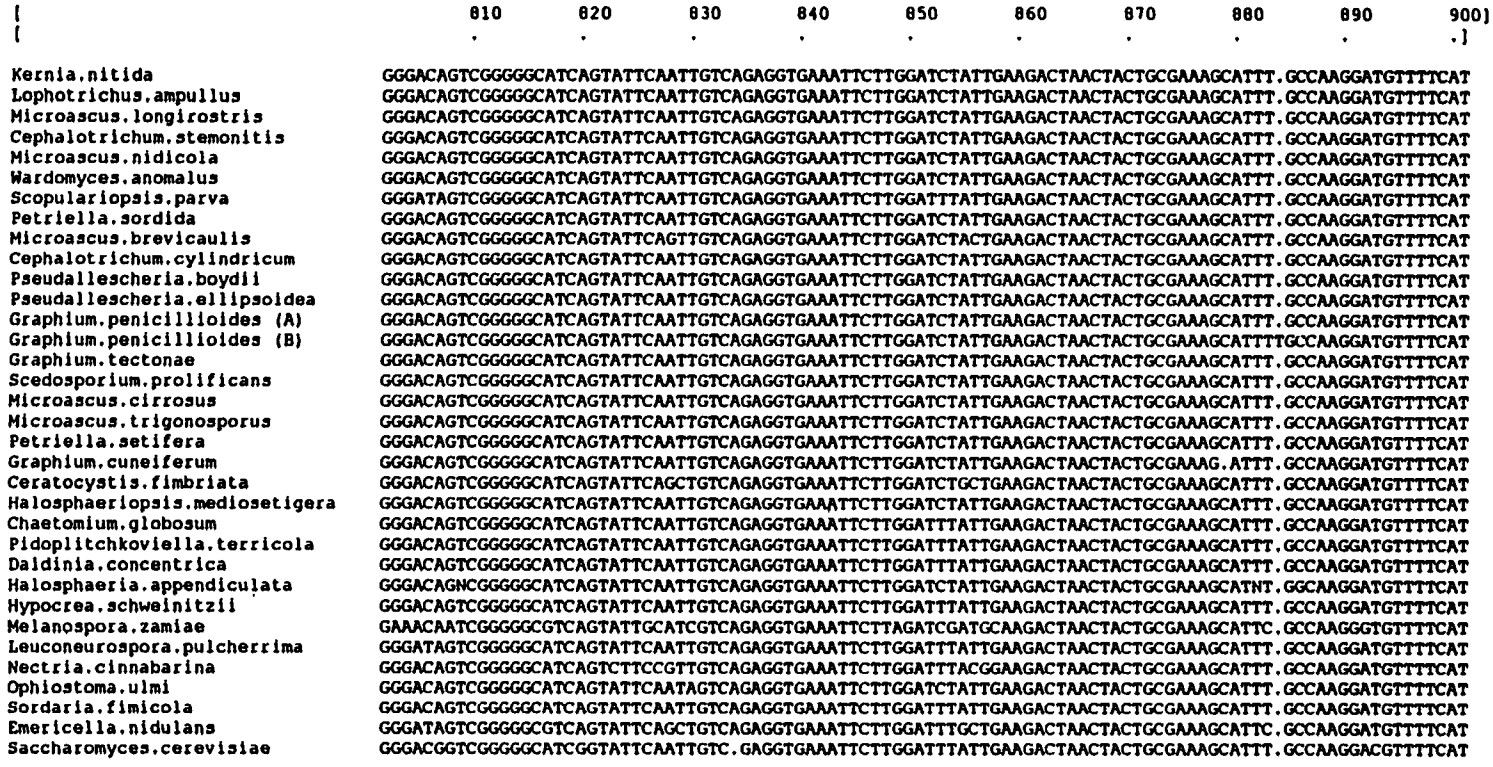
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Lophotrichus.ampullus GGGACAGTCGGGGGCATCAGTATTCAATTGTCAGAGGTGAAATTCTTGGATCTATTGAAGACTAACTACTGCGAAAGCATTT.GCCAAGGATGTTTTCAT
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Petriella.sordida                   TGACGCGTTCGGCACCTTT
Microascus.brevicaulis              TGACGCGTTCGGCACCTTT
Cephalotrichum.cylindricum          TGACGCGTTCGGCACCTTT
Pseudallescheria.boydii             TGACGCGTTCGGCACCTTT
Pseudallescheria.ellipsoidea        TGACGCGTTCGGCACCTTT
Graphium.penicillioides (A)         TGACCCGTTCGGCACCTTT
Graphium.penicillioides (B)         TGACCCGTTCGGCACCTTT
Graphium.tectonae                   TGACGCGTTCGGCACCTTT
Scedosporium.prolificans            TGACGCGTTCGGCACCTTT
Microascus.cirrosus                 TGACGCGTTCGGCACCTTT
Microascus.trigonosporus            TGACGCGTTCGGCACCTTT
Petriella.setifera                  TGACGCGTTCGGCACCTTT
Graphium.cuneiferum                 TGACGCGTTCGGCACCTTT
Ceratocystis.fimbriata              TGACTCGTTCGGCACCTTT
Halosphaeriopsis.mediosetigera      TGACTCGTTCGGCACCTTT
Chaetomium.globosum                 TGACCCGTTCGGCACCTTA
Pidoplitchkoviella.terricola        TGACTCGTTCGGCACCTTA
Daldinia.concentrica                TGACTCGTTCGGCACCTTA
Halosphaeria.appendiculata          TGGCTCGTCCGGNACCTTN
Hypocrea.schweinitzii               TGACGCGTTCGGCACCTTA
Melanospora.zamiae                  TGACCCGCTCGGCACCTTA
Leuconeurospora.pulcherrima         TGACTCGCTCGGCACCTTA
Nectria.cinnabarina                 NGACTCGTNNNNNNNNNNN
Ophiostoma.ulmi                     TGACTCGTTCGGCACCTTA
Sordaria.fimicola                   TGACTCGTTCGGCACCTTA
Emericella.nidulans                 TGACCCGCTCGGCACCTTA
Saccharomyces.cerevisiae            TGACCCACTCGGTACCTTA
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