"My hope still is to leave the world a little bit better for my having been here."

Jim Henson

"We cannot find the truth unless we look along all possible roads."

A.H.R. Buller

University of Alberta

The dispersal of saprobic fungi by arthropods, and fungal mechanisms that facilitate microfaunal transport.

by

Matthew Daniel Greif ©

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Abstract

Arthropods are important vectors for a diverse range of fungal pathogens. However, little is known about the role arthropods play in dispersing fungal saprobes between substrates, or about structural adaptations exhibited by these fungi that facilitate transport. An examination of fungi associated with arthropods in an aspen-dominated parkland forest was conducted to investigate interactions between these two groups of organisms. Additionally, developmental studies on a select group of fruiting bodies (gymnothecia, cephalothecoid cleistothecia, and apothecioid ascomata) of saprobic fungi were conducted to detect mechanisms that encourage arthropod attachment and dispersal.

Arthropods caught in traps baited with coyote dung, moose dung, brown-rotted wood, white-rotted wood, or fibreglass yielded over 65 species of fungi. Many of these species were ubiquitous, but some fungal taxa were specific to arthropods attracted to particular bait types. Ultra-structural observations on gymnothecia showed that insect setae were able to impale this type of fruiting body, thereby attaching it to the exoskeleton. Structural characteristics found in cephalothecoid cleistothecia allowed arthropods to rupture the fruiting body, liberating reproductive propagules in the process. Finally, adaptations in apothecioid ascomata caused spores to be retained in a gel-like matrix, ostensibly to enhance contact and transport by passing invertebrates. This research has shown that arthropods are involved in the dispersal of a wide variety of fungal saprobes, and that these fungi have developed a variety of mechanisms that exploit passing invertebrates for transport to new substrates.

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Chapter 1

Introduction

Spore dispersal is an integral component of the fungal lifecycle. Fungi are unable to actively seek out and colonize new areas where there are sufficient resources for growth and reproduction, and therefore depend on passive dispersal by abiotic and biotic agents to dislodge physically and carry spores to fresh substrates. To facilitate spore dispersal, a number of structural features have evolved among fungal taxa. Pioneering mycologists, such as Ingold (1961) and Brodie (1975), identified a diverse range of mechanisms in the structure, or reproductive architecture, of fruiting bodies produced by fungi that take advantage of abiotic dispersal factors such as wind and water. Fungi dispersed abiotically grow, or at least produce spore-bearing structures, on exposed spaces such as the surfaces of plant material (i.e., leaves and wood) or on the surface of soil. The reproductive architecture produced by these taxa encourage spore dispersal by air by allowing meiotic propagules to be shot past the boundary layer separating the fungus from the turbid air mass (e.g. Pezizales), or channel air currents to create turbulence to dislodge reproductive material (e.g. the distinct hemispherical caps produced by diverse Basidiomycete taxa) (Ingold 1961). The reproductive architecture of fungi dispersed by water also exhibit a range of adaptations such as modified spores that can ride on the surface of running water by producing branched, coiled, or tetraradiate conidia or specialized appendages on ascospores, or use the kinetic energy of falling rain to knock spores out of specially designed fruiting bodies, or to simply bounce spores between substrates (Ingold 1961, Brodie 1975, Webster and Descal 1981).

The main drawback inherent in exploiting abiotic mechanisms is that dispersal is dependant on chance. If air currents do not move in the direction of required substrates, or if water is not available, then spores cannot reach new habitats and the lifecycle of the fungus is interrupted. Biotic (animal) dispersal eliminates some of this chance. Animals can actively seek out particular substrates and fungi that are adapted for animal transport can exploit the mobility of these organisms for targeted dispersal. Many vertebrates aid in disseminating spores through the consumption of fungal material (mycophagy), and as a result the reproductive architecture of many taxa (e.g. *Tuber* and *Elaphomyces*) have become adapted exclusively for animal dispersal by producing fragrant, enclosed fruiting bodies that retain their spores. An important sub-set of animal vectors are arthropods. Substrates utilized for food, shelter, or habitats to deposit eggs (e.g. dung, decaying wood, and leaf litter) by arthropods are also frequently colonized by fungi. The similar habitat preferences and close proximity between fungi and arthropods has led to many interesting interactions. Members of the Laboulbeniales and Trichomycetes have become so dependant on arthropods for dispersal that their fruiting structures have become adapted to form either on or in the dispersal agents themselves (Tavares 1985, Lichtwardt 1986). A wide range of fungal plant pathogens, in genera such as *Leptographium, Ophiostoma, Ceratocystis,* and *Amylostereum* (Levieux et al. 1989, Slippers et al. 2000, Jacobs and Wingfield 2001, Haberkern et al. 2002), have a reproductive architecture adapted to aid in spore attachment by locating slimy droplets of spores on the end of elongate vegetative or reproductive structures.

The bulk of our knowledge on arthropod-fungal interactions, especially pertaining to dispersal, is the result of work on plant pathogenic fungi. These organisms have a high economic impact and there has been extensive effort invested to elucidate the identity of arthropod vectors and their fungal associates, with the dispersal of plant and arthropod pathogens being major areas of research activity. This has led to a somewhat lopsided body of knowledge on the involvement of arthropods in fungal dispersal. Interactions between arthropods and saprophytic fungi (fungi that break down dead organic material) are poorly documented and there is no clear understanding of the impact arthropods have on the dispersal of fungal saprobes. While this lack of information is frustrating when researching fungal dispersal by arthropods, it also provides an untapped area of study in arthropod-fungal interactions with many basic questions waiting to be tested.

In a boreal forest ecosystem, organic substrates rich in cellulose and lignin (e.g. wood) or rich in keratin (e.g. hair, skin, and dung containing these materials) have been found to host fungi able to break down these compounds (e.g. Myxotrichaceae and Onygenales respectively) (Lumley et al. 2000, Currah 1985). Many of these organic substrates tend to be uncommon in time and/or space, as is the case with dung or animal remains. Other organic substrates (i.e., fallen logs, or cavities under bark) are usually protected or sheltered from wind and rain. These types of substrates are referred to as cryptic habitats because they are difficult for fungi to access. How fungal saprobes are able to reach and colonize these habitats is unknown. Additionally, since cryptic habitats tend to be protected from the elements it is also unknown how fungi that occur on these habitats, and generally lack access to abiotic dispersal mechanisms, disperse their spores to similar substrates. Saprobic fungi associated with cryptic habitats are infrequent in surveys of airborne fungi (Franca and Caretta 1984, Marchisio et al. 1992, Marchisio et al. 1993, Airaudi and Marchisio 1996), and it is poorly reported in the literature how spores from saprophytic species are capable of locating and colonizing substrates without the aid of wind or water (Pugh 1963, Pugh 1965, Pugh and Evans 1970).

Many cryptic habitat-associated saprophytic fungi in the Ascomycota produce fruiting structures (ascomata) with a reproductive architecture that implies a reliance on arthropods for dispersal. These ascocarps often do not release their ascospores, and instead produce asci that deliquesce, or embed spores in sticky gel-like material, and thus require external inputs of energy to dislodge and transport spores. Examples include gymnothecia (found in the Onygenales and Myxotrichaceae), cephalothecoid cleistothecia (found in the Cephalothecaceae and Sordariales), and apothecia with gel-like pseudoepithecia (in the Helotiales and Patellariales).

Gymnothecia are specialized cleistothecia, constructed of thick walled hyphae that form a loose cage around the asci (Novak and Galgoczy 1966), and have evolved independently in multiple taxa in the Leotiales and Onygenales (Hambleton et al. 1998, Sugiyama et al. 1999, Sugiyama and Mikawa 2001). Hooked or curved appendages growing outwards from this cage give the gymnothecium a burr-like appearance. Gymnothecial taxa have been isolated from dung, hair, skin, and other substrates rich in keratin, as well as from wood, paper, and substrates rich in cellulose (Currah 1985). The morphology of the gymnothecia and the substrates from which these fungi are isolated, led to the hypothesis that these taxa rely on arthropods and other animal vectors for dispersal (Currah 1985). The appendages produced by the burr-like gymnothecia were predicted to latch on to passing arthropods that could transport spores to fresh substrates. However, there is no data either from the field, or *in vitro* that supports this hypothesis.

Cephalothecoid cleistothecia were first described by Von Höhnel in 1917 in his description of the genus *Cephalotheca*. A cephalothecoid cleistothecium has an outer layer (peridium) composed of plates of tightly packed cells. These plates have a centre composed of isodiametric cells and an outer region of elongated peridial elements. Dehiscence lines, which rupture upon desiccation and allow the peridium to shatter or disintegrate (Hawksworth and Booth 1974), circumscribe these plates and in some species the cleistothecium can open up fully to expose the ascospores (Chesters 1934, Samuels and Rodrigues 1989). As is the case with gymnothecia, the cephalothecoid cleistothecium lacks a spore ejection mechanism, and this peridial type is a convergent feature found in unrelated orders in the Sordariales, Ophiostomatales, and Dothideales (Suh and Blackwell 1999). Cephalothecoid taxa have been isolated from under bark, or around beetle galleries in branches, leading a number of researchers to speculate that these fungi are dispersed by arthropods, but there are few empirical data supporting this hypothesis (Chesters 1934, Malloch and Cain 1970, Benny et al. 1980).

Apothecia with gel-like pseudoepithecia are produced by diverse taxa in both the Leotiomycetes and the Dothideomycetes (Bellèmere 1967, Sivanesan 1983, Barr and Huhndorf 2001, Pfister and Kimbrough 2001), and are commonly found in cavities in or under rotting wood. These fungi are able to eject their spores forcibly, but are protected from abiotic disturbance, so it is unclear if wind or water dispersal would effectively carry spores to suitable habitats. The convergent fruiting body morphology in these taxa has been hypothesized to be a response to harsh environmental conditions with the gel-like pseudoepithecium viewed as adaptation that prevents water loss, or minimizes damage due to freezing (Sherwood 1981). The gel-like layer in these disc-shaped fruiting bodies fungi tend to trap discharged ascospores, resulting in a gel-spore matrix positioned on the surface of the apothecia. In the Ophiostomatales, spores are produced in a sticky mucilaginous matrix which collect in a mass positioned at the tips of perithecia and attach to passing arthropods (Jacobs and Wingfield 2001) and it is possible that the gel-spore matrix produced by taxa in the Leotiomycetes and the Dothideomycetes has a similar function.

The numbers and diversity of arthropods associated with cryptic habitats suggest these animals, as they travel from one patch of woody or fecal debris to another, would carry on the surface of their bodies not only a wide range of ubiquitous fungi but also specific groups of specialized saprophytic taxa specialized for these substrates. However, this hypothesis has thus far not been tested in the field. There are a limited number of studies investigating associations between saprophytic fungi and arthropods, and most have looked at either specific arthropod or fungal species (Talbot 1952, Christen 1975, Balazy et al. 1987, Martin et al. 1987, Visser et al. 1987, Gambino and Thomas 1988, Zoberi and Grace 1990, Lee et al. 1993, Sella Nunes Sales et al. 2002). In many of these studies, fungi are isolated from arthropods collected directly from substrates of interest or from the immediate vicinity, making connections with dispersal less clear. Additionally, there is little or no research available investigating the lifecycle of many specific cryptic-habitat associated fungi. How these fungi react to contact with arthropods is only hypothesized and our understanding of these dispersal mechanisms is much poorer than our understanding of mechanisms that take advantage of abiotic agents (Ingold 1961, Brodie 1975).

To investigate the role arthropods play in dispersing saprophytic fungi from one cryptic substrate to the next, and how these fungi can facilitate this dispersal, I proposed the following questions to guide my research program: What exoskeleton associated saprophytic fungi are present in a general arthropod population? As arthropods travel between cryptic habitats, do they carry saprophytic fungi associated with, or specialized for, these habitats? Can mechanisms that facilitate arthropod dispersal be identified in the reproductive architecture of fruiting bodies produced by saprophytic fungi, and how do these mechanisms function?

My investigations are organized into six chapters (i.e. chapters two-seven). Chapter two reports the results of a survey of fungi borne on the exoskeletons of arthropods attracted to substrates representative of cryptic habitats. Traps baited with either animal dung (moose and coyote), decaying wood (brown- and white-rotted wood), or fibreglass were used to capture arthropods in the vicinity of Elk Island National Park. Fungi were then selectively isolated from these arthropods using cycloheximide-amended corn meal agar. Statistical analyses on the resulting collection data was used to search for patterns between fungi, arthropod vector, and bait. Chapter three describes *Leptographium piriforme,* a new species of arthropod-associated fungus isolated from this survey. The morphology, physiology, and molecular sequence data for this fungus are unique in comparison with other species of *Leptographium*. Chapter four assesses the relationship between gymnothecial structure and mechanisms for arthropod attachment *in-vitro*. Gymnothecia of *Myxotrichum deflexum* and *Auxarthron conjugatum* were exposed to *Neobulleria bullata* (flesh flies) to investigate the ability of gymnothecia to attach to arthropod exoskeletons and identify what mechanism was responsible for this attachment. Chapter five investigates the development of the cephalothecoid peridium of *Cryptendoxyla hypophloia* (another species isolated during this survey), using light, scanning electron and transmission electron microscopy. The effect of desiccation on the peridium was observed using a dissection microscope, allowing comment on its possible role in facilitating dispersal by arthropods. A similar approach was used to investigate the development of a second, and unrelated, cephalothecoid species, *Aporothielavia leptoderma,* in chapter six. Chapter seven investigates the morphological development and taxonomic position of *Catinella olivacea.* This fungus, common in cavities found in wet decorticated wood, produces a discoid fruiting body with a gelatinous pseudoepithecial layer. Observations on the development of the fruiting body allowed for the formulation of new hypotheses concerning how this fungus is able to exploit arthropods to locate fresh substrates and, together with sequence data from the small sub-unit gene region (SSU), were used to re-assess the taxonomic placement of this fungus.

My research into the diversity of saprobic fungi dispersed by arthropods will contribute to our overall understanding of fungal-arthropod interactions. Following the development of fungal fruiting structures in this thesis will provide valuable taxonomic characters that will aid in refining the phylogeny of these fungi. These data also aid in identifying and evaluating the effectiveness of dispersal mechanisms present in the reproductive architecture of these taxa and allow for the formulation of new hypotheses concerning the lifecycle of these and other fungi with similar habitats and fruiting structures.

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Chapter 2

Patterns in the occurrence of saprophytic fungi carried by arthropods caught in traps baited with rotted wood and dung[1].

INTRODUCTION:

The numbers and diversity of arthropods associated with decaying wood and dung suggest that these animals would carry on the surface of their bodies not only a wide range of ubiquitous saprobic fungi but also specific groups of more specialized taxa associated with the breakdown of these materials. There are few data available supporting this hypothesis although it is well known that mycangial arthropods, e.g., wood wasps and bark beetles, are involved in the transfer of specific fungi from substrate to substrate (Slippers et al. 2000, Levieux et al. 1989) and that others carry specific plant pathogenic fungi from one host to another (e.g., *Ophiostoma ulmi* carried by bark beetles in Dutch elm disease, agents of bluestain, etc.) (Harrington, 1993, Jacobs and Wingfield 2001). Some investigators have isolated and identified fungi on the bodies of specific types of arthropods, including springtails from soils (Visser et al. 1987, Christen 1975), mites (Renker et al. 2005), wasps (Gambino and Thomas 1988), beetles (Haberkern et al. 2002) and termites (Zoberi and Grace 1990) from wood, and show that arthropods, removed or emerging from a given sample, are carrying propagules of the fungi involved in the decomposition of the main constituents of that sample (Talbot 1952). It is not known if these saprobic fungi are effectively transmitted to new substrates or if their transmission to appropriate new substrates by arthropod carriers is anything more than a purely random process.

To test the hypothesis that particular arthropod taxa carry unique sets of saprobic fungi to different substrates, I set up a series of traps, baited with either decaying wood or dung, in a relatively undisturbed woodland. Trapped arthropods and adhering, filamentous fungi which were isolated in pure culture, were both identified. Using principal components analyses of the resulting taxonomic and numerical data, I searched

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[1] A version of this chapter has been submitted as:

Greif MD, Currah RS 2006 Patterns in the occurrence of saprophytic fungi carried by arthropods caught in traps baited with rotted wood and dung. Mycologia (Submitted March 15 2006; ref # 06-056) for patterns in the relationship, first between arthropod taxa and bait type and second between the fungal taxa being carried on the body surface of these animals and the bait to which they had been attracted.

MATERIALS AND METHODS:

Arthropods were collected from May through Aug in 2002 and 2003 using baited traps set in a southern boreal mixed wood forest dominated by *Populus tremuloides* Michx. and located 100 km east of Edmonton, Alberta. Traps consisted of 5L plastic pails with a pair of holes, 2.2 cm in diameter, cut approximately 11 cm from the bottom and on opposite sides. The neck of the top 10 cm portion of a plastic 2L plastic pop bottle was fitted into each hole and fastened in place to form a funnel that opened into the pail. The interior surface of the lid and the top third of the interior walls of each pail were coated with Fluon tm (AGC Chemicals Americas Inc., Bayonne, New Jersey) to prevent arthropods from crawling out of the trap (Appendix 3).

Forty traps were prepared: ten each were baited with moose (herbivore) dung, coyote (carnivore) dung, white-rotted wood or brown-rotted wood, all previously collected as fresh samples from the study site and kept frozen at -4°C until needed. Three additional traps were baited with moistened fibreglass. Each bait sample was placed in the bottom half of a plastic Petri plate that formed the floor of a 9 x 9 x 9 cm cage constructed of 1 mm diameter bailing wire. To prevent trapped arthropods from coming into contact with the bait, and picking up fungi developing on it, the cage was covered with nylon fabric (mesh size 0.3 - 0.5 mm), and suspended from a hook on the inside of the lid of the pail.

Traps were placed on the ground and fastened with wire to nearby trees. Nine groups of traps were placed approximately 100 m apart along a 1 km trail. Each group consisted of four to seven traps positioned 4-5 m from its neighbour. Baits were remoistened with sterile water two weeks later and replaced with fresh material monthly. Captured arthropods were removed once a week and placed in sterile, 64-ml plastic vials for transport to the laboratory.

Arthropods were stored at 4°C until examined individually under a dissecting microscope, within 24 - 36 h of collection, for evidence of attachment of fungal propagules. Using sterile, fine tiped, insect forceps (Bioquip Products Inc., Rancho Dominguez, California), arthropods were either rolled or, if very small or delicate, flipped end-over-end across the surface of a single Petri plate of Mycobiotic ^{tm} agar (35.6g Mycobiotic agar (BD, Oakville, Ontario) and 1L dH2O). This medium contains 0.05g/L chloramphenicol to suppress bacterial growth and 0.5g/L cycloheximide, a fungal inhibitor that slows or prevents the growth of common aggressive species and allows detection of slower growing taxa. Arthropod specimens were identified, at least to order, and those that did not disintegrate during streaking were stored in 70% ethanol-5% glycerine solution and deposited in the Strickland Insect Collection at the University of Alberta. Fungal vouchers were deposited as permanent slides in the University of Alberta Cryptogamic Herbarium (ALTA) or as living cultures in the University of Alberta Microfungus Collection and Herbarium (UAMH).

Plates were incubated for 4-6 mo at room temperature and under ambient light and examined regularly for fungal growth. Colonies from primary isolation plates were transferred to corn meal agar (CMA, 17g Acumedia ^{tm} corn meal media (Neogen Corp., Lansing, Michigan) and 1 L dH_20) incubated under ambient light at room temperature, and identified using morphological criteria.

Data from both years of collection were combined and principal components analyses were conducted using PC-ORD 4.0 (MJM software design, Gleneden Beach, Oregon) with the variance/covariance (centred) option selected for the cross product matrix. The first analysis compared bait types with the number and identity of arthropod orders caught in each trap as variables (Note that ants (Hymenoptera: Formicidae) and all unidentified arthropods were each treated as a separate order). The second analysis compared bait types using the number and identity of fungal species isolated from arthropods retrieved from each trap as variables. From the resulting point swarms, the pair of orthogonal axes accounting for the maximum linear variation was determined. The effect of trap location on arthropods recovered and fungi isolated, i.e., among the nine groups, was determined by PCA to be negligible and is not considered further.

RESULTS:

Over the two-year period, 1696 arthropods were captured and most were identified at least to order (Table 2.1). Direct observation, using the dissecting microscope, of the scant amounts of debris adhering to their surface was insufficient to distinguish and identify fungal propagules, but 1687 isolates of filamentous fungi representing at least 65 species were recovered as pure cultures from streaks made with 1068 arthropod specimens (Table 2.2). Fungal taxa were scored once per primary isolation plate regardless of the number of colonies that had formed. Yeasts and bacteria were discarded. The majority (81.7%) of isolates was represented by species of *Cladosporium, Beauveria, Penicillium* and *Verticillium*. Species of *Acremonium, Geomyces, Leptographium* and *Paecilomyces* made up an additional 10.1%, and 35 species in 23 other genera made up the remaining 8.2% (Table 2.2). Most fungi were Hyphomycetes with ascomycetous affinities. Eight of these formed ascomata and were identified with a teleomorph name. The Zygomycota was represented by five species. Filamentous basidiomycetes were not isolated. There was a linear relationship between numbers of arthropods captured per taxon and numbers of fungal isolates recovered ($R^2 = 0.9593$, $p < 0.0001$) (Fig. 2.1), and a logarithmic relationship between number of arthropods captured per taxon and number of fungal species recovered ($R^2 = 0.923$, $P < 0.0001$) (Fig. 2.2).

The average number of arthropods caught was lowest in May and highest in July although exceptions occurred with beetles, and butterflies and moths, whose numbers peaked in June, and harvestmen, whose numbers peaked in August. On average over the two-year sampling period, traps baited with moose dung, brown-rotted wood, white-rotted wood and fibreglass attracted 31-37 arthropods per trap and coyote dung 54 arthropods per trap. The coyote dung, brown-rotted wood, and white-rotted wood attracted representatives from all 13 orders of arthropods recorded. Traps baited with moose dung and fibreglass each attracted arthropods representing 10 orders (Table 2.1).

Traps baited with coyote dung attracted arthropods that yielded 476 fungal isolates representing 36 species in eight orders; eight fungal taxa were unique to this group. Arthropods from traps baited with brown-rotted wood yielded 392 fungal isolates representing 29 species in eight orders. Three of these species were unique. Traps baited with white-rotted wood attracted arthropods that yielded 361 fungal isolates representing 26 species in six orders. Three species in this group were unique to traps with this bait type. From traps baited with moose dung, arthropods yielded 352 fungal isolates representing 30 species in eight orders; five of these species were unique. The traps baited with fibreglass yielded 106 fungal isolates representing 19 species in six orders. Only one species was unique to the fibreglass baited traps (Table 2.3).

An examination of the broken-stick eigenvalues obtained from the first PCA (bait type vs. number and type of arthropod) showed that the first four axes were significant, accounting for 88.9% of total variation, with axis one (representing number of captures of each taxon) accounting for 46.4% of the variation, and axis two (representing the taxonomic richness of the captured arthropods) representing 19%. Axes three and four were significant at 12.8% and 10.6% but were not considered further. Plotting data along the first two axes resulted in the majority of points representing traps baited with coyote dung and moose dung positioned to the left of the origin and points representing traps baited with both types of decayed wood mostly to the right (Fig. 2.3). Traps baited with white-rotted wood fell closely together to form a cluster lying below the origin of axis 2. One trap baited with coyote dung appeared as an outlier to the left of the main cluster; it had the most flies, mites, and caddisflies for this bait type. One trap, baited with moose dung, was also positioned far to the left and had a much higher number of beetles than other traps with this bait (Fig. 2.3).

An examination of the broken-stick eigenvalues obtained from the second PCA analysis (i.e., bait type vs. number and identity of fungal isolates) showed that the first five axes were significant and accounted for 80.6% of variation, with axis one (representing the number of isolates of each species) accounting for 44.8% of the variation, and axis two (representing the taxonomic richness of the isolated species) accounting for 15.6%. Axes three, four and five were significant but accounted for only 9.7%, 6.1%, and 4.2% of total variation respectively and were not considered further.

Plotting data along the first two axes resulted in points representing all but one trap baited with each of coyote dung, moose dung, brown-rotted wood, and white-rotted wood positioned in a loose central cluster around the origin (Fig. 2.4). Seven of the traps baited with coyote dung were to the right of the origin while the majority of traps baited with moose dung (7 of 10) and white-rotted wood (7 of 10) were to the left (Fig. 2.4). Eight of 10 traps baited with brown-rotted wood formed a tight cluster just below axis 2 with a majority of these traps located to the left of the origin. Among traps baited with coyote dung the most distant outlier in the lower right hand quadrant had exceptionally high numbers of isolates of species of *Beauveria*, *Penicillium*, and *Verticillium*. The outlier among traps baited with moose dung had the highest number of fungal isolates for this bait as well as the highest number of isolates of *Beauveria bassiana*, *Cladosporium cladosporioides*, and *Verticillium lamellicola*. It also yielded the only isolates of *Scopulariopsis brevicaulis* and *V. psalliotae* for this bait type. The outlier for the traps baited with brown-rotted wood had the most isolates of species of *Cladosporium* in addition to the only isolates of species of *Cryptendoxyla*, *Oidiodendron*, and *Rhizopus* recovered from traps with this bait type. The outlier for the traps baited with white-rotted wood had the highest number of isolates of *Hormiactis candida*, *Penicillium* cf. *steckii* and *Verticillium lamellicola* as well as the only isolates of *Mucor heimalis* and *P.*cf. *griseofulvum* for this bait type. The three traps baited with moistened fibreglass were close to the origin in both analyses (Figs. 2.3-2.4).

DISCUSSION:

The objective of this study was to test the hypothesis that arthropods associated with different types of decaying wood and dung carry and potentially deliver specific groups of saprophytic fungi that are associated with the breakdown of these materials. This hypothesis would be supported by finding fungal taxa with known predilections for cellulose and lignocellulose on arthropods caught in traps baited with decayed wood and moose dung, and fungal taxa with predilections for keratin on the arthropods caught in traps baited with coyote dung. Although each of the baits had a preponderance of the native forms of these complex macromolecules, they also contained many other substances that could affect the types of arthropods lured into the traps. In addition, the unavoidable isolation of ubiquitous fungal taxa from trapped arthropods ostensibly created some level of "background noise" that reduced the level of resolution of the analyses. Nevertheless, several patterns emerged from my observations and analyses that provide some support, albeit weak, for the initial hypothesis.

I was unable to recognize fungal propagules on the surface of the captured arthropods but the isolation data show that a diverse range of viable fungi was being transported into the traps. The trapped microfauna are thus dispersal agents for the species of fungi they were carrying (Dowd 1998). The linear relationship between the number of fungal isolates recovered and the numbers of arthropods collected, and the logarithmic relationship between fungal species and arthropods recovered indicate that continued trapping and isolating using this culturing protocol would be expected to yield greater numbers of isolates, but diminishing numbers of new fungal species (Figs. 2.1-2.2).

As anticipated, most fungi isolated were ubiquitous taxa; 81.7% were species of *Beauveria, Verticillium, Cladosporium* and *Penicillium,* all versatile saprobes and prolific spore producers. The entomopathogen, *Beauveria bassiana* represented one quarter of all isolates and was frequent on mites, beetles, flies, and ants and was particularly abundant on spiders. Species of *Verticillium* (*V. lamellicola, V. lecanii,* and *V. psalliotae*) were most abundant on flies and spiders and, like *B. bassiana*, were evenly distributed across bait types. The abundant recovery of entomopathogenic species across multiple taxa and from presumably healthy specimens suggests that these fungi are common components of the surface mycota of these animals and are not restricted to specimens exhibiting obvious signs of mycosis.

Species of *Cladosporium* and *Penicillium* together accounted for 47% of all isolates. *Cladosporium cladosporioides* was the most common, representing 77% of isolates in the genus. Its distribution was similar to *B. bassiana*, being most common on mites, spiders, beetles, flies, ants and bugs. These observations are similar to prior reports concerning the prevalence of *C. cladosporioides* on arthropods (Visser et al. 1987, Pherson and Beattie 1979, Senna Nunes Sales et al. 2002, Zoberi and Grace 1990, Martin et al. 1987, Reddersen 1995). Species of *Penicillium* comprised 17% of all isolates and, although abundant on arthropods attracted to all bait types, almost half of all isolates came from flies and spiders, the two most abundant arthropod groups recovered. *Penicillium* cf. *steckii* was the most common, representing 35% of isolates in this genus. *Penicillium* species are a common component of the mycoflora isolated from arthropods (Visser et al. 1987, Pherson and Beattie 1979, Senna Nunes Sales et al. 2002, Zoberi and Grace 1990, Martin et al. 1987, Gambino and Thomas 1988). *Cladosporium* and *Penicillium* are also among the most common fungi isolated during surveys of airborne fungi (Airaudi and Marchisio 1996, Marchisio et al. 1993, Calvo et al. 1982).

Some ubiquitous hyphomycete taxa, i.e., *Alternaria, Fusarium, Gliocladium,* and *Scopulariopsis*, and zygomycete taxa, i.e., *Absidia corymbifera*, *A. glauca*, *Mucor hiemalis*, and *Rhizopus stolonifer*, were recovered in remarkably small numbers. These 62 isolates (4% of total) were fewer than expected considering their usual high frequencies in soil and among airborne spores (Keller and Bidochka 1998, Franca and Caretta 1984). Some intolerance to cycloheximide may partly explain this observation for some taxa, such as species of *Mucor* and *Rhizopus*, but *Scopulariopsis, Alternaria,* and *Fusarium* are cycloheximide resistant and also common components of the airborne mycoflora (Franca and Caretta 1984, Airudi and Marchisio 1996, Marchisio et al. 1993, Calvo et al. 1982). These fungi are all common saprobes on decaying herbaceous plant materials (Loiveke et al. 2004, Ioos et al. 2004) and may have been partially excluded by arthropods that are associated with or attracted to rotted wood and dung. Higher frequencies for these taxa may have been obtained if a set of traps had been baited with decaying herbaceous plant material.

These records were in contrast to less frequently isolated taxa with more specific habitat preferences. Uncommon in surveys of airborne fungi (Airudi and Marchisio 1996, Marchisio et al. 1993, Calvo et al. 1982), these taxa have a presumed reliance on animals for dispersal. These include isolates in the Onygenales (species of *Auxarthron*, *Arthroderma*, and *Chrysosporium*) and Myxotrichaceae (species of *Geomyces*, *Oidiodendron* and *Myxotrichum*), *Cryptendoxyla hypophloia*, *Leptographium* sp. I, *Conidiobolus coronatus*, and species of *Chalara*.

The gymnothecial ascomata produced by many of the Arthrodermataceae, Onygenaceae (Onygenales) and Myxotrichaceae (Leotiales, *incertae sedis*) have a mesh-like peridial wall (reticuloperidium) that, *in vitro*, allows the setae of insects to pass through the spaces between peridial hyphae, causing the mass of ascospores to cling to the body of the arthropod (Greif and Currah 2003). Many of these taxa also produce dry, cylindrical arthroconidia which may adhere electrostatically to arthropod carriers. Gymnothecial fungi were obtained from 3.4% of the arthropods. The Arthrodermataceae has been reported previously from captured insects (Diptera) (Pinetti et al. 1974, Gip and Svenson 1968), but these reports of the Onygenaceae and Myxotrichaceae from living arthropods are unique. Gymnothecial taxa tend to be poor competitors (Pugh 1963) and presumably rely primarily on direct substrate-to-substrate transfer to establish new colonies. The recovery here of 11 different gymnothecial species suggests their shared suite of reproductive characteristics is playing some role in their dispersal by arthropods. A similar targeted dispersal mechanism has been suggested for species of *Arthroderma, Ctenomyces,* and their anamorphs (Onygenales) associated with birds and bird nests (Pugh 1965, Pugh and Evans 1970).

A majority of representatives of the Onygenaceae and Arthrodermataceae, both groups with known proclivities for keratin-rich substrates (Currah 1985), was isolated from arthropods attracted to the coyote dung, while species in the Myxotrichaceae, a group known primarily from cellulose-rich substrates, were mostly isolated from arthropods attracted to baits with ostensibly higher levels of cellulose (moose dung, brown- and white-rotted wood). Of 47 isolates representing the Myxotrichaceae, 60.7% were isolated from visitors to traps containing moose dung, brown-rotted wood and white-rotted wood. Three isolates from the Arthrodermataceae were collected from traps baited with coyote dung and the fourth was collected from a round fungus beetle (Coleoptera: Leodidae: *Catops* sp.) from a fibreglass-baited trap. Species of *Catops* are known to visit habitats rich in keratin, such as animal dung, the soil around animal burrows, and owl pellets (Peck and Cook 2002, Peck 2001).

Leptographium sp. I exhibited the most specific pattern of occurrence with 22 of 29 isolates coming from arthropods attracted to traps containing coyote dung. This species was most abundant on ants with seven individuals yielding this fungus, followed by beetles (five isolates) (Table 3.2). These isolates represent a species similar to *L. crassivaginatum* M.J. Wingf. (Griffin 1968, Jacobs and Wingfield 2001) but show marked differences in the morphology of the conidia and conidiogenous cells. Other species in *Leptographium* have well-known associations with arthropods and many are common and well-known pathogens of timber species (Jacobs and Wingfield 2001). *L. crassivaginatum* has been reported from *Populus tremuloides* (Griffin 1968) and *Leptographium* sp. I may also be a pathogen on this species, but its presence on arthropods associated with dung suggests a coprophilous phase in its life history.

Two isolates of *Cryptendoxyla hypophloia,* a cleistothecial ascomycete with a presumed affiliation for woody substrates and arthropod dispersal agents (Malloch and Cain 1970, Greif et al. 2004), came from a beetle and a springtail, both of which had been captured in traps baited with decayed wood. This fungus forms cephalothecoid ascomata that open and close with alternating dry and wet conditions and also produces an unnamed *Chalara* anamorph that produces cylindrical conidia in sticky clumps. *Chalara* anamorphs have also been linked to ophiostomatoid species which are mainly vectored by beetles (Malloch and Blackwell 1993, Seifert et al. 1993), although here *Leptographium* sp. I was from a wide variety of arthropods (see above), the single unidentified isolate of *Ceratocystis* was from an ant, and *Chalara fusidioides* and *Chalara* sp. I came from a mite and spider, respectively.

Conidiobolus coronatus was obtained from two flies and a spider captured in traps baited with coyote and moose dung respectively. This fungus, reported previously as a saprophyte and also a pathogen of arthropods (Chandler et al. 2000) and mammals (Rippon 1974), has been recorded from mites in Germany (Renker et al. 2005), and springtails in the US and Denmark (Christen 1975, Dromph et al. 2001), although it is more common in warmer climates. Other species in the genus have also been isolated from mites (Chandler et al. 2000, Balazy et al. 1987).

The PCA of bait types according to the suites of arthropod taxa trapped reveals considerable overlap among clusters, but some trends can be discerned. Clusters comprising traps baited with both types of decayed wood (i.e., cellulose and ligno-cellulose-rich materials) show considerable overlap and tend to be distinct from the traps baited with coyote dung (keratin-rich material). The cluster comprising traps baited with moose dung overlaps in part with the cluster baited with coyote dung, and with both white- and brown-rotted wood (Fig. 2.3). This position could be coincidental or might reflect the obvious high levels of lignocellulosic debris in the moose dung which also contains materials of animal origin, such as hair from grooming. As a result it would ostensibly attract arthropods seeking both lignocellulosic and faecal materials. A subsequent examination of the raw data after performing the principal components analyses indicated that axis one represents the number of arthropods (or fungal isolates in the second PCA, Fig. 2.4) and axis two taxonomic richness. Traps baited with coyote dung captured not only the most arthropods compared to other baits, but also more ants, flies, beetles, and butterflies on average than traps baited with moose dung and decayed wood. Traps baited with decayed wood yielded more spiders and springtails than traps baited with either type of dung. Specific suites of volatile compounds arising from each of these materials (e.g., Honda et al. 1988) may have been signals indicating the availability of a direct food source, protective habitat for adults or eggs/offspring, or a suitable hunting ground for prey (Daly et al. 1998) and may account for these differences in arthropod richness.

The second PCA (using the number and identity of fungal isolates as variables) yielded clusters with an overall greater degree of overlap than in the first PCA (Fig. 2.3), but was somewhat similar in that the cluster based on traps baited with coyote dung diverged from the others (Fig. 2.4). The number of fungal species and isolates thereof from arthropods captured in traps baited with coyote dung differed from traps baited with other materials and account in part for the divergent position of this cluster; more arthropods were associated with the traps baited with coyote dung and, as a result, a greater number of fungi were isolated. The taxonomic diversity of fungi associated with the arthropods also differed from other bait types, and included species with known proclivities for keratin rich substrates (i.e. taxa in the Onygenales).

Traps baited with brown-rotted wood formed a tight cluster, below the first axis, that also diverged somewhat from clusters comprising traps baited with moose dung and white-rotted wood. Difference in cluster shape, size and position between these bait types can also be attributed to species richness and abundance. Arthropods captured in traps baited with brown-rotted wood yielded more isolates than arthropods attracted to moose dung and white-rotted wood. Species in common between traps baited with brown-rotted wood and with moose dung were generally more abundant in the former (Table 2.3). In addition, more species of fungi were associated with traps baited with brown-rotted as opposed to white-rotted wood. Clusters based on traps baited with moose dung and with white-rotted wood almost completely overlapped. This overlap can be attributed to the similarity in number of fungal isolates and species richness between these two bait types

The three fibreglass traps were spread out along axis one in the first and second PCA (Figs. 2.3-2.4) and were located within the clusters of two or more of the other bait types, indicating that neither arthropod nor fungal richness differed substantially from the organic baits. These data also show that the arthropods were carrying fungi into the traps rather than picking up propagules from the bait samples once inside.

The differences in position among cluster swarms, among bait types in both statistical analyses, indicates that there is some detectable variation in the suites of fungi being dispersed by different taxonomic groups of arthropods attracted to particular substrates, but the great degree of overlap suggests that most fungal saprobes are generalists rather than associates of specific substrates. The lack of resolution among clusters may also be a consequence of the experimental design. My trapping protocol was designed to capture arthropods attracted to different types of substrate and while results from the first PCA (Fig. 2.3) indicate that it was at least partially effective, the structure of the traps would tend to eliminate crawling species (e.g., centipedes and millipedes) and larger taxa such as dragon flies. Trap modifications such as the provision of ground-level access points and/or larger openings may lead to the capture of a broader spectrum of arthropods. In addition, some arthropods may have entered the traps in search of shelter or in the pursuit of prey rather than being drawn in by the bait. A greater volume of bait per trap might create a stronger attractant for specific arthropods; this may result in an improvement in the cluster resolution in statistical analyses. Additional patterns may be detected by identifying arthropods to family, genus, or species, or classifying arthropods into functional groups such as feeding preferences (e.g., carnivores, detritivores, fungivores) or other morphological features (i.e. mouthparts). Grouping these organisms according to order may have obscured potential patterns between arthropods, fungus and substrate that might occur between specific taxonomic or functional invertebrate groups. Since collected arthropods from this survey have been deposited as voucher specimens in UASM (Appendix 1), future statistical analysis for this data set, at least, is only dependant on additional time spent classifying these organisms.

The amount of overlap among clusters in the second PCA (Fig. 2.4) suggests that fungal species richness was similar across bait types, and this may have resulted from the choice of isolation medium. For example, the use of cycloheximide eliminated basidiomycetes from the suite of fungi recovered. The use of more types of isolation media, including those containing different restrictive agents, such as Benomyl, which discourages the growth of most fungi other than basidiomycetes, and molecular techniques (Renker et al. 2005) would be expected to contribute to the creation of a more robust data set and a potential improvement in cluster resolution in the principal components analysis.

Prior studies have found a variety of habitat-specific fungi associated with the arthropods collected directly from decaying logs (Lilleskov and Bruns 2005, Talbot, 1952), wheat fields (Christen 1975), and leaf litter (Lilleskov and Bruns 2005, Renken et al. 2005, Visser et al. 1987, Pherson and Beattie 1979), and arthropod visitation has been shown to affect species diversity in dung (Lussenhop et al. 1980). To obtain a clearer picture of the role arthropods play in the dispersal of saprobic fungi, data of this sort require complementary investigations concerning which fungal species arrive at new habitats in viable condition. More data of this type will elucidate patterns among substrates, fungal saprobes and their arthropod carriers, and will contribute to our understanding of the dynamics of fungal communities and their broader importance to biodiversity and landscape ecology.

Fig. 2.1. Number of fungal isolates (corrected for number of species) per arthropod taxon.

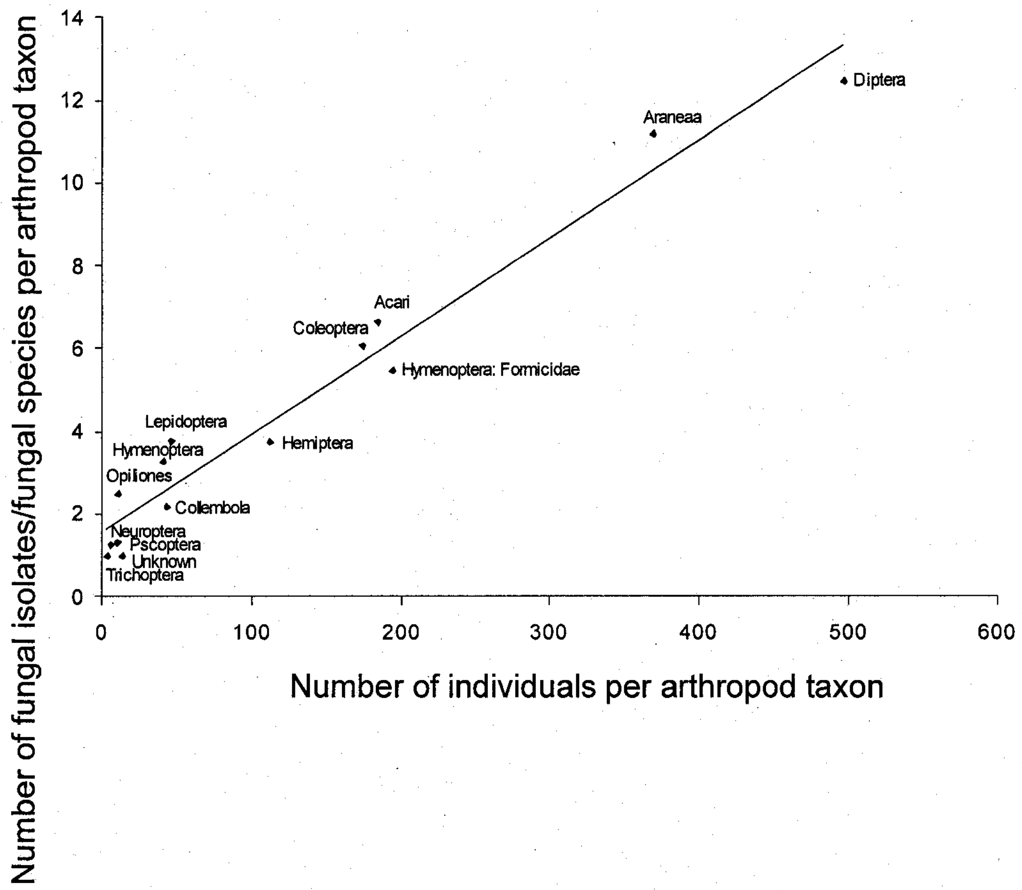
Number of fungal isolates/fungal species per arthropod taxon
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
Number of individuals per arthropod taxon
Diptera
Araneaa
Acari
Coleoptera
Hymenoptera: Formicidae
Lepidoptera
Hymenoptera
Hemiptera
Opiliones
Collembola
Neuroptera
Pscoptera
Unknown
Trichoptera

Fig. 2.2. Number of fungal species recovered from each arthropod taxon.

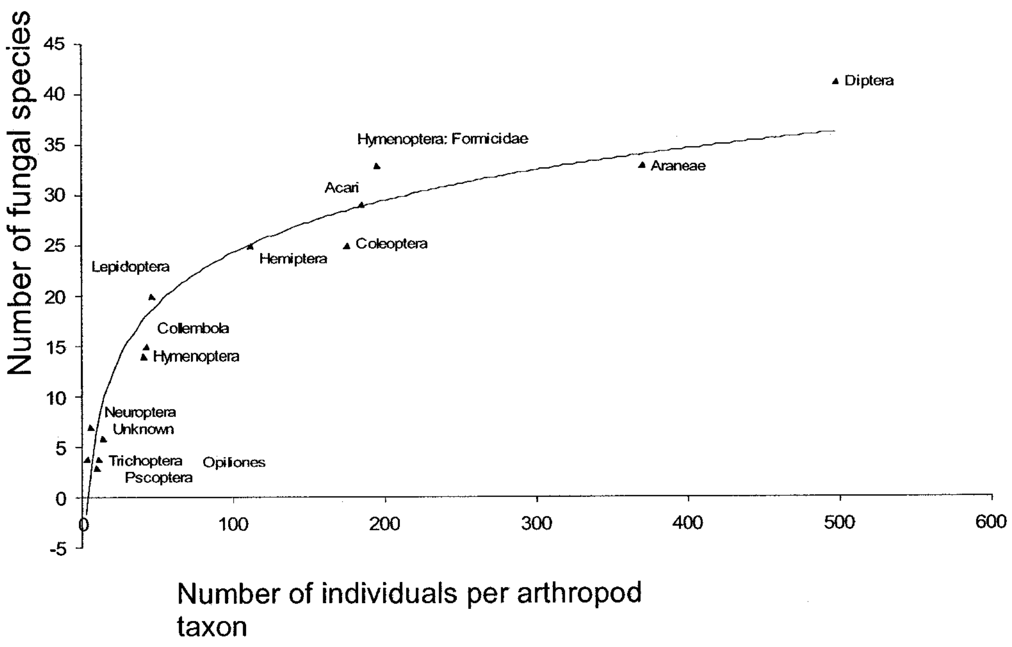
Number of fungal species
45
40
35
30
25
20
15
10
5
0
-5
0
100
200
300
400
500
600
Number of individuals per arthropod taxon
Diptera
Hymenoptera: Formicidae
Araneae
Acari
Coleoptera
Hemiptera
Lepidoptera
Collembola
Hymenoptera
Neuroptera
Unknown
Trichoptera
Opiliones
Pscoptera

Fig. 2.3. Scatterplot of the PCA of 43 baited traps using number and identity of captured arthropods. Traps were baited with either coyote dung (♦ ……), moose dung (■ -·-·-·-), brown-rotted wood (Δ——), white-rotted wood (□------), or fibreglass (X). Lines demarcate cluster swarms to aid in viewing and do not indicate % similarity.

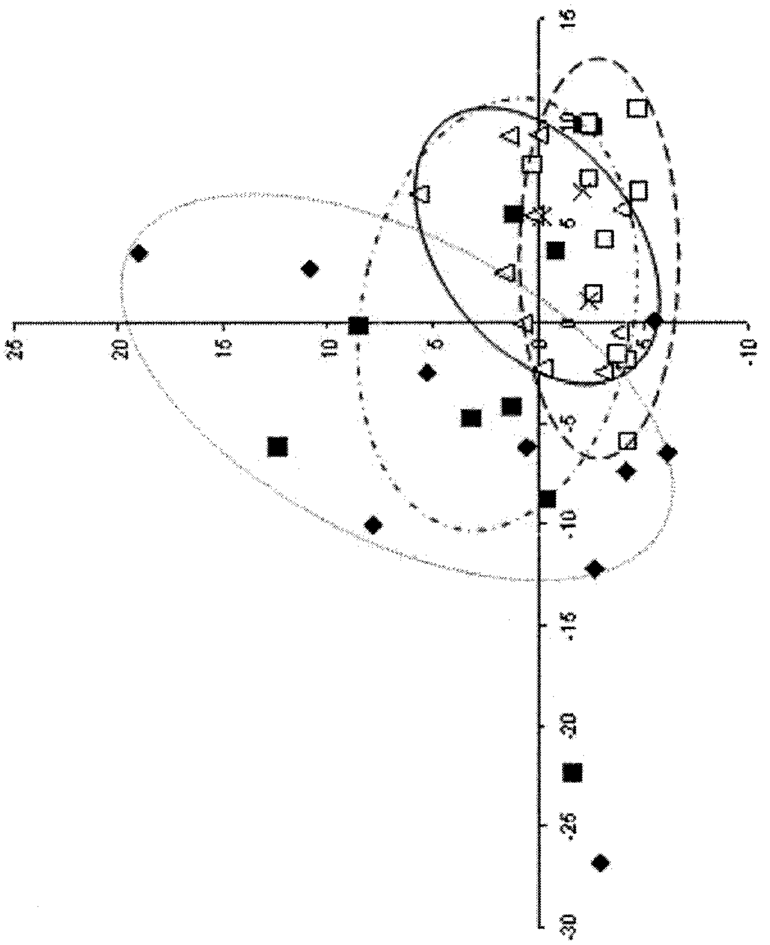
25
20
15
10
5
0
-5
-10
15
10
5
0
-5
-10
-15
-20
-25
-30

Fig. 2.4. Scatterplot of the PCA of 43 baited traps using number and identity of fungi isolated from arthropods. Traps were baited with either coyote dung (♦ ······), moose dung (■ -·-·-), brown-rotted wood (Δ——), white-rotted wood (□---), or fibreglass (X). Lines demarcate cluster swarms to aid in viewing and do not indicate % similarity.

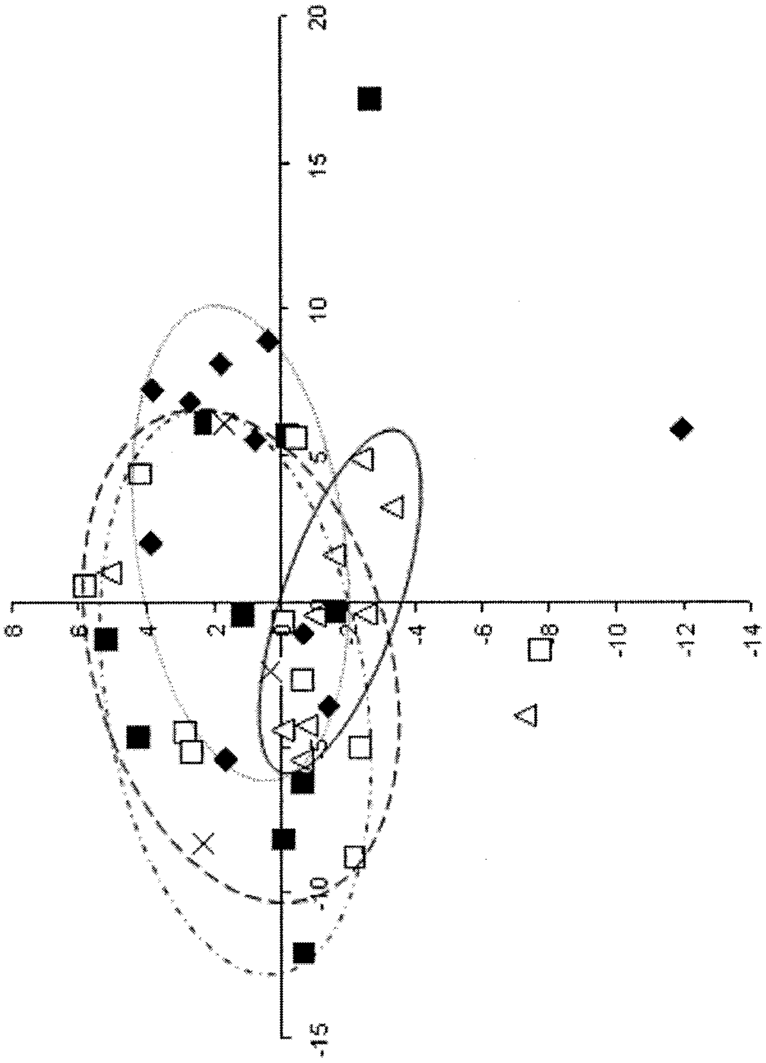
20
15
10
5
-5
-10
-15
8
6
4
2
-2
-4
-6
-8
-10
-12
-14

Table 2.1 Total numbers of arthropods per taxon (i.e., 12 Orders, with the Formicidae and Unknowns each treated as a separate Order) captured in traps baited with five different materials.

	Coyote dung	Moose dung	Brown-rotted wood	White-rotted wood	Fibreglass	Total
Acari (Mites)	55	29	35	50	15	184
Araneae (Spiders)	78	67	92	94	38	369
Coleoptera (Beetles)	79	20	44	20	11	174
Collembola (Springtails)	9	0	16	15	2	42
Diptera (Flies)	171	138	82	83	23	497
Hemiptera (Bugs)	32	35	24	13	7	111
Hymenoptera (Bees and Wasps)	10	4	12	11	3	40
Hymenoptera: Formicidae (Ants)	79	50	43	11	11	194
Lepidoptera (Butterflies and Moths)	19	7	10	5	4	45
Neuroptera (Lacewings)	1	0	1	3	0	5
Opiliones (Harvestmen)	1	5	3	1	0	10
Pscoptera (Booklice)	2	1	3	3	0	9
Trichoptera (Caddisflies)	1	0	1	1	0	3
Unknown	5	1	4	2	1	13
	542	357	370	312	115	1696

Table 2.2 Identity and numbers of fungi isolated from each arthropod taxon over the two-year trapping period.

	Acari	Araneae	Coleoptera	Collembola	Diptera	Hemiptera	Hymenoptera	Hymenoptera: Formicidae	Lepidoptera	Neuroptera	Opiliones	Pscoptera	Trichoptera	Unknown	total
Absidia corymbifera	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Absidia glauca	4	0	2	0	2	0	3	5	0	0	0	0	0	0	16
Acremonium butyri	0	1	0	1	4	0	0	0	0	0	0	0	0	0	6
Acremonium fusidioides	1	3	0	0	5	0	0	1	0	0	0	0	0	0	10
Acremonium kiliense	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2
Acremonium longisporum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Acremonium strictum	2	8	0	0	11	2	0	0	1	0	0	0	0	0	24
Alternaria alternata	3	0	4	0	5	0	0	3	2	0	0	0	0	0	17
Aphanocladium aranearum	0	0	0	0	5	0	0	0	0	0	0	0	0	0	5
Arthroderma curreyi	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Arthroderma sp. I	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3
Aspergillus candidus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Aspergillus fumigatus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Auxarthron compactum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Auxarthron conjugatum	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Beauveria bassiana	47	120	47	8	103	19	10	45	22	2	5	1	0	0	429
Ceratocystis sp. I	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Chalara fusidioides	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Chalara sp. I	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Cladosporium cladosporioides	35	93	34	3	136	33	11	41	20	2	3	2	1	1	415
Cladosporium sphaerospermum	19	28	6	1	38	6	6	9	2	1	1	0	0	1	118
Cladosporium herbarum	1	0	0	0	1	0	0	1	0	0	0	0	0	0	3
Cladosporium orchidis	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
Conidiobolus coronatus	0	1	0	0	2	0	0	0	0	0	0	0	0	0	3
Cryptendoxyla hypophloia	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
Chrysosporium merdarium	0	0	1	0	1	1	0	0	0	0	0	0	0	0	3
Eupenicillium brefeldianum	1	2	1	0	5	1	1	3	1	0	0	0	0	0	15
Fusarium cf. *solani*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Geomyces pannorus	2	4	7	1	10	2	0	11	2	1	0	0	0	0	40
Gliocladium cf. *penicillioides*	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Hormiactis candida	0	2	0	1	0	0	0	1	0	0	0	0	0	1	5
Leptographium sp. I	3	3	5	1	4	2	0	7	2	0	0	1	1	0	29
Mucor hiemalis	0	2	1	0	12	1	0	1	0	0	0	0	1	0	18
Myxotrichum deflexum	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
Oidiodendron griseum	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Oidiodendron maius	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Oidiodendron periconioides	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Oidiodendron state of *Myxotrichum arcticum*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Paecilomyces farinosus	7	4	1	0	7	2	0	2	3	1	0	0	0	0	27
Paecilomyces fumosoroseus	2	0	0	0	1	1	0	1	0	0	0	0	0	0	5
Paecilomyces marquandii	7	6	1	0	6	1	1	2	2	0	0	0	0	1	27
Penicillium cf. *brevicompactum*	9	12	7	1	23	3	0	6	4	0	0	0	1	1	67
Penicillium cf. *frequetans*	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
Penicillium cf. *griseofulvum*	1	1	0	0	1	0	0	1	0	0	0	0	0	0	4
Penicillium cf. *implicatum*	1	1	0	1	3	0	0	2	0	0	0	0	0	0	8
Penicillium cf. *inflatum*	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
Penicillium cf. *janthinellum*	0	1	0	0	3	0	1	1	1	0	0	0	0	0	7
Penicillium raistrickii	1	1	4	0	1	0	0	0	0	0	0	0	0	0	7
Penicillium restrictum	0	1	0	0	3	0	0	0	0	0	0	0	0	0	4
Penicillium cf. *rubrum*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2
Penicillium cf. *steckii*	10	23	11	3	35	6	5	5	2	0	0	0	0	0	100
Penicillium sp. I	5	3	0	0	3	0	1	0	0	1	0	0	0	0	13
Penicillium sp. II	5	11	6	0	10	1	0	8	1	0	0	0	0	1	43
Phialophora americana	1	0	1	0	4	1	1	2	1	0	0	0	0	0	11
Polyscytalum pustulans	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Ramichloridium schulzeri	1	2	0	0	0	1	0	1	0	0	0	0	0	0	5
Rhizopus stolonifer	1	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Sagenomella diversispora	1	0	0	0	1	0	0	1	0	0	0	0	0	0	3
Scopulariopsis brevicaulis	0	3	0	0	0	1	0	1	0	0	0	0	0	0	5
Veronaea carlinae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Veronaea indica	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Veronaea parvispora	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Verticillium lamellicola	6	12	1	0	24	1	1	4	4	0	0	0	0	0	53
Verticillium lecanii	12	12	3	3	25	4	1	7	3	1	1	0	0	0	72
Verticillium psalliotae	4	4	0	4	8	1	3	3	0	0	0	0	0	0	27
Total isolates	193	369	152	33	510	94	46	181	76	9	10	4	4	6	1687
Total species	28	33	25	15	41	25	14	33	20	7	4	3	4	6	

Table 2.3. Number of isolates per fungal species from arthropods associated with each of five types of bait.

			Bait type				
	Coyote dung	Moose dung	Brown-rotted wood	White-rotted wood	Fibreglass	Total	ALTA number
Absidia corymbifera (Cohn) Sacc. & Trotter	1	0	0	0	0	1	ALTA13222
Absidia glauca Hagem	2	4	5	5	0	16	ALTA13223
Acremonium butyri (J.F.H. Beyma) W. Gams	0	1	3	1	1	6	ALTA13224
Acremonium fusidioides (Nicot) W. Gams	3	3	4	0	0	10	ALTA13225
Acremonium kiliense Grütz	1	0	0	1	0	2	ALTA13226
Acremonium longisporum (Preuss) W. Gams	1	0	0	0	0	1	ALTA13274
Acremonium strictum W. Gams	6	7	4	5	2	24	ALTA13227
Alternaria alternata (Fr.) Keissl.	3	5	4	4	1	17	ALTA13228
Aphanocladium aranearum (Petch) W. Gams	3	2	0	0	0	5	ALTA13229
Arthroderma curreyi Berk.	1	0	0	0	0	1	UAMH 10694
Arthroderma sp.	2	0	0	0	1	3	ALTA13230
Aspergillus candidus Link	0	1	0	0	0	1	ALTA13276
Aspergillus fumigatus Fresen.	0	0	0	1	0	1	ALTA13275
Auxarthron compactum G.F. Orr & Plunkett	0	0	1	0	0	1	UAMH 10695
Auxarthron conjugatum (Kuehn) G.F. Orr & Kuehn	0	1	1	0	0	2	UAMH 10597
Beauveria bassiana (Bals.-Criv.) Vuill.	124	95	102	83	25	429	ALTA13231
Ceratocystis sp. I	1	0	0	0	0	1	ALTA13232
Chalara fusidioides (Corda) Rabenh.	1	0	0	0	0	1	ALTA13233
Chalara sp.	0	2	0	0	0	2	ALTA13234
Chrysosporium merdarium (Ehrenb.) J.W. Carmich.	3	0	0	0	0	3	ALTA13235
Cladosporium cladosporioides (Fresen.) G.A. de Vries	119	96	84	89	27	415	ALTA13236
Cladosporium sphaerospermum Penz.	35	20	27	30	6	118	ALTA13237
Cladosporium herbarum (Pers.) Link	3	0	0	0	0	3	ALTA13238
Cladosporium orchidis E.A. Ellis & M.B. Ellis	0	1	1	0	0	2	ALTA13239
Conidiobolus coronatus (Costantin) A. Batko	2	1	0	0	0	3	ALTA13240
Cryptendoxyla hypophloia Malloch & Cain	0	0	1	1	0	2	ALTA13241
Eupenicillium brefeldianum (B.O. Dodge) Stolk & D.B. Scott	3	6	3	3	0	15	ALTA13242
Fusarium solani (Mart.) Sacc.	0	0	1	0	0	1	ALTA13243
Geomyces pannorus (Link) Sigler & J.W. Carmichael	11	8	10	6	5	40	ALTA13244
Gliocladium cf. *penicillioides* Corda	0	0	0	2	0	2	ALTA13245

Hormiactis candida Höhn.	2	0	0	3	0	5	ALTA13246
Leptographium sp. I	22	1	2	2	2	29	UAMH 10680
Mucor hiemalis Wehmer	8	3	3	2	2	18	ALTA13247
Myxotrichum deflexum Berk.	1	0	0	0	1	2	UAMH 10696
Oidiodendron griseum Robak	1	0	1	0	0	2	UAMH 10699
Oidiodendron maius G.L. Barron	0	0	0	1	0	1	UAMH 10698
Oidiodendron periconioides Morrall	0	0	1	0	0	1	UAMH 10700
Oidiodendron state of *Myxotrichum arcticum* Udagawa, Uchiy. & Kamiya	0	1	0	0	0	1	UAMH 10697
Paecilomyces farinosus (Holmsk.) A.H.S. Br. & G. Sm.	10	6	7	2	2	27	ALTA13248
Paecilomyces fumosoroseus (Wize) A.H.S. Br. & G. Sm.	1	0	0	2	2	5	ALTA13249
Paecilomyces marquandii (Massee) S. Hughes	9	2	3	7	6	27	ALTA13250
Penicillium cf. *brevicompactum* Dierckx	17	12	19	17	2	67	ALTA13251
Penicillium cf. *frequetans* Westling	0	0	1	1	0	2	ALTA13252
Penicillium cf. *griseofulvum* Dierckx	1	1	0	1	1	4	ALTA13253
Penicillium cf. *implicatum* Biourge	0	1	5	2	0	8	ALTA13254
Penicillium cf. *inflatum* Stolk & Malla	2	0	0	0	0	2	ALTA13255
Penicillium cf. *janthinellum* Biourge	0	2	4	1	0	7	ALTA13256
Penicillium raistrickii G. Sm.	3	1	1	2	0	7	ALTA13257
Penicillium restrictum J.C. Gilman & E.V. Abbott	1	1	1	0	1	4	ALTA13258
Penicillium cf. *rubrum* Sopp	1	0	0	0	1	2	ALTA13259
Penicillium cf. *steckii* K.M. Zalessky	15	13	35	35	2	100	ALTA13260
Penicillium sp. I	2	3	1	7	0	13	ALTA13261
Penicillium sp. II	9	11	8	11	4	43	n/a
Phialophora americana (Nannf.) S. Hughes	2	2	5	2	0	11	ALTA13262
Polyscytalum pustulans (M.N. Owen & Wakef.) M.B.	1	0	0	0	0	1	ALTA13263
Ramichloridium schulzeri (Sacc.) de Hoog	1	2	1	0	1	5	ALTA13264
Rhizopus stolonifer (Ehrenb.) Vuill.	0	0	1	1	0	2	ALTA13265
Sagenomella diversispora (J.F.H. Beyma) W. Gams	1	1	1	0	0	3	ALTA13266
Scopulariopsis brevicaulis (Sacc.) Bainier	2	2	1	0	0	5	ALTA13267
Veronaea carlinae M.B. Ellis	0	0	0	0	1	1	ALTA13268
Veronaea indica (Subram.) M.B. Ellis	0	1	0	0	0	1	ALTA13269

Veronaea parvispora M.B. Ellis	0	1	0	0	0	1	ALTA13270
Verticillium lamellicola (F.E.V. Sm.) W. Gams	14	11	14	11	3	53	ALTA13271
Verticillium lecanii (Zimm.) Viégas	16	20	16	15	5	72	ALTA13272
Verticillium psalliotae Treschew	9	1	10	5	2	27	ALTA13273
Total	476	352	392	361	106	1687	

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Chapter 3

Leptographium piriforme sp. nov., from a taxonomically diverse collection of arthropods collected in an aspen-dominated forest in Western Canada[1].

INTRODUCTION:

Leptographium Lagerb. and Melin is a genus accommodating anamorphs affiliated with the Ophiostomatales and is defined on the basis of its macronematous, melanized conidiophores bearing brush-like clusters of annellidic conidiogenous cells that produce slimy masses of conidia. Each conidium is pushed aside after its formation by a pronounced percurrent proliferation of the annellide. Delayed secession of the conidia gives the conidiogenous axis a sympodial appearance (Wingfield 1985, Jacobs and Wingfield 2001).

There are 52 named species of *Leptographium* based on morphological and molecular characters (Wingfield 1985, Van Wyk et al. 1988, Hausner et al. 2000, Jacobs and Wingfield 2001, Masuya et al. 2004, Kim et al. 2004, Kim et al. 2005). Many are saprobes on plant material, particularly of coniferous origin, some are weak plant pathogens (Harrington 1988, Jacobs et al. 1998, Jacobs and Wingfield 2001, Six and Bentz 2003) and others cause economically important timber diseases such as black-stain root disease and white pine root decline (Harrington and Cobb Jr. 1986, Lewis and Alexander 1986, Lewis et al. 1987, Harrington 1993). Arthropods are the presumptive carriers of these fungi and bark beetles are well-documented vectors of the conifer pathogens (Wingfield 1985, Van Wyk et al. 1988, Hausner et al. 2000, Jacobs and Wingfield 2001, Masuya et al. 2004, Kim et al. 2004, Kim et al. 2005).

In a survey of the microfungi associated with arthropods visiting different types of organic debris in a broad-leaved forest, dominated by *Populus tremuloides* Michx., in western Canada, 29 isolates of a unique species of *Leptographium* were obtained from a collection of trapped insects, spiders, and mites (Greif and Currah 2006*). Its distinct

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[1] A version of this chapter has been submitted as:

Greif MD, CFC Gibas, and RS Currah 2006 *Leptographium piriforme* sp. nov., from a taxonomically diverse collection of arthropods collected in an aspen-dominated forest in Western Canada. Mycologia (Submitted April 24 2006; ref # 06-088) morphology, along with the range of arthropod carriers and the non-coniferous habitat, suggested the taxon was new. Additional physiological and molecular characters supported the supposition that the species had not previously been described. In this paper, I describe these unique isolates under the name *Leptographium piriforme* sp. nov.

MATERIALS AND METHODS:

Arthropods were trapped from May through August in 2002 and 2003 in a broad-leaved boreal forest dominated by *Populus tremuloides* located 100 km east of Edmonton, Alberta. Traps were baited with dung (coyote and moose), rotted wood (brown- and white-rotted aspen), and fibreglass (Greif and Currah 2006*). Trapped arthropods, 1687 in total, were identified and streaked across Mycobiotic ™ agar (35.6g Difco Mycobiotic agar (BD Biosciences, Mississauga, Ontario) /1 L dH_2O) which contains 0.05g/L chloramphenicol and 0.5g/L cycloheximide. Colonies developing under ambient temperature and light of the laboratory over a period of 4-6 months were subcultured and identified. From among approximately 1700 isolates of microfungi, 29 conspecific isolates of *Leptographium* were identified. Six of these were deposited in the University of Alberta Microfungus Collection and Herbarium (UAMH)(Table 3.2). These six isolates were then cultured in triplicate on Petri plates of corn meal agar (CMA, 17g Acumedia ™ corn meal media (Neogen Corp., Lansing, Michigan) and 1 L dH_20) and malt extract agar (MEA, 15g Difco ™ malt extract (BD Biosciences, Mississauga, Ontario), 20 g Invitrogen ™ select agar (Invitrogen Canada Inc., Burlington, Ontario) and 1 L dH_20) and incubated at 5°C increments, from 5°C to 40°C, to determine growth rates and temperature optima. Colony diameters were measured twice at right angles at 5 days post inoculation, with the exception of isolates grown at 5°C and 10°C which were measured at 15 days. Growth rates in mm/day ± standard deviation (sd) were calculated using the average diameter from both measurements for all three replicates of each of the six isolates.

Morphological data were obtained from isolates grown on CMA and MEA at room temp under ambient light. The range and mean ± standard error (SE) for dimensions, rounded to the nearest decimal place, were based on measurements of 25 structures selected at random. Photographs of direct mounts stained with lactofuchsin

(0.1 g acid fuchsin in 100 ml 85% lactic acid) were taken using a Canon Powershot A75^{TM} digital camera (Canon Canada Inc., Mississauga, Ontario) through the eyepiece of an Olympus BH-2 light microscope (LM) (Olympus America Inc., Melville, New York).

For scanning electron microscopy (SEM), disks of agar, 5 mm in diameter and bearing conidiophores were fixed in buffered 2% glutaraldehyde for 4 hours, placed in phosphate buffer overnight at 5°C, and post-fixed in 2% OsO_4 for four hours at room temperature. Fixed material was dehydrated in an ethanol series, critical-point dried using carbon dioxide (SeeVac Inc., Hialeah, Florida), coated with gold using an Edwards S150 B gold coater (BOC-Edwards Inc., Crawley, West Sussex) and examined under a Hitachi S-2500 scanning electron microscope (Hitachi Ltd., Tokyo, Japan).

DNA sequences for the internal transcribed spacer region (ITS) of the nuclear rDNA region were obtained from subcultures of three isolates (UAMH 10680, 10682, and 10681)(Table 2) on MEA overlaid with sterile Cellophane^{TM} sheets (UCB Films, Somerset, Britain). DNA extraction was done following the method described by Cubero et al. (1999) with some modification. Approximately 100 mg of mycelium was scraped off the cellulose and ground in 2X CTAB extraction buffer (10% CTAB, NaCl, 0.25 M EDTA, 1 M Tris-HCl pH 8.0, 2% PVP, and dH_2O). After incubation for 2 h in a 65°C water bath, genomic DNA was extracted using a chloroform:isoamyl alcohol (24:1v/v) solution. Crude DNA was purified using a QIAquick DNA purification kit (Qiagen Inc., Mississauga, Ontario). Amplification of the ITS region was done using the primers ITS1 (White et al. 1990) and BMB-CR (Lane et al. 1985). PCR was run for 30 cycles in a PE GeneAmp 9700 thermal cycler (Applied Biosystems, Foster City, California) set to the following parameters: Denaturation at 94°C for 1 min, annealing at 55°C for 1 min, extension at 72°C for 2 min, then final extension at 74°C for 7 min followed by a cool down stage at 4°C for 10 min. The amplicon was purified using the QIAquick DNA purification kit and DNA concentration was determined using a Nanodrop ND-1000 (Nanodrop technologies, Wilmington, Deleware). Cycle sequencing was done using internal primers ITS1, ITS2, ITS4, and BMB-CR (White et al. 1990, Lane et al. 1985) and BigDye terminator cycle sequencing kit (Applied Biosystems, Foster, California). The amplicons were run on an ABI 377 automated DNA sequencer (Amersham Pharmacia Biotech Inc, Piscataway, New Jersey). A consensus sequence was constructed and edited using Sequencher version 4.0.2 (Gene Codes Corp., Ann Arbor, Michigan). The newly determined ITS sequence, was subjected to a BLAST search (Altschul et al. 1990) to find related sequences in GenBank (www.ncbi.nlm.nih.gov).

The newly determined ITS sequence (DQ885241, DQ885242, and DQ885243) was manually aligned with 22 ITS sequences of representative species of *Leptographium* and *Ophiostoma* retrieved from GenBank (www.ncbi.nlm.nih.gov) (Fig. 3.16) using Se-Al v2.0a11 Carbon (http://evolve.zoo.ox.ac.uk/). *Peziza varia* (GenBank AF491568) was used as the outgroup. The aligned sequence matrix was analysed using PAUP v 4.0 b10 (Swofford 2002). A heuristic search was done using parsimony as the optimality criterion. Gaps were treated as missing data. Starting trees were obtained at random via stepwise addition with tree-bisection-reconnection as the branch-swapping algorithm. Confidence in the branches of the resulting trees was evaluated by bootstrap analysis (Felsenstein 1985) using 100 replicates.

RESULTS:

Taxonomy.

Leptographium piriforme Greif, Gibas, and Currah, sp. nov. Figs. 3.1-3.15

Latin Diagnosis: Conidiophora macromatea cum stirpe brevi, 7.2-45.6 μm longitudine. Apparatus conidiogenosus 28.8-93.6 μm a basi ramorum primariorum ad apicem cellularum conidiogenosarum, cum 2-3 (rare 4) ordinibus ramorum. Rami primarii 2-3 numero in conidiophoris quibusque, pigmentati, leves, aliquando septati, 3.4-15.4 x 1.9-4.8 μm. Rami secundarii pigmentati, aliquando septati, leves, 7.2-17.3 x 1-4.8 μm. Rami tertiani et quartani hyalini, leves, 3.8-11.5 x 1-1.9 μm. Annelida orientia a ramis secundariis vel tertianis vel quartanis, saepe solitaria in ramis secundariis vel in catenis 2-4 continentibus in ramis tertianis vel quartanis, fastigata ad apicem, 8.6-15.4 x 1.0-1.4 μm. Conidia aseptata, hyalina, levia, curvata, truncata ad extremum proximum, 2-4-4.6 x 1.0-1.4 μm, accumulantia in stilla limosa. Conidiophora micronematea abundantia, simplicia, claviformia, orientia directe a hyphis vegetativis, producent conidia hyalina et tenuiter curvata, 4.8-14.4 x 2.4-4.8 μm. Cellulae piriformes abundantes, 14.4-31.2 x 7.2-16.8 μm, portatae in culmis 1-4 cellulas continentibus, 7.2-45.6 x 4.8 -7.2 μm. Incrementum optimum ad 35°C.

Holotypus: Cultura exsiccata preparata a UAMH 10680, isolata a musca capta in laqueo excrementum canis latrantis continenti, collecta 16 Iulii 2003 in silva populorum tremuloidum 2 km a Elk Island National Park, Alberta, Canada.

Etymology: Species epithet is derived from the latin word for pear (*pirum*) in reference to the pear-shaped cells formed in culture.

On CMA, mycelium sparse, hyaline and submerged; conidia forming in white to beige droplets on agar surface. On MEA, mycelium on surface of agar abundant, light brown, dense, floccose; submerged mycelium dark brown, conidia forming in white to beige droplets among the aerial hyphae. Vegetative hyphae septate, 2-10 µm wide, smooth-walled on CMA and roughened on MEA with a granular surface (Fig. 3.1). Pear-shaped cells 14.4-31.2 (23.4 ± 0.8) x 7.2-16.8 (12 ± 0.4) µm, borne on a one- to four-celled stalk, 7.2-45.6 (27.4 ± 2.6) x 4.8-7.2 (4.2 ±0.3) µm (Figs. 3.2-3.3) abundant 18 days post inoculation on MEA only.

Conidiophores micronematous and macronematous, forming simultaneously. Micronematous conidiophores abundant, simple and peg-like, arising directly from vegetative hyphae and producing hyaline, slightly curved conidia, 4.8-14.4 (9.7 ± 0.5) x 2.4-4.8 (2.6 ± 0.1) µm (Figs. 3.4, 3.12). Macronematous conidiophores with short stipes, 7.2-45.6 (29.9 ± 3.9) µm long and up to 5 cells in length (Figs. 3.5-3.6). Basal cell cylindrical, pigmented, 7.2-21.6 (12.2 ±0.9) x 2.4-7.2 (5.2 ± 0.3) µm. Apical cell cylindrical, pigmented, 9.6-21.6 (14.5 ± 0.9) x 2.4-7.2 (5.2 ± 0.3) µm.

Conidiogenous apparatus 28.8-93.6 (57.4 ± 3.8) µm from base of primary branches to tip of conidiogenous cells, with 2-3 (rarely 4) tiers of cylindrical branches. Primary branches symmetrically arranged, 2-3 per conidiophore, pigmented, smooth, occasionally septate, 3.4-15.4 (8.8 ± 0.7) x 1.9-4.8 (3.4 ± 0.2) µm (Fig. 3.7). Secondary branches pigmented, occasionally septate, smooth, 7.2-17.3 (10.9 ± 0.5) x 1-4.8 (2.7 ± 0.2) µm. Tertiary and quaternary branches hyaline, smooth, 3.8-11.5 (7.6 ± 0.4) x 1-1.9 (1.4 ± 0.1) µm. Conidiogenous cells annellides, developing from secondary, tertiary, and quaternary branches, often solitary on secondary branches and in groups of 2-4 on tertiary/quaternary branches, tapering towards apex, 8.6-15.4 (11.7 ±0.4) x 1.0 -1.4 (1 ± 0.02) µm (Figs.3.8-3.9, 3.13).

Conidia aseptate, hyaline, smooth, curved, truncate at the proximal end, 2.4-4.6 (3.8 ± 0.1) x 1.0-1.4 (1 ± 0.05) µm, slow to secede from annellides and accumulate in a mass at the tip of conidiogenous cells to form a slimy droplet (Figs. 3.10-3.11, 3.14-3.15).

Optimal growth rate at 35°C (10.3 mm/day ± 0.4 mm) on MEA. No growth detected below 5°C or above 40°C (Table 3.1).

Specimens examined. Canada. Alberta: Edmonton, Elk Island National Park. From a fly captured in a trap baited with coyote dung, 16 July 2003, collected by M.D. Greif, *Greif UAMH 10680,* (Holotype. UAMH).

Canada. Alberta: Edmonton, Elk Island National Park. From a springtail caught in trap baited with brown-rotted wood, 28 May 2003, collected by M.D. Greif, *Greif UAMH 10682* (B-182), (Paratype. UAMH). Canada. Alberta: Edmonton, Elk Island National Park. From a beetle caught in a trap baited with coyote dung, 23 July 2003, collected by M.D. Greif, *Greif UAMH 10681* (C-439), (Paratype. UAMH). Canada. Alberta: Edmonton, Elk Island National Park. From a fly caught in trap baited with coyote dung, 23 July 2003, collected by M.D. Greif, *Greif UAMH 10683* (C-445), (Paratype. UAMH). Canada. Alberta: Edmonton, Elk Island National Park. From an ant caught in a trap baited with moose dung, 16 July 2003, collected by M.D. Greif, *Greif UAMH 10684* (M-273), (Paratype. UAMH).Canada. Alberta: Edmonton, Elk Island National Park. From a caterpillar caught in a trap baited with fibreglass, 20 August 2003, collected by M.D. Greif, *Greif UAMH 10685* (Ct-111), (Paratype. UAMH).

Provenance data for the 29 isolates of *Leptographium piriforme* are given in Table 2.

Molecular analysis.

Sequences of the ITS region of the nuclear rDNA were compared among 24 isolates. The final alignment generated a total of 561 characters, 211 of which were constant, 164 were parsimony-uninformative, and 186 were parsimony-informative. Maximum parsimony analysis yielded two most parsimonious trees (MPT) one of which is shown in FIG. 16. The consistency index (CI) was 0.760, the homoplasy index (HI) 0.240, and the retention index (RI) was 0.790

Leptographium piriforme formed a distinct basal lineage within a clade with bootstrap support of 77% containing two isolates of *L. lundbergii* Lagerb. and Melin (one of which had been submitted as *L. truncatum*), *L. terebrantis* S.J. Barras and T.J. Perry, *L. wingfieldii* M. Morelet, *Ophiostoma clavigerum*, *L. guttulatum* M.J. Wingf. and K. Jacobs, *L. wageneri* (W.B. Kendr.) M.J. Wingf. *L. procerum* (W.B. Kendr.) M.J. Wingf., *O. laricis* K. van der Westh., Yamaoka and M.J. Wingf., and *O. europhioides* (E.F. Wright and Cain) H. Solheim (Fig. 3.16). This clade was distinct from other clades containing *Ophiostoma* species with known *Leptographium* anamorphs, such as *Ophiostoma penicillatum* (Grosmann) Siemaszko (anamorph = *L. penicillatum* Grosmann), *O. americanum* K. Jacobs and M.J. Wingf. (anamorph = *L. americanum* K. Jacobs and M.J. Wingf.), and *O. dryocoetidis* (W.B. Kendr. and Molnar) de Hoog and R.J. Scheff (anamorph = *L. dryocoetidis* M.J. Wingf.). The sub-generic affinity of the new taxon, specifically among *Leptographium* species, however, was unresolved.

DISCUSSION:

Leptographium piriforme most closely resembles *L. crassivaginatum* M.J. Wingf. in having short stipitate conidiophores and similar, although larger, pear-shaped cells (Table 3) (Griffin 1968, Jacobs and Wingfield 2001). Conidia produced by *L. piriforme*, however, are curved rather than oblong and conidiogenous cells are approximately half the width of their counterparts in *L. crassivaginatum* (Table 3.3). Additionally, *L. crassivaginatum* grows more slowly in culture and shows little growth at 35°C (Jacobs and Wingfield 2001) which is the optimum for *L. piriforme* (Table 3.1 and 3.3). *Leptographium piriforme* is unique in the genus in having an unusually high optimum growth rate at 35°C (Table 3.1). Most other species grow slowly or not at all at this temperature (Jacobs and Wingfield 2001) although *Ophiostoma grandifoliae* (R.W. Davidson) T.C. Harr. and *O. leptographioides* (R.W. Davidson) Arx are reported to show "some" and "significant" growth, respectively, at 35°C (Jacobs and Wingfield 2001), and *L. calophylli* (Wiehe) J. Webber, K. Jacobs and M.J. Wingf. can grow at temperatures just under 40°C (Webber et al. 1999).

The size and curvature of conidia in *L. piriforme* make the species somewhat similar to *L. abietinum, L. hughesii*, and *L. penicillatum* but the conidiophores of all three have a longer stipe and the conidia of *L. penicillatum* are considerably larger than those of *L. piriforme* (Table 3.3). Stipe length varies in *L. abietinum* from 35-440 µm, overlapping slightly at the lower end with the 7.2-45.6 μm stipe length of *L. piriforme*. However, the stipe of *L. abietinum* is two to seven cells in length (Jacobs and Wingfield 2001) and one-celled stipes (as observed in *L. piriforme*) are not produced (Table 3.3). *Leptographium yunnanensis* X.D. Zhou, K. Jacobs and M.J. Wingf., *L. robustum* M.J. Wingf., and *L. calophylli* also produce short stipitate conidiophores (8-85 μm, 9-39 μm, and 5-30 μm respectively) but these species have oblong conidia and lack micronematous conidiophores (Jacobs and Wingfield 2001). Finally, *L. pruni* H. Masuya and M.J. Wingf., is also similar to *L. piriforme* in being short stipitate (32-190 um) and producing micronematous conidiophores, but differs in the generation of oblong to ellipsoidal conidia, and in having a *Sporothrix* synanamorph (Jacobs and Wingfield 2001, Masuya et al. 2004).

The unusual stalked pear-shaped cells in *Leptographium piriforme* on MEA are also found in *L. crassivaginatum* (Griffin 1968, Jacobs and Wingfield 2001). Griffin (1968) did not suggest a function for these structures but they bear a striking resemblance to the gongylidia (or bromatia, *fide* Kirk et al. 2001) produced by *Leucoagaricus gongylophorus* (A. Møller) Singer, a basidiomycete actively cultivated on piles of masticated plant material by leaf cutter ants (North et al. 1997). Gongylidia are snipped off and eaten by tending ants or fed to developing larvae (Bass and Cherrett 1996). In *L. piriforme*, these structures may function as a nutritious reward or attractant for presumed arthropod carriers, increasing the chances for spore contact and dispersal. Casual experiments (data not shown) done with reared mites (*Sancassania berlesei* Michael) showed that more individuals moved toward inoculated blocks of agar bearing mycelium with pear-shaped cells than without. The abundant fragments of the pear-shaped cells in expressed gut contents (Fig. 3.3) confirmed that the animals did graze on them. If these structures do form in nature, their role in attracting or at least prolonging the length of visitation by arthropods could possibly lead to larger numbers of the sticky conidia being picked up for transport to new habitat. However, the grazing observed may simply be due to possible generalist feeding behaviour by the mites. Collections of *L. piriforme* on natural substrates to confirm if these structures are formed in the wild, along with observations on the feeding behaviour of arthropods associated with these substrates will provide more insight into the possible function of these pear-shaped cells.

Sequence data (ITS) for 34 named species of *Leptographium*, and 101 named species of its teleomorphic counterpart *Ophiostoma*, were available in GenBank (www.ncbi.nlm.nih.gov) but none matched *L. piriforme*. *L. wageneri* was the closest, but it has a much longer stipe (503-757 µm), oblong rather than curved conidia, and an optimal growth rate at 20°C (Jacobs and Wingfield 2001). A partial sequence of the ITS region (200 bp) of *L. crassivaginatum* was available, but was not used in the sequence matrix. However, a blast search comparing corresponding sequences of *L. piriforme* and *L. crassivaginatum* resulted in only 93% similarity. The use of the ITS region in constructing a phylogenetic hypothesis, while confirming the generic placement of *L. piriforme*, was unable to imply affinities at the species level. Better resolution of the relationships between *L. piriforme* and other members of the genus, in particular the morphologically similar *L. crassivaginatum*, may be resolved by an examination of the β-tubulin gene (Kim et al. 2004, Kim et al. 2005).

An association with beetles is often cited as a characteristic of species of *Leptographium* (e.g., *L. wageneri, L. procerum, L. abietinum,* and *L. terebrantis*) (Cobb Jr. 1988, Lewis and Alexander 1988, Jacobs and Wingfield 2001) and some have evolved close mutualisms with these animals. For example, bark beetles in the family Scolytidae carry inoculum in mycangia to uninfested trees where both eggs and fungi are deposited (Jacobs and Wingfield 2001). The fungus becomes established in its new environment and can affect the nutrition and survival of developing larvae (Jacobs and Wingfield 2001, Six and Bentz 2003). However, of 1687 arthropods obtained in the survey (Greif and Currah 2006*), none was from the family Scolytidae, which may account for the lack of other *Leptographium* species among isolated fungi. Some *Leptographium* species have been reported from a wider range of arthropods, indicating a casual or non-specific association (Olchowecki and Reid 1974, Harrington 1988). 29 isolates of *L. piriforme* were obtained from arthropods not generally associated with the genus. While cross contamination may account for some of these isolates, the diversity of arthropods carrying *L. piriforme* was greater than any reported for other *Leptographium* species and suggests this species has a much less specific type of relationship.

The production of pear-shaped cells may serve to attract a diverse range of arthropod carriers to sites where the fungus is sporulating, but the preferred host or substrate of *L. piriforme* is unknown. Because most isolates (i.e., 23 of 29, see Table 3.2) were from arthropods caught in traps baited with animal dung, it is possible that the fungus is coprophilous. The unusually high optimum growth temperature would suggest that composting dung piles may indeed be a place to look for this species. Alternatively, inoculum may have been picked up from soil, colonized plant material, or through casual transfer from other arthropods. At any rate, the habitat is unique; very few species of *Leptographium*, or *Ophiostoma* with *Leptographium* anamorphs, have been described previously as associates of the dominant plants in the southern Boreal broadleaved forests of Western Canada where Salicaceae (e.g. *Populus tremuloides, Salix* spp.) and Betulaceae (e.g., species of *Alnus, Betula* and *Corylus*) are the dominant components of the canopy (Farr et al. 1989). Most species of *Leptographium* are associated with conifers or conifer wood; only two are known from soil (*L. reconditum* Jooste and *L. costaricense* G. Weber, Spaaij, and M.J. Wingf.) (Jooste 1978, Weber et al. 1996), and eight from broadleaved trees (*O. leptographioides*, *L. francke-grosmannia* K. Jacobs and M.J. Wingf., *O. grandifoliae*, *L. eucalyptophilum* K. Jacobs, M.J. Wingf. and J. Roux, *O. brevicolle* (R.W. Davidson) de Hoog and R.J. Scheff, *L. hughesii*, *L. pruni*, and *O. crassivaginatum*, see Farr et al. 1989 and Jacobs and Wingfield 2001). Additional sampling directly from various types of substrate including soil, plant material, and dung may result in additional isolates of *L. piriforme*, which will help clarify the life history of this species.

Figs. 3.1-3.11 ***Leptographium piriforme.***

Fig. 3.1. Vegetative hypha with a granular surface on MEA. Bar = 8.5 μm.

Fig. 3.2. Pear-shaped cells borne on septate stalks on MEA. Bar = 22 μm.

Fig. 3.3. Gut contents of *Sancassania berlesei* after grazing on colony. Arrows indicate remnants of pear-shaped cells. Bar = 26 μm.

Fig. 3.4. Micronematous conidiophores on CMA. Conidia aggregate in loose clusters on tips of peg-like conidiophores (arrows). Note that vegetative hyphae are smooth-walled on CMA. Bar = 26 μm.

Fig. 3.5. Macronematous conidiophore displaying a characteristic branching head. Bar = 26 μm.

Fig. 3.6. Macronematous conidiophores arising from a vegetative hypha. Note variation in stipe length and septation. Bar = 38 μm.

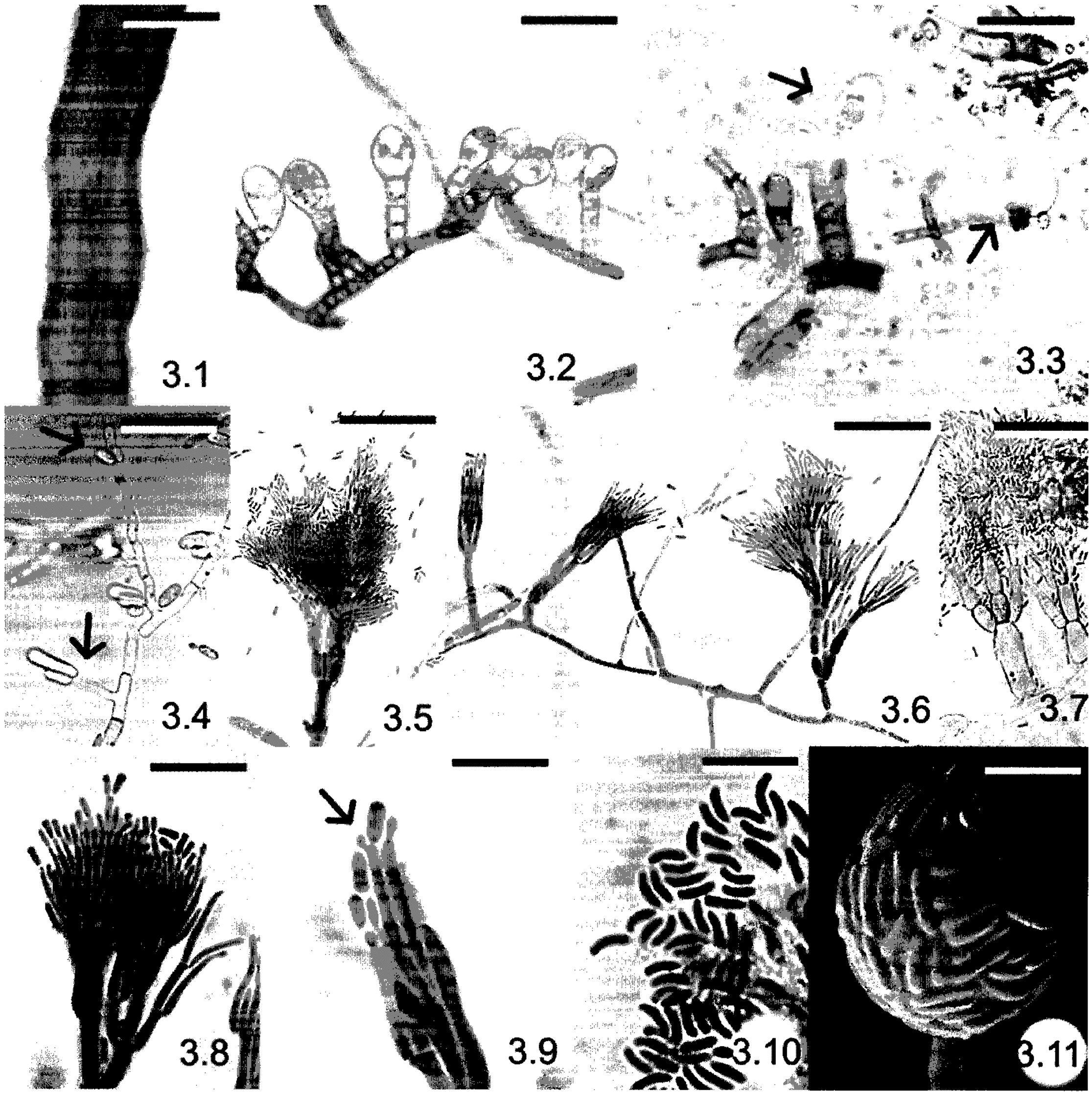
Fig. 3.7. Conidiophores with symmetrical conidiogenous apparatus. Bar = 26 μm.

Fig. 3.8. Conidiogenous apparatus with primary, secondary, and tertiary branches. Conidiogenous cells arise from both secondary and tertiary branches. Bar = 22 μm.

Fig. 3.9. Close up of conidiogenous cells. Conidiogenesis annellidic with delayed succession (arrow). Bar = 7 μm.

Fig. 3.10. Mature conidia are curved, aseptate, and smooth walled. Bar = 7 μm.

Fig. 3.11. Conidia form a slimy mass at the tip of a conidiogenous apparatus (SEM). Bar = 6 μm.


3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
3.10
3.11

Figs. 3.12-3.15. Scanning electron micrographs of *L. piriforme*.

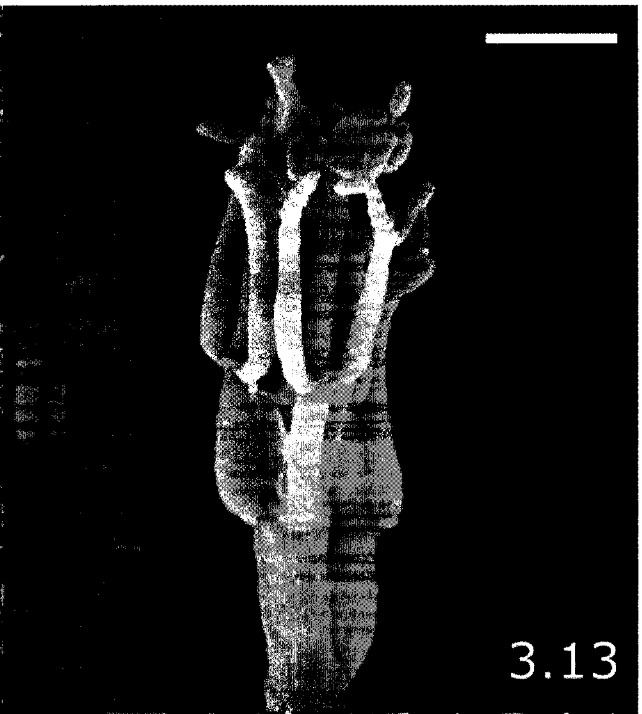
Fig. 3.12. Conidia produced by micronematous conidiophores are two to three times larger than conidia produced by macronematous conidiophores. Bar = 6 µm.

Fig. 3.13. Macronematous conidiophore displaying conidiogenous cells and conidia. Bar = 5µm.

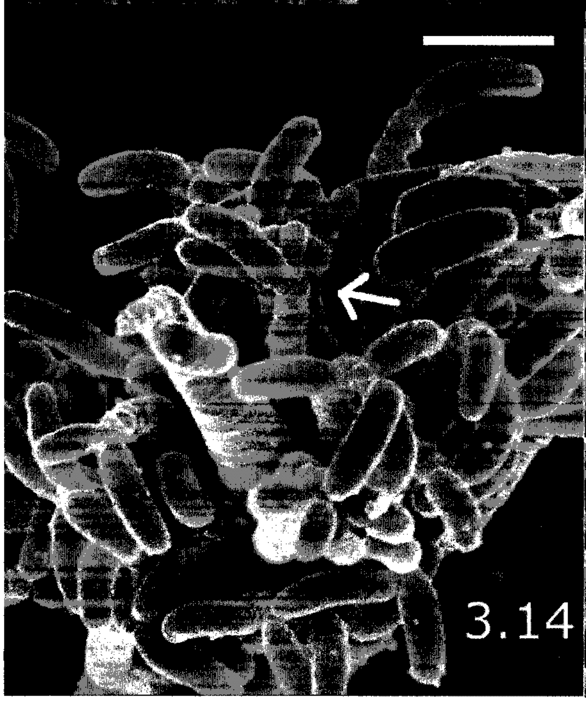
Fig. 3.14. Conidiogenous cells displaying annellations at tips and signs of delayed conidial succession (arrow). Bar = 3 µm.

Fig. 3.15. Conidia produced by macronematous conidiophores display a distinct curvature and are truncate at the proximal end (arrows). Bar = 3 µm.

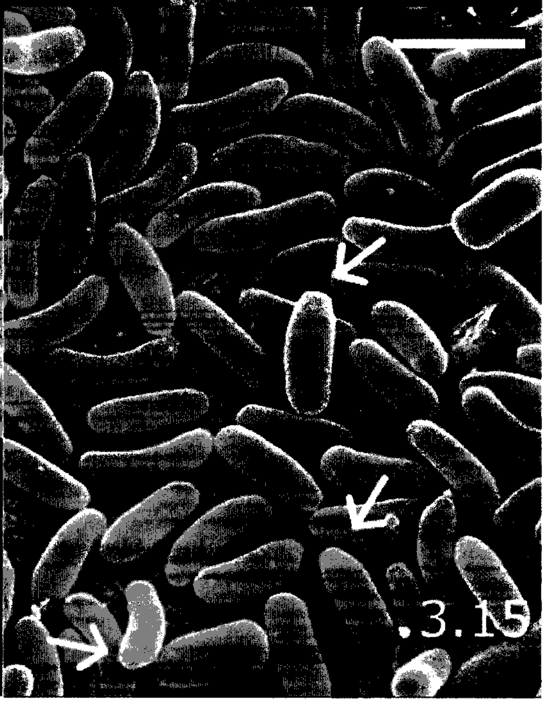
3.12



3.13



3.14



3.15

Figs. 3.16. One of two most-parsimonious trees generated from ITS sequences of representative species of *Leptographium, Ophiostoma,* and *Graphium.* *Leptographium piriforme* forms a basal lineage in a clade predominantly composed of *Leptographium* species. Genbank accession numbers are listed beside species. Bootstrap values >50% are shown above branches.

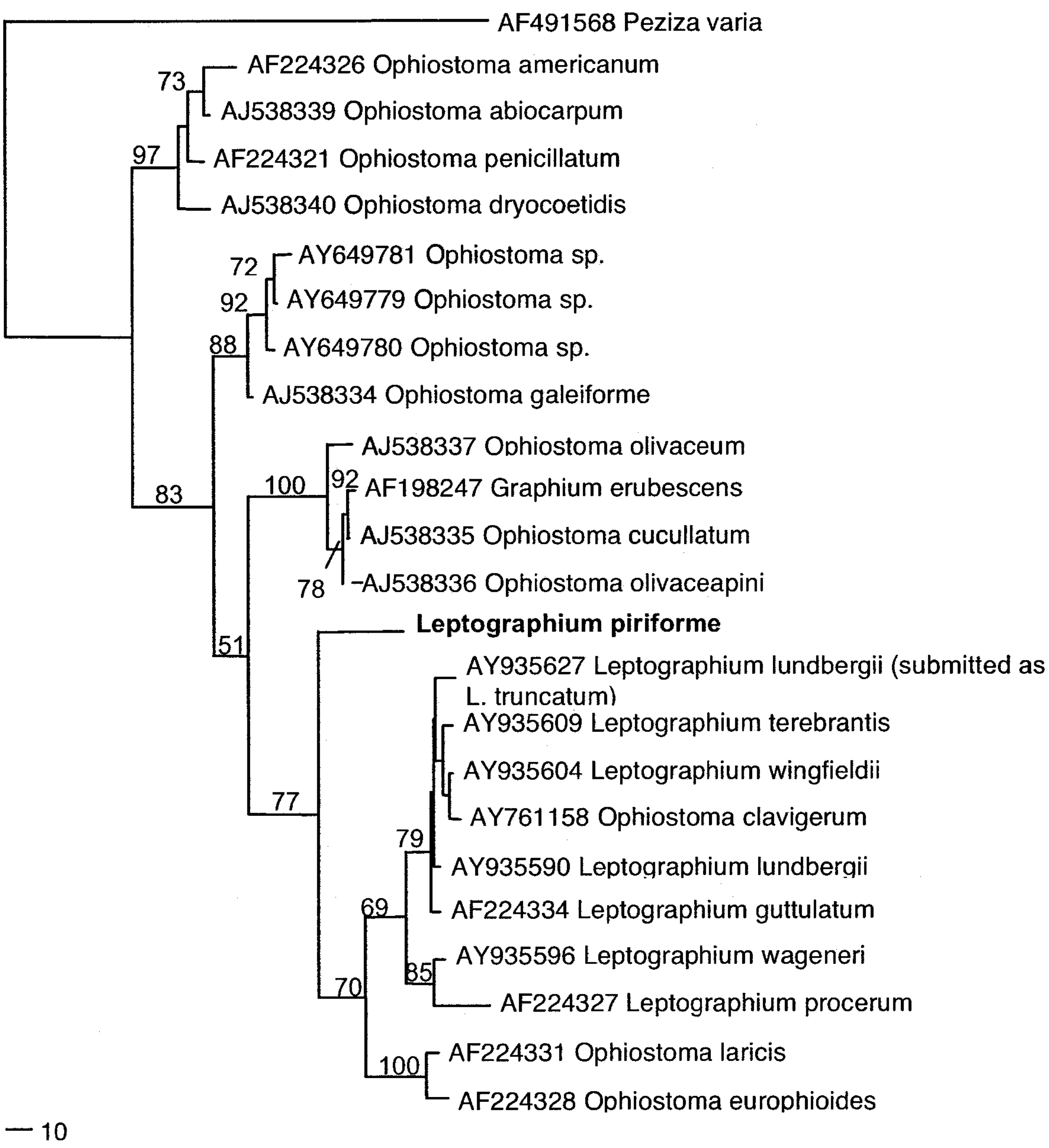

AF491568 Peziza varia
73
AF224326 Ophiostoma americanum
AJ538339 Ophiostoma abiocarpum
97
AF224321 Ophiostoma penicillatum
AJ538340 Ophiostoma dryocoetidis
72
AY649781 Ophiostoma sp.
92
AY649779 Ophiostoma sp.
88
AY649780 Ophiostoma sp.
AJ538334 Ophiostoma galeiforme
AJ538337 Ophiostoma olivaceum
83
100
92
AF198247 Graphium erubescens
AJ538335 Ophiostoma cucullatum
78
AJ538336 Ophiostoma olivaceapini
Leptographium piriforme
51
AY935627 Leptographium lundbergii (submitted as L. truncatum)
AY935609 Leptographium terebrantis
AY935604 Leptographium wingfieldii
77
AY761158 Ophiostoma clavigerum
79
AY935590 Leptographium lundbergii
69
AF224334 Leptographium guttulatum
AY935596 Leptographium wageneri
85
70
AF224327 Leptographium procerum
100
AF224331 Ophiostoma laricis
AF224328 Ophiostoma europhioides
10

Table 3.1. Mean growth rates of *Leptographium piriforme* on malt extract agar incubated at 5 degree increments from 5 to 40°C.

Temperature (°C)	Growth rate (mm/d ± sd)
5	0
10	0.9 ± 0.3
15	1.6 ± 0.6
20	3.7 ± 1.1
25	6.6 ± 1.6
30	9.8 ± 1.2
35	10.3 ± 0.4
40	0

Table 3.2. Provenance data for isolates of *Leptographium piriforme* obtained from arthropods. Isolates marked with an asterisk were used to measure morphological and physiological characteristics.

Isolate number	UAMH Number	Bait type	Date collected	Arthropod
*182	10682	Brown-rotted wood	May 28/03	Collembola (Springtail)
190		Brown-rotted wood	May 28/03	Hymenoptera: Formicidae (Ant)
138b		Coyote dung	July 18/02	Coleoptera (Beetle)
140		Coyote dung	July 18/02	Trichoptera (Caddisfly)
195		Coyote dung	Aug 21/02	Hemiptera (Bug)
196		Coyote dung	Aug 21/02	Diptera (Fly)
197		Coyote dung	Aug 21/02	Hymenoptera: Formicidae (Ant)
262		Coyote dung	May 28/03	Coleoptera (Beetle)
312		Coyote dung	June 25/03	Diptera (Fly)
313		Coyote dung	June 25/03	Coleoptera (Beetle)
365		Coyote dung	July 2/03	Coleoptera (Beetle)
367		Coyote dung	July 2/03	Acari (Mite)
368		Coyote dung	July 2/03	Pscoptera (Booklice)
369		Coyote dung	July 2/03	Lepidoptera (Moth)
375		Coyote dung	July 9/03	Hymenoptera: Formicidae (Ant)
379		Coyote dung	July 9/03	Acari (Mite)
405		Coyote dung	July 16/03	Hemiptera (Bug)
406		Coyote dung	July 16/03	Hymenoptera: Formicidae (Ant)
*421	10680	Coyote dung	July 16/03	Diptera (Flies)
* 439	10681	Coyote dung	July 23/03	Coleoptera (Beetle)
*445	10683	Coyote dung	July 23/03	Diptera (Fly)
448		Coyote dung	July 23/03	Acari (Mite)
536		Coyote dung	Aug 27/03	Hymenoptera: Formicidae (Ant)
537		Coyote dung	Aug 27/03	Hymenoptera: Formicidae (Ant)
79		Fibregass	July 2/03	Araneae (Spider)
*111	10684	Fibregass	Aug 20/03	Lepidoptera (Moth)
*273	10685	Moose dung	July 16/03	Hymenoptera: Formicidae (Ant)
85		White-rotted wood	July 24/02	Araneae (Spider)
186		White-rotted wood	July 2/03	Araneae (Spider)

Table 3. Characteristics of *Leptographium piriforme* and other morphologically similar *Leptographium* species.

	Leptographium piriforme	*L. crassivaginatum* M.J. Wlngf.*	*Leptographium hughesii* K. Jacobs, W.J. Wingf. and T.C. Harr.*	*Leptographium abietinum* (Peck) M.J. Wingf. *	*Leptographium penicillatum* Grossmann*
Conidial shape	Curved	Ellipsoidal	Curved	Curved	Curved
Conidial size	2.4-4.6 x 1-1.4 µm	4-5 x 1-2 µm	3-5 x 1-2 µm	(3-) 4-5 (-7) x 1-2 µm	(4-) 6-7 (-10) x 2-3 µm
Conidiogenous cell dimensions	8.6-15.4 x 1-1.4 µm	(7-) 8-10 (-12) x 2-3 µm	(8-) 9-15 (-18) x 1-2 µm	10-23 (-25) x 1-2 µm	(10-) 12-16 (-25) x 2-3 µm
Conidial apparatus length	28.8-93.6 µm	15-55 (-60) µm	(30-) 67-89 (-175) µm	(25-) 45-50 (-100) µm	(35)- 51-87 (-110) µm
Stipe length	7-45.6 um	8-60 (-85) µm	(210-) 484-711 (-1130) µm	35-440 (-470) µm	(75-) 199-248 (-340) µm
Number of cells per stipe	One to four	One to six	Four to eighteen	Two to seven	One to ten
Secondary conidial state	Micronematous conidiophores	None reported	None reported	None reported	None reported
Teleomorph	None reported	*Ophiostoma crassivaginatum* (H.D. Griffin) T.C. Harr.	None reported	None reported	*Ophiostoma penicillatum* (Grossmann) Siemaszko
Pear-shaped cells	Stalk 7.2-45.6 x 4.8-7.2 µm Tip 14.4-31.2 x 7.2-16.8 µm	12-20 x 8-12 µm**	None reported	None reported	None reported
Arthropod associates	Coleoptera, Diptera, Araneae, Acari, Hemiptera, Lepidoptera, Collembola, Pscoptera, Trichoptera, and Hymenoptera: Formicidae	Coleoptera: *Trypodendron retusus*	None reported	Coleoptera*: Dendroctonus*, *Hylastes*, and *Hylurgops* sp.	Coleoptera*: Dendroctonus*, *Hylastes*, *Hylurgops*, *Dryocoetus*, *Ips*, *Pityogenes*, *Polygraphum*, *Tetropium*, and *Trypodendron* sp.
Optimal growth temp on MEA	35°C	30°C	25°C	25°C	30°C
Growth rate at optimum	51 mm in 5 days	31 mm in 9 days	8 mm in 8 days	39 mm in 8 days	12mm in 8 days
Hosts	Unknown	Angiosperms: *Populus grandidentata, P. tremuloides* Conifers: Picea and Pinus sp.	Angiosperms*: Parashorea plicata*, *Aquilana* sp.	Conifers*: Picea* and *Pinus* spp.	Conifers*: Abies*, *Picea*, and *Pinus* spp.
Distribution	Alberta, Canada	Canada	Vietnam	N.W. United States and W. Canada	Europe and Japan

*Data from Jacobs and Wingfield 2001

**Additional data from Griffin 1968

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Chapter 4

A functional interpretation of the role of the reticuloperidium in whole-ascocarp dispersal by arthropods[1].

INTRODUCTION:

The peridium of some cleistothecial ascomycetes is a cage- or mesh-like arrangement of thin- or thick-walled peridial hyphae. Ascocarps with this type of peridium are often referred to as "gymnothecia," a term first used by Novak and Galgoczy (1966), because the asci and ascospores are "naked" or at least not enclosed by a complete membrane. The peridium of some gymnothecial ascomycetes is made up of a rigid, thick-walled, branched and anastomosed network of hyphae, termed a reticuloperidium (Currah 1985). In many reticuloperidial species, distinctive, hooked, curved or barbed appendages arise from the reticuloperidial network. This visually striking peridial architecture occurs in several distinct lineages, including the eurotiomycete families *Arthrodermataceae*, *Gymnoascaceae* and *Onygenaceae* (*Onygenales*), and in the *Myxotrichaceae*, a group of uncertain taxonomic position (Eriksson et al. 2001), but with affinities to the inoperculate discomycetes (see below).

Ascomycetes with these distinctive reticuloperidia were once assembled together in a common family (e.g., *Gymnoascaceae* Benjamin) or order (*Gymnascales* Clements and Shear)(Currah 1985). The value of the reticuloperidial structure as a taxonomic feature was considered high given its frequent co-occurrence with dry arthroconidia, as found, for example in *Oidiodendron* (mitosporic states of *Myxotrichum*, Hambleton et al. 1998) and *Malbranchea* (mitosporic states of *Auxarthron* and other fungi, Currah 1985). However, the importance of the reticuloperidium, and other types of gymnothecial peridia in delimiting taxa above the genus level was questioned by Currah (1985), who proposed that the peridial modifications (and appendages) common in the "gymnoascaceous" fungi had arisen independently in unrelated taxa because of a

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common reliance on arthropods for dispersal. The congruent occurrence of arthroconidial mitosporic states with reticuloperidial anamorphs remained unexplained.

Recent molecular phylogenetic analyses of a number of reticuloperidial ascomycetes (Hambleton et al. 1998, Sugiyama et al. 1999, Sugiyama and Mikawa 2001) have confirmed the independent development of similar reticuloperidia among gastroid members of the inoperculate discomycetes, (*Myxotrichaceae*: *Myxotrichum, Pseudogymnoascus* and *Gymnostellatospora*); and among members of the Eurotiomycetes (*Onygenaceae*: *Auxarthron, Pectinotrichum; Arthrodermataceae*: *Arthroderma*; *Gymnoascaceae*: *Gymnoascus*), further reinforcing the hypothesis that the reticuloperidium is related to a specific function.

These fungi produce meiospores within evanescent asci, and having no ability for forcible spore discharge, had to evolve an alternate means of spore liberation and dispersal. The majority of these reticuloperidial ascomycetes are known primarily from substrates such as dung, soil, and rotting wood; these substrates are the habitat of a variety of arthropods. It has been suggested that the elongate, hooked or barbed appendages, extending from the reticuloperdium, might hook onto the legs of arthropods which would then disperse the fungus as the meiospores sifted out through the openings in the peridial wall (Currah 1985). Summerbell (2000) suggested, alternatively, that the reticuloperidium of species of the *Arthrodermataceae* could play a role in deterring arthropod grazers. Given the clear taxonomic and phylogenetic significance of the reticuloperidium and the absence of empirical data or direct observations to explain the mechanistic aspects of this architecture in different lineages of ascomycetes, I did a simple *in vitro* experiment to test the hypothesis that the morphology of the reticuloperidium and its appendages in two distantly related ascomycetes is functionally related to dispersal by arthropods.

MATERIALS AND METHODS:

Myxotrichum deflexum (UAMH[1] 7569) and *Auxarthron conjugatum* (UAMH 3156) were grown on plates of corn meal agar (CMA, Difco). After four to eight weeks, when mature cleistothecia with well-developed reticuloperidia had formed, 1cm^2 explants

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[1] University of Alberta Microfungus Collection and Herbarium, Edmonton, Alberta.

of agar bearing clusters of gymnothecia were placed individually into six empty sterile plastic Petri plates per fungal species. Adult flies (*Neobellieria bullata, Sarcophagidae*), obtained from the insect rearing room at the University of Alberta, were introduced singly into each of these plates (12 plates total). *N. bullata*, one of a series of species known as fleshflies, was chosen for this experiment because it was large enough and sufficiently hairy to pick up ascocarps (Greif and Currah 2001) and was easily obtained in sufficient quantities. I contend that this species is a satisfactory experimental surrogate because its characteristics (size range and hairiness) are shared by many different species of insects that frequent dung and rotting wood. Flies and fungus culture explants were incubated together and observed periodically for 24 hours. The flies were then killed by freezing for ten minutes at -12°C and observed with a dissecting microscope for adhering ascocarps. Flies with attached ascocarps were air dried for 48 hours, mounted on stubs, gold coated using a Nanotek Semprep II gold coater and examined under a JEOL JSM6301FXV scanning electron microscope.

RESULTS AND DISCUSSION:

Observations showed ascocarps of both *M. deflexum* and *A. conjugatum* were dislodged easily from the substrate and adhered to the limbs and bodies of the flies as they fed on the corn meal agar block. Adhering ascocarps appeared to stimulate a grooming response during which some peridia were pulled apart to release a fine dust of meiospores, some of which fell onto the limbs of the fly. Other ascocarps could be seen attached to limbs, or being transferred during grooming to other body parts (Fig. 4.1). All 12 flies had ascocarps attached to their exoskeletons at the end of the 24 hour period. When frozen insects were examined with the dissecting microscope, whole ascocarps were, in most cases, attached to the dorsal side of the thorax (Fig. 4.1) as well as to other body parts including limbs and abdomen. Examination by SEM showed that attachment was by an impalement mechanism in which the stiff insect hairs passed, lance-like, through the interhyphal spaces of the reticuloperidium (Figs. 4.2-4.5). In some cases, peridial fragments and ascospores adhered to hairs and limbs in the vicinity of impaled cleistothecia (Figs. 4.3-4.4). The hooked appendages did not appear to function in attachment as suggested previously (Currah 1985). Instead, they were caught by the limbs of the flies during grooming and this played a role in the ascocarp disruption and dislodgement, and the concomitant release of ascospores.

Because *N. bullata* uses a suction pump mechanism (proboscis) to feed and lacks chewing mouthparts, this experiment could not provide evidence to support or refute the idea that the reticuloperidium and its appendages discourage ascocarp grazing. However, the presence of the ascocarps did not prevent the flies from feeding on the corn meal agar block beneath the ascocarps, indicating that the peridial structure at least did not prevent visitation of the substrate.

That arthropods play an important role in spore dispersal in a wide variety of fungal taxa is a well-known phenomenon (e.g., Haberkern et al. 2002, Levieux et al. 1989, Blackwell and Malloch 1991), although the association usually involves the pick up and transport of sticky mito- or meiosporic propagules. Instances in which the entire fructification adheres to a carrier are less common. In the Laboulbeniales, minute, club-shaped ascocarps develop directly on their carriers, adhering through a basal attachment point (Tavares 1985), although in this example, these ascocarps remain attached to their hosts, and dispersal is by infection of new host exoskeleton via spore transfer. Unlike the Laboulbeniales, the results of this study have no supporting data from field observations. I have not found reports of insects captured in their natural habitats with adhering reticuloperidia, although it is unlikely that arthropod collectors would recognize the significance of entire or fragmented reticuloperidial structures if they did see them. Nonetheless, I propose that the obvious effectiveness of ascocarp attachment through impalement on arthropod hairs is strong evidence supporting the contention that the reticuloperidium is an evolutionary innovation that has arisen independently on several occasions and is an adaptation to arthropod dispersal. In this scenario, the structural characteristics of the reticuloperidium and its appendages in distantly related lineages of ascomycetes have evolved to exploit not only insect morphology, but also insect behaviour.

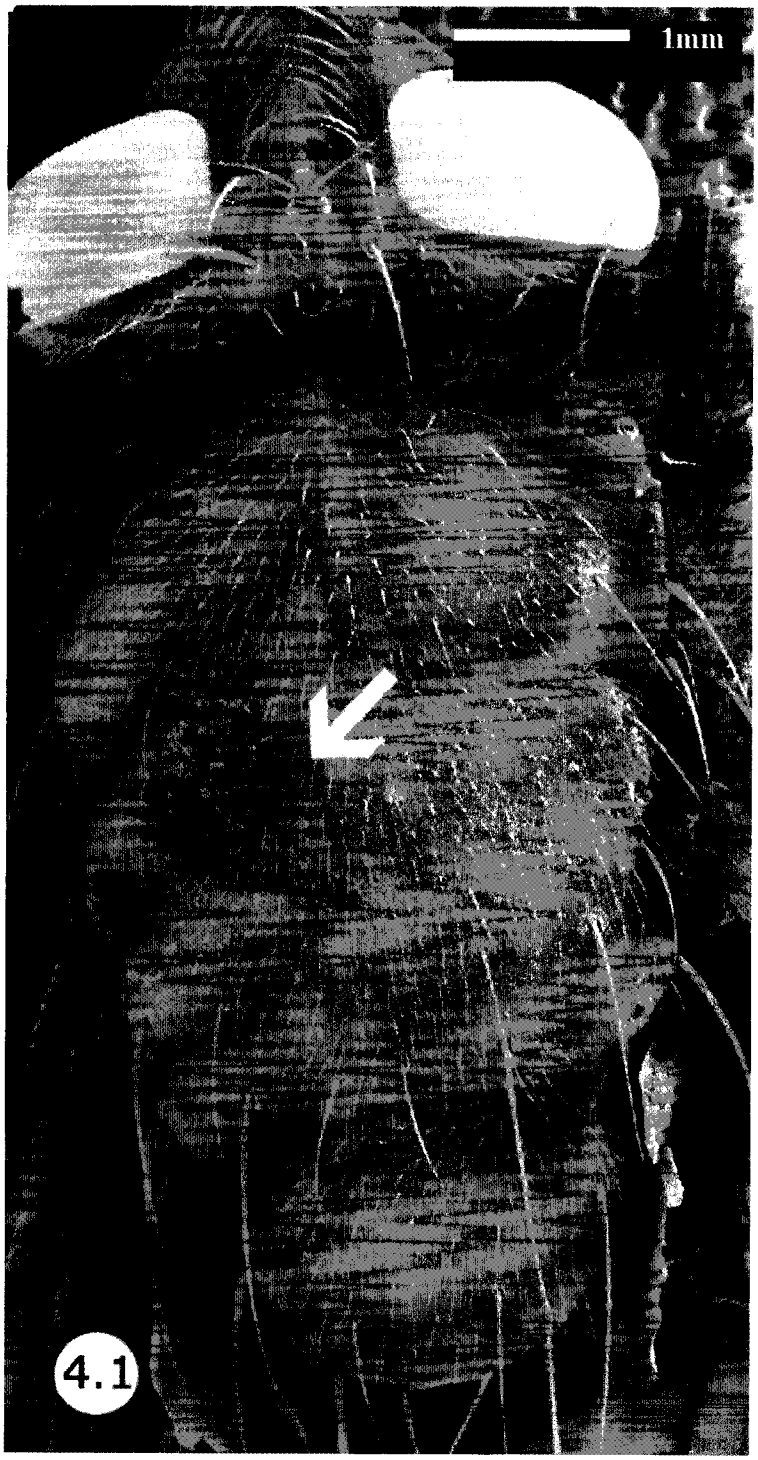
These observations do not provide data that might explain the parallel association of arthroconidial states with reticuloperidial ascocarps but do invite some speculation on the phenomenon. Given that both of these lineages fruit on decaying materials attractive to arthropod visitors, it is likely that both the meiosporic and mitosporic stages are adapted in some way to dispersal by these animals. I suggest that the dry, cylindrical arthroconidia produced by the majority of reticuloperidial fungi would enhance electrostatic attachment to arthropods because they have a greater surface area than spherical conidia. In species that produce arthroconidia (e.g. *Auxarthron conjugatum* and *Myxotrichum arcticum*), these asexual propagules form in abundance much earlier than the reticuloperidial cleistothecia which may take weeks or even months to develop. The minute size of these conidia would allow attachment to a wide range of arthropods and would permit an early start to dissemination from a relatively small thallus. In this way, smaller arthropods (e.g. mites) might distribute the fungus locally while larger ones (e.g. beetles) might distribute the fungus over a wider area. By the time ascocarps develop, substrates may be almost exhausted and thus dispersal on a local scale is not advantageous. A similar delay in the development of the teleomorph has been reported in species of *Pyxidiophora* (anamorphic Laboulbeniales). In this taxon, early development of conidia allows phoretic mites to disperse the fungus locally, while ascospores are produced later and are better suited to long-range dispersal by phoretic mites and their associated beetle carriers (Blackwell and Malloch 1989). Likewise, by producing minute meiospores within a larger propagule (i.e. the reticuloperidial cleistothecium), adapted for pick up by larger arthropods (Greif and Currah 2001), reticuloperidial ascomycete taxa would increase their potential for targeted dissemination to newly available substrates over a geographically wider area.

While all reticuloperidial ascomycetes (that produce mitospores) are arthroconidial, not all arthroconidial ascomycetes produce reticuloperidia. In fact, this type of mitospore is found associated with a wide range of ascocarp morphologies. For example, species of *Onygena* and *Aphanoascus* produce ascospores within an ascocarp that has a solid or membranous wall. *Shanorella spirotricha* has an unusual reticuloperidium that shatters at maturity and some *Gymnascella* species produce ascocarps that have a few thin-walled, or oddly shaped, vegetative hyphae associated with the ascospore mass (Currah 1985). While the relationship between form and function in the mitosporic and meiosporic states of many species of the *Arthrodermataceae* has been speculated upon (Summerbell 2000), hypotheses regarding the role of these other peridial variants are rare or nonexistent. Further direct observations of the relationship of these structures with selected arthropods could indicate the biological significance of these variants and improve our ability to formulate hypotheses about the life histories of these fungi and how reproductive strategies come to bear on evolutionary trajectories and relationships in the ascomycetes.

This paper provides the first empirical evidence that the reticuloperidium is an adaptation that facilitates the attachment and transfer of the ascocarp via arthropods. The next step is to challenge this hypothesis (that these ascocarps are picked up and transferred or dispersed through impalement) with evidence from arthropods and reticuloperidial fungi collected from the field. Close observations of insects frequently found with rotting wood and dung, and that share some or all of the characters found in *N. bullata* (e.g. *Calliphoridae* in the *Diptera*, *Staphylinidae* and *Carabidae* in the *Coleoptera*, and some members of the *Formicidae* in the *Hymenoptera*) is expected to yield additional information on the role of the reticuloperidium in nature.

Fig. 4.1. Scanning electron micrograph of *Neobellieria bullata.*

Fig. 4.1. Scanning electron micrograph showing the head and thorax of a fly (*Neobellieria bullata*) after exposure to an explant of agar bearing mature reticuloperidial gymnothecia of *Myxotrichum deflexum.* Note the aggregation of gymnothecia adhering to the dorsal surface of the thorax (arrow). Bar = 1mm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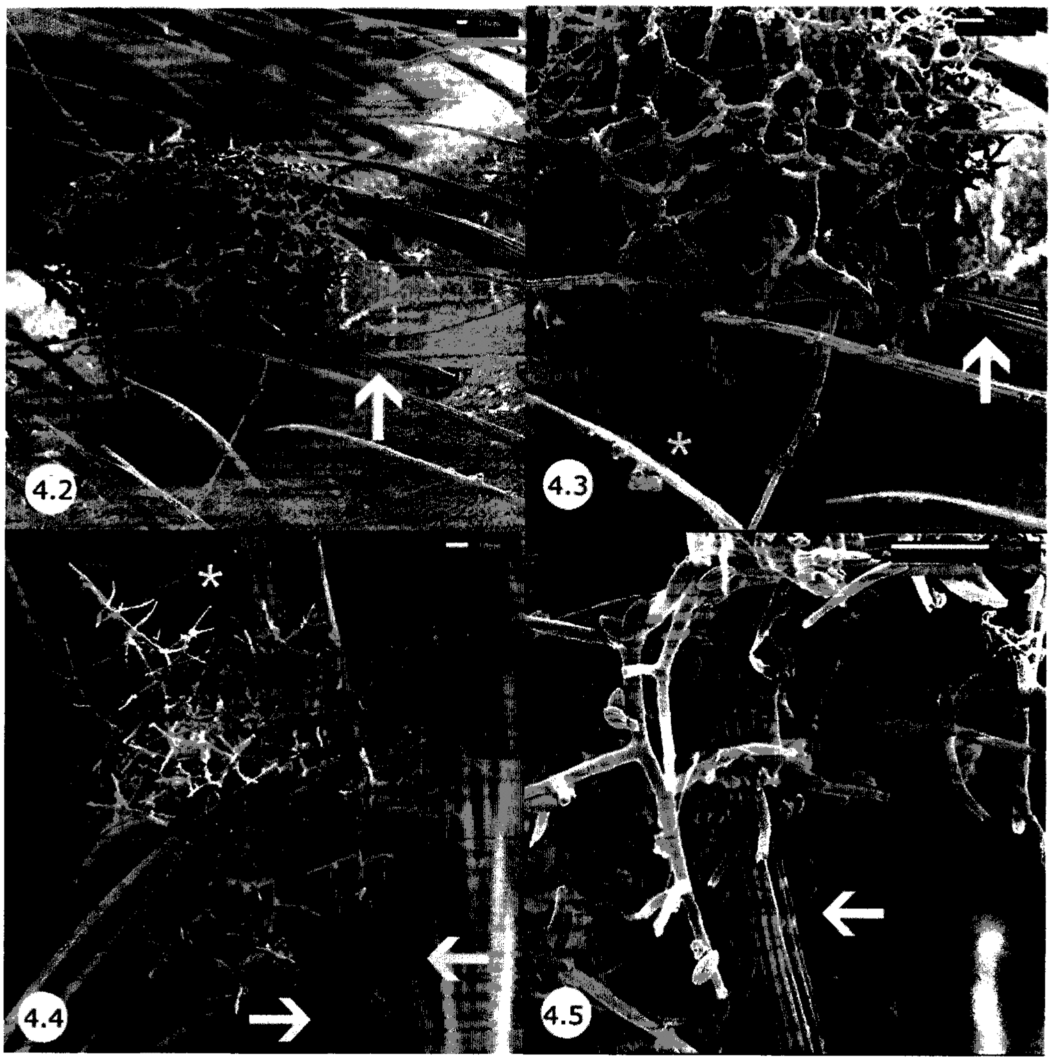
Figs. 4.2-4.5. Reticuloperidial gymnothecia impaled by hairs of *Neobellieria bullata.*

Fig. 4.2. Ascocarp impalement showing several hairs passing through the spaces between the rigid hyphae of the reticuloperidium of *Auxarthron conjugatum*. Bar = 10 µm.

Fig. 4.3. Impalement at a higher magnification showing the fit between the size of the insect hairs (arrow) and the reticuloperidial spaces of *Auxarthron conjugatum*. Note the liberated ascospores adhering to an adjacent hair (*). Bar =10 µm.

Fig. 4.4. Ascocarp impalement showing several hairs (arrows) passing through the spaces between the rigid hyphae of the reticuloperidium of *Myxotrichum deflexum*. Note liberated ascospores adhering to adjacent hairs (*). Bar = 10 µm.

Fig. 4.5. Impalement at a higher magnification showing the path taken by an insect's hair as it passes through the interhyphal spaces of the reticuloperidium of *Myxotrichum deflexum*. Bar = 10 µm.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Chapter 5

The peridial development and dehiscence mechanism of *Cryptendoxyla hypophloia*, a cleistothecial ascomycete isolated from the bodies of arthropods[1].

INTRODUCTION:

A variety of ascocarp forms have resulted from the evolutionary optimization of the mechanisms required to disperse the ascospores. Disk shaped apothecia permit the unhindered, forcible ejection of ascospores from an exposed hymenial surface so they can be carried on air currents. Flask shaped perithecia permit a similar ejection of ascospores or may extrude spores as a slimy mass that may adhere to an animal carrier. The ascocarps of many ascomycetes are cleistothecial and have a solid peridium that completely encloses their ascogenous cells and their products and often lack the ability to eject or extrude ascospores. Consequently, ascospore release and dispersal in cleistothecial species must rely on alternative mechanisms.

Recently, I obtained from the bodies of arthropods three different isolates of *Cryptendoxyla hypophloia* Malloch and Cain, a cleistothecial fungus originally placed in the Pseudeurotiaceae (Malloch and Cain 1970) but having molecular similarities to the Sordariales (Suh and Blackwell 1999). In *C. hypophloia*, ascospores are released from the ascus by dissolution of the ascus wall and accumulate within a peridium consisting of six to eight disarticulating plates. This distinctive peridial type, described first by Von Höhnel (1917) in Cephalotheca sulfurea and later referred to as "cephalothecoid" by Malloch and Cain (1970), is particularly fragile at maturity and shatter or breakage of the peridium by external agents is considered to be the primary means by which ascospores are released from these cleistothecial ascocarps (Chesters 1934, Parguey-Leduc 1970, Hawksworth and Booth 1974, Uecker 1977, Benny et al. 1980). The ascocarps of *C. hypophloia* may shatter in some instances but usually they exhibit an active dehiscence mechanism that allows the ascocarp to open, flower-like, when ascospores are mature.

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The cephalothecoid peridium presumably represents innovations adapted for specific environments because this peridial type has evolved in distantly related lineages including the Sordariales, Ophiostomatales, and Dothideales (Suh and Blackwell 1999, Uecker 1977). This widespread occurrence, plus reports of both active and passive (i.e., shattering) dehiscence in cephalothecoid ascomycetes, strongly suggest that a peridial wall composed of disarticulating plates represents a convergence of different ontogenetic sequences and anatomical features. Unfortunately, reports of the peridial development or ultrastructural mechanisms associated with dehiscence are too few to make meaningful comparisons. Of three studies dealing with the development of cephalothecoid peridia (Chesters 1934, Uecker 1977, Benny et al. 1980) only one was done at an ultrastructural level and focused on a species (*Chaetomidium arxii*) in which dehiscence is passive (Benny et al. 1980). The structural components underlying active dehiscence have not been investigated and, consequently, the development and structure of the cleistothecium and its retracting plates in *C. hypophloia* are unknown. This information is fundamental to teasing out the selective pressures that lead to the evolution of the cephalothecoid peridium.

Using light (LM), scanning (SEM), transmission electron microscopy (TEM) and *C. hypophloia* grown on agar-based medium, I describe the development and the structural basis of the active dehiscence mechanism of its cleistothecial ascocarp and describe how the cephalothecoid peridium in this species might function in the release and dissemination of ascospores in nature.

MATERIALS AND METHODS:

Three isolates of *C. hypophloia* were obtained from insects trapped in a southern boreal mixed wood forest 70 km east of Edmonton, Alberta, and deposited in the University of Alberta Microfungus Collection and Herbarium (UAMH). UAMH 10412, from *Mycetophagus californicus* (order Coleoptera, family Mycetophagidae), was studied in detail using a combination of LM, SEM, and TEM. UAMH 10413 and 10414, from a European Ground Beetle (order Coleoptera, family Carabidae) and a Springtail (order Collembola), respectively, were examined by LM only. Isolates were cultured on corn meal agar (CMA, Becton Dickinson Microbiology Systems) and on sterile moist filter paper.

For SEM, 5 mm disks of agar bearing immature and mature cleistothecia of *C. hypophloia* were fixed in unbuffered 2% glutaraldehyde for 4 hours, placed in 2% tannic acid-2% guanidine hydrochloride overnight at 5°C, and post-fixed in 2% OsO_4 for three hours at room temperature. Fixed material was dehydrated in an ethanol series, taken to amyl acetate, critical-point dried in a Polaron E-3000 dryer using carbon dioxide and then coated with gold and examined at 15 kV with a Hitachi S-510 electron microscope. For TEM, specimens were fixed in 2% glutaraldehyde and 2 % OsO_4 in phosphate buffer at pH 7.3 and dehydrated in an ethanol series. Samples were then embedded in Spurr's resin. Ultrathin sections were stained with uranyl acetate and lead citrate. Photomicrographs of these samples were taken at 75 kV with a Hitachi H-7000 electron microscope.

RESULTS:

Development of the cleistothecium.

Four weeks after inoculation, all stages in cleistothecium development could be located in cultures. Cleistothecia were minute and white to pale brown when immature and then black, globose and 70-115 µm in diameter (Fig. 5.1) when mature and ready to dehisce. At this stage, the upper portion of the peridium would split open when the lid of the petri dish was removed, or when cultures were allowed to dry out (Fig. 5.2).

Cleistothecium development was initiated by the formation of short lateral branches (gametangia) that grew towards each other from adjacent vegetative hyphae (Fig. 5.3). On contact, one branch enlarged and encircled the other to form an ascogonium (Figs. 5.4, 5.5). Six to eight branches arising from nearby vegetative hyphae then grew towards the ascogonium (Fig. 5.6). Each of these hyphae, once appressed to the ascogonium, branched repeatedly to form a cluster of loosely arranged cells. Hyphal branches originating within each cluster grew out at acute angles from parent hyphae and formed radiating parallel bands, giving rise to the peridial plate (Fig. 5.7). Paraphyses were absent although, within the centrum of the immature cleistothecium, larger sterile cells separated the more densely cytoplasmic and smaller ascogenous cells (Fig. 5.8). Sterile, thin walled cells also formed a layer against the inner surface of the peridium

(Figs. 5.8-5.9). At maturity, both the interascal cells and the cells lining the inner surface of the peridium had collapsed leaving a cavity in the first instance and an amorphous residue in the second (Fig. 5.10). The outer peridium was composed of multiple layers of thick walled hyphae (Figs. 5.9-5.10)

In squash mounts, immature cleistothecia contained clusters of young, club shaped asci that had arisen from croziers and which were at different stages of development (Figs. 5.11-5.12). Under TEM, these clusters were irregularly disposed among the sterile cells of the centrum (Fig. 5.8). By TEM, immature ascospores were delimited by a double membrane system (Fig. 5.13) that later enclosed an inner electron translucent and an electron opaque outer layer of wall material (Figs. 5.14-5.15). At maturity, asci had deliquesced and ascospores adhered as a central mass within the cleistothecial cavity (Fig. 5.10).

Peridial plates were composed of parallel arrangements of thick walled pigmented hyphae. Each plate developed radially from a central cluster of cells through the formation of acute lateral branches and tip growth (Figs 5.7, 5.16). Elongating hyphal tips from opposing fronts met and grew between each other so that the hyphae of adjacent plates were interdigitated (Fig. 5.16). By TEM, in long section, hyphae of the peridial plates were vacuolated at maturity and along the inner wall surface had pronounced thickenings that formed a banding pattern that was perpendicular to the direction of growth (Figs. 5.1-.17). In immature cleistothecia, a mucilaginous material adhered to the outer surface of the peridium (Figs. 5.7, 5.18).

Rows of thin walled cells, equidistant from the points of origin of individual plates and perpendicular to the orientation of growth of peridial hyphae, were visible from very early stages of cleistothecium development (Figs. 5.7, 5.19). By SEM each of these cells had a transverse groove in the cell wall (Figs. 5.19-5.21) that aligned with those of neighbouring cells to form the dehiscence lines that delineated incipient peridial plates (Fig 5.21). By TEM, peridial cross sections showed that the hyphae underlying these lines lacked the pronounced wall thickenings described above (Fig. 5.22) and were present in only one or two layers (Figs. 5.10, 5.23). The outer mucilaginous layer was not present when cleistothecia were mature (Figs. 5.24-5.25). Close to maturity, the peridium comprised 6 to 8 well-defined polygonal plates (Figs. 5.24-5.25), each 3-4 cells thick

(Fig. 5.25). The arrangement of plates and dehiscence lines gave the surface of the peridium an appearance resembling a “soccer ball” (Figs 5.21, 5.24-5.25).

Dehiscence of the cleistothecium.

At room temperature and under the lamp of the dissecting scope the uppermost peridial plates of mature cleistothecia everted in 3-5 minutes, exposing the ascospores. Although eversion rates differed, a similar change in the shape of these plates occurred when dishes were left unsealed and placed in the dark at 4°C and 37°C. Regardless of temperature and illumination, placing a drop of sterile water on opened cleistothecia caused the peridial plates to revert to their former shape, in 5-10 seconds in some cases. Subsequent cycles of drying and wetting caused a repeat of this eversion-inversion pattern. The first indication of plate eversion was a change in the shape of the cleistothecium from globose to polygonal as individual concave plates began to flatten. Soon afterwards, fissures following the dehiscence lines opened across the thin walled hyphal cells (Figs. 5.2, 5.22, 5.24-5.25).

Eversion of the uppermost peridial plates exposed a conglobate and tightly adhering mass of darkly pigmented, unicellular ascospores in the lower portion of the peridium. In a few instances, plate eversion was extreme and caused the ascospore mass to roll out of the opened cleistothecium. Mature ascospores remained in a tight cluster when placed in a drop of water but dispersed readily in immersion oil.

DISCUSSION:

In the original taxonomic description of *Cryptendoxyla hypophloia*, Malloch and Cain (1970), using only LM and direct mounts, observed the development of the cleistothecia in cultured material from “simple coils”, through the early stages of cleistothecium formation, and finally to the mature “subglobose to globose, black… nonostiolate ascocarps” that would “split open along the dehiscence lines and spread apart… under the drying effect of the microscope lamp.” Most of their preliminary observations concerning development are compatible with mine although SEM and TEM provided me with an opportunity to make more detailed interpretations of the relationship between structure and function.

Features associated with centrum development agree closely with those reported by Malloch and Cain (1970) who also observed that asci arose from croziers. They did not report that the pattern of ascus maturation was asynchronous nor did they comment on the hydrophobic nature of the ascospore wall. During development, TEM shows that an osmiophilic substance is present in the outer layer of the ascospore wall, suggesting the presence of lipids and is an observation compatible with the behaviour of the ascospores when placed in water and in immersion oil. The hydrophobic nature of the ascospore wall may have a role in dispersal (see below).

Malloch and Cain (1970) were intrigued by the developmental sequence leading to the formation of the cephalothecoid peridium but were not able to confirm the origin of the "plate-like complexes" comprising this structure. They did identify the bilayered nature of the peridial wall, noting the presence of a darkly pigmented outer layer of thick walled, pigmented "nearly square" cells and an inner layer of hyaline thin walled cells. SEM observations indicate that the peridial tissues originate from vegetative hyphae that arise near conjoined gametangia and grow toward and become appressed to the ascogonial coil. The cells of the peridial hyphae along with the "nodular growths of wall material around the periphery of the septa and other points" (Malloch and Cain 1970) are, in part, a misinterpretation of the perpendicular banding pattern in the hyphae of the peridial plates. The transverse wall thickenings, in face view, do resemble septa and cause these hyphae to resemble files of square cells. The functional significance of the nodular growths and the squared cells in the outer layers of the peridial plates was not mentioned in the original description but is related to the peculiar active dehiscence mechanism in this fungus which is explained below.

On drying, peridial plates of the more or less globose cleistothecia lose their curvature, presumably because the radial arrangements of banded hyphal elements of the outer peridial layer contract as surface tension increases inside the cells. As the plates flatten, stress exerted on the thin walled cells around the periphery of each plate causes these cells to tear and a fissure develops along the dehiscence line. Similar dehiscence mechanisms occur in the sporangia of some bryophytes, leptosporangiate ferns (Raven et al. 1992) and the anthers of some angiosperms (Esau 1977). In these examples, localized bands of wall material in otherwise thin-walled cells allow columns of such cells to contract and, while doing so, pull apart the sporangial wall.

As the outer layers of thick-walled cells in the peridial plates continue to contract, the plates evert even further and expose the mass of ascospores within. Cells along the dehiscence lines that do not rupture act as hinges between plates, allowing the cleistothecium to open and close when moisture is removed or added and preventing the cleistothecium from shattering and collapsing in on itself. The mucilaginous sheath found on the immature cleistothecia and the hyaline, thin walled layer of cells lining the interior of the peridium may serve to prevent premature drying and eversion of the peridial plates of *C. hypophloia*.

Among the cephalothecoid ascomycetes, some aspects of the origin and development of peridial plates in *C. hypophloia* may be unique. In this species, the number of peridial plates per cleistothecium is established early in development and additional plates do not form as cleistothecia mature. Continued branching and tip growth increase the size of each plate in a more or less radial fashion and account for the characteristic pattern of interdigital growth of new hyphae along the expanding margins of peridial plates (Figs. 5.15-5.22). Tip growth permits the ascocarp to swell and ensures that the thin-walled cells destined to tear apart during dehiscence, and which develop early in ascocarp ontogeny, remain aligned as the peridium increases in surface area. In contrast, most previous observations of the development of cephalothecoid peridia implicate meristematic growth (subdivision and subsequent growth of cells) in the expansion (and proliferation) of plates. For example, in *Zopfia rhizophila* (Uecker 1977) and *Zopfia nicotiae* (Parguey-Leduc 1970), new peridial plates form by a meristematic process that is initiated between pre-existing plates and after the dehiscence lines develop. This pattern also permits uniform expansion of the peridium (Uecker 1977). In *Chaetomidium arxii*, peridial plate initiation continues after the formation of the first set of peridial plates and new dehiscence lines continue to form late in the development of the cleistothecium, although the specific mechanism of plate formation has not been reported (Benny et al. 1980). Chesters (1934) stated that growth and expansion of the cleistothecia of *Cephalotheca* species resulted from meristematic proliferation of new cells in cephalothecoid plates. In addition to meristematic growth, tip growth was exhibited in *Zopfia rhizophila* in the vicinity of dehiscence lines (Uecker 1977). Cells underlying these dehiscence lines first lost pigmentation and then elongated, growing in between the peridial cells on both sides of the dehiscence line, creating an expanding zone of cells between peridial plates.

A peridium of thick walled cells is a character shared by all cephalothecoid fungi (Chesters 1934, Uecker 1977, Benny et al. 1980) but the transverse banding pattern in the peridial cells that seems to drive the plate eversion mechanism is, so far, unique to *C. hypophloia*. A similar dehiscence mechanism may operate in *Cephalotheca reniformis* (Chesters 1934) and in *Batistia annulipes* (Samuels and Rodrigues 1989) but ultrastructural data are unavailable for these species. In other cephalothecoid genera, e.g., *Zopfia* (Uecker 1977, Parguey-Leduc 1970), *Chaetomidium* (Benny et al. 1980), *Apiosordaria* (Stchigel et al. 2000), and *Corynascella* (Guarro et al. 1997), eversion of peridial plates has not been reported and the ascocarps of these representatives may simply shatter when mature.

Cryptendoxyla hypophloia was described as a monotypic genus with a *Chalara* anamorph by Malloch and Cain (1970) based on cultures derived from cleistothecia collected from under the bark of a dead maple tree in Ontario. Three additional specimens from similar habitats (beneath the bark of dead hardwoods) are mentioned in the original description and a fourth, from a standing dead aspen in Alberta, is reported in Lumley et al. (2000). Malloch and Cain (1970) observed numerous mites beneath the bark where their original collections were made and noticed that some mites had cleistothecia (whole and broken) and ascospores attached to their bodies or entrained among their hairs. Their suggestion, that *C. hypophloia* "is probably dispersed by arthropods", is further supported by isolates from my survey which are the first reports of this fungus solely from the bodies of live trapped insects. It was not possible to determine if these isolates from insects were derived from ascospores, peridial tissue, conidia, or fragments of vegetative hyphae.

The functional relationship between this type of ascocarp dehiscence and ascospore dispersal by arthropod carriers remains speculative but a potential scenario may be as follows. During periods of dry weather the peridia of cleistothecia, formed in cavities under bark or in logs, split open. At the same time, insects (or other arthropods) in seeking refuge from desiccating conditions (Daly et al. 1998) enter these cavities and come into contact with the exposed masses of the hydrophobic ascospores. These propagules adhere to the hydrophobic cement and wax layers on the carrier's exoskeleton and are eventually carried away to suitable new habitats. A relationship between cephalothecoid cleistothecia and arthropod dispersal agents has also been suggested for the brittle cleistothecia of *Chaetomidium arxii* (Benny et al. 1980) and for *Cephalotheca reniformis*, a species known from the galleries of wood boring beetles (Chesters 1934). The precise relationship between the behaviour of carriers and ascocarp dehiscence mechanisms must remain speculative until direct observations of these phenomena can be made in the field or *in vitro*.

An *in vitro* approach was taken by Greif and Currah (2003) during an investigation of the functional basis of the reticuloperidium, another convergent type of peridial morphology that has developed in both the discomycetous Myxotrichaceae and cleistothecial Onygenaceae. In these examples, when both fungi and insects were enclosed in a petri dish for observation, the stiff hairs investing the bodies of dipterans passed, lance-like, through the spaces in the peridial mesh, effectively attaching the ascocarp to the insects body by ascocarp impalement. Similar direct observations of the interaction of insects and cephalothecoid ascocarps *in vitro* may lead to a clearer rationalization of the selective forces that have given rise to this peridial type. It would also be useful to know the potential role of conidia and hyphal fragments as dispersal agents. In addition, more isolates of these cephalothecoid fungi from their natural habitats and from arthropods would contribute substantially to the development of hypotheses concerning the evolution and function of the cephalothecoid ascocarp.

Figs. 5.1-5.7. Stages in the cleistothecial development of *Cryptendoxyla hypophloia.*

Fig. 5.1. Culture on filter paper showing mature black globose cleistothecia along with smaller pale immature cleistothecia (arrow). Bar = 77 µm.

Fig. 5.2. A cleistothecium that has opened. Bar = 77 µm.

Fig. 5.3. Gametangium initiated as a short side branch (arrow) from vegetative hypha. Bar = 2 µm.

Fig. 5.4. Gametangial branches (arrow) encircling each other upon contact. Bar = 2 µm.

Fig. 5.5. Ascogonial coil (arrow) formed from gametangia. Bar = 2 µm.

Fig. 5.6. Ascogonium enveloped by peridial initials that have originated from neighbouring vegetative hyphae. Bar = 2 µm.

Fig. 5.7 Immature cleistothecium displaying cluster of loosely arranged cells. Hyphal branches originate from this cluster to form the peridium. Arrow indicates a dehiscence line. Bar = 10 µm.


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Figs. 5.8-5.13. Development of centrum and ascogenous tissue.

Fig. 5.8. Interior of cleistothecium displaying large sterile cells separating more densely cytoplasmic and smaller ascogenous cells. Sterile cells form a layer against the inner surface of the peridium (arrow). Ascospores are interspersed throughout the central cavity (arrow). Bar = 2 µm.

Fig. 5.9. Close up view of peridial wall. Thin walled cells form a layer against thick walled outer peridial layer. Bar = 2 µm.

Fig. 5.10. Cross section of mature cleistothecium. The large sterile cells and thin walled inner peridial layer have collapsed, leaving behind an amorphous residue (a). Ascospores form a mass in the centre of cleistothecial cavity. Arrow indicates position of dehiscence line in section. Bar = 10 µm.

Fig. 5.11. Formation of asci. Asci arise from croziers (arrows). Bar = 10 µm.

Fig. 5.12. Cluster of asci at different stages of development. Bar = 10 µm.

Fig. 5.13. Interior of ascus showing immature ascospores delineated by a double membrane (arrow). Bar = 1 µm.


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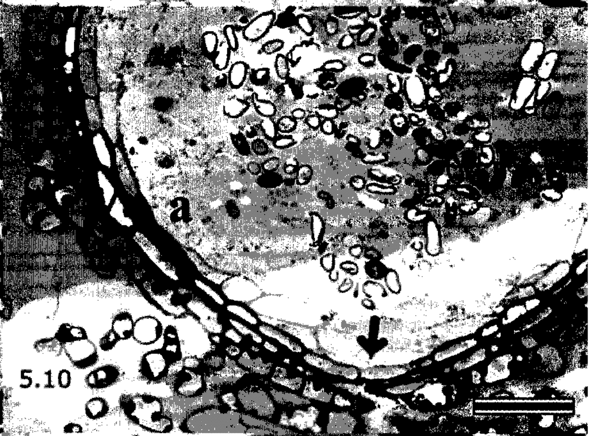
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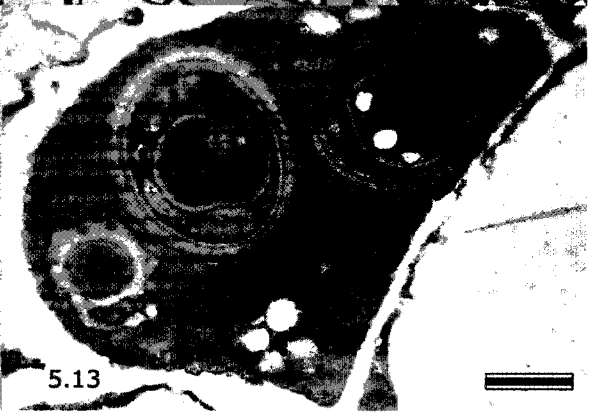
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Figs. 5.14-5.19. Formation of ascospores and peridial plates.

Fig. 5.14. Ascospores delineated by an outer membrane (arrows). Bar = 1 µm.

Fig. 5.15. Liberated ascospores showing the mature ascospore wall composed of an electron light inner layer (white arrow) and an electron dense outer layer (black arrow). The outer layer is osmiophilic, indicating the presence of lipids. Bar = 1 µm.

Fig. 5.16. Long section through a developing peridial plate. The plate increases in size by tip growth and branching (white arrows). Interdigital growth (black arrow) is visible between opposing plates. Bar = 10 µm.

Fig. 5.17. Hyphae of the peridial plates are vacuolated at maturity (*). Pronounced thickenings form a banding pattern visible along the inner wall surface (arrow). Bar = 1 µm.

Fig. 5.18. Immature cleistothecium bearing mucilaginous layer. Bar = 10 µm.

Fig. 5.19. Dehiscence line (black arrow) equidistant from the points of origin of individual plates (white arrows) in immature cleistothecium visible through ruptured mucilagenous layer. Bar = 10µm.


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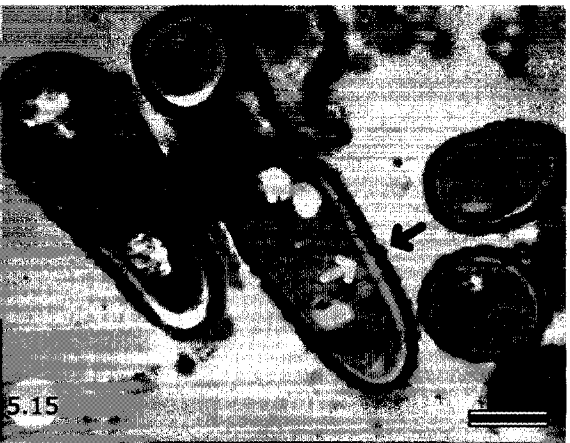
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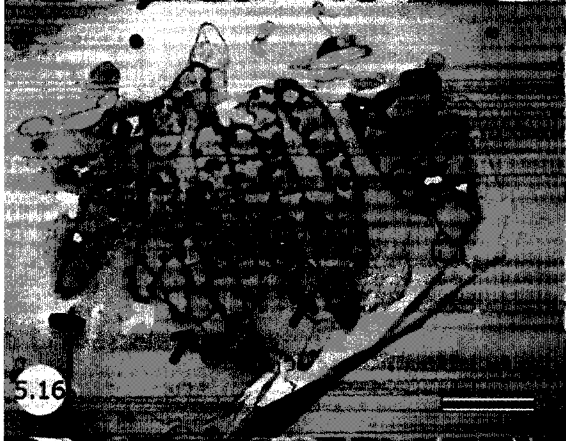
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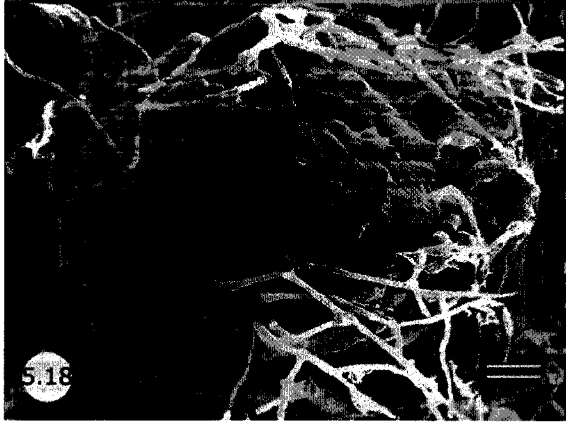
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Figs. 5.20-5.25. Opening of cleistothecium.

Fig. 5.20. Close up view of dehiscence line (arrow). Dehiscence line is visible as a transverse groove perpendicular to the direction of growth of the peridial cells. Bar = 2 µm.

Fig. 5.21. Dehiscence lines delineating peridial plates. Bar = 10 µm.

Fig. 5.22. TEM of dehiscence line. Cells are thin walled (white arrow) and rupturing occurs across mid-region of dehiscence cells (black arrow). Bar = 10 µm.

Fig. 5.23. End view of peridial plate after dehiscence. Dehiscence lines are only 1-2 cell layers thick. Bar = 2 µm.

Fig. 5.24. Opened cleistothecium. The peridium is composed of 6 to 8 well defined plates each 3-4 cells thick. Desiccation has caused the peridial plates to flatten and evert, rupturing the cleistothecium along the dehiscence lines. The outer mucilaginous layer is no longer present. Bar = 20 µm.

Fig. 5.25. Opened cleistothecium with a mass of ascospores at the bottom. Bar = 20 µm.

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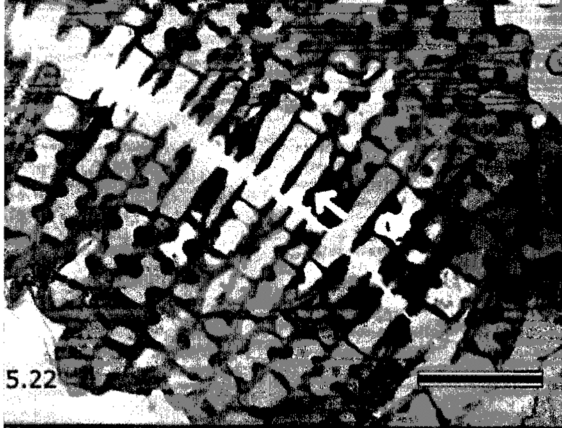

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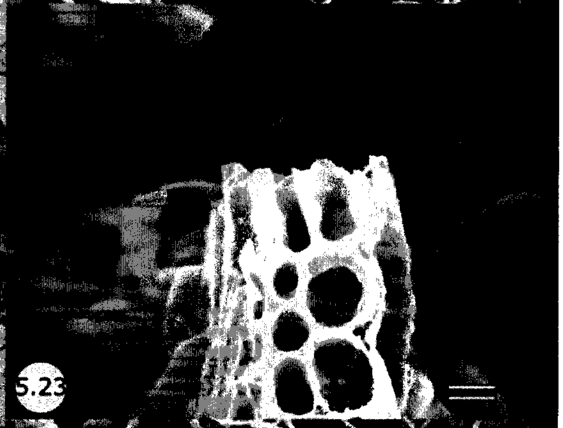

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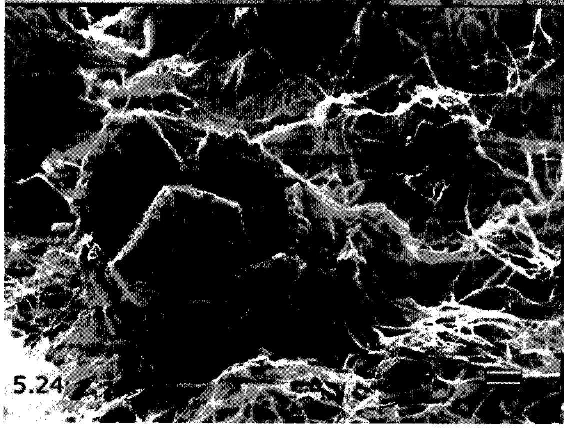

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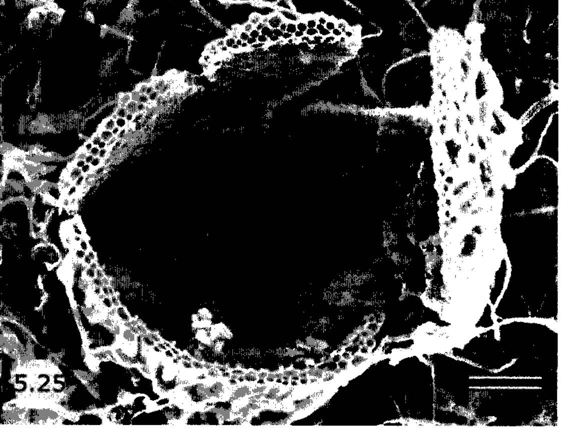

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Chapter 6

Development and dehiscence of the cephalothecoid peridium in *Aporothielavia leptoderma* and a proposal to transfer the species to *Chaetomidium*[1].

INTRODUCTION:

Aporothielavia leptoderma (Booth) Malloch and Cain is a cleistothecial fungus in the *Chaetomiaceae* (Huhndorf et al. 2004) and, like several morphologically similar species in the genus *Chaetomidium*, has a cephalothecoid peridium. This species, known only on the basis of isolates obtained from soil collected in the United Kingdom (Booth 1961), was first placed in *Thielavia* Zopf., and later made the type of *Aporothielavia*, a taxon erected to accommodate fungi resembling *Thielavia* but having ascospores without germ pores (Malloch and Cain 1973).

The cephalothecoid peridium has arisen independently in several lineages of ascomycetes (Suh and Blackwell 1999) and ostensibly is an adaptation that facilitates the dispersal of meiospores in these cleistothecial taxa (Hawksworth and Booth 1974) although there are few data supporting this hypothesis. Cephalothecoid peridia consist of discrete plates made up of hyphae that radiate from a central point. Adjacent plates are able to separate at maturity. In some species (e.g., *Cryptendoxyla hypophloia* Malloch and Cain and *Batistia annulipes* (Mont.) Ciferri) plates actively disarticulate (Malloch and Cain 1970, Samuels and Rodrigues 1989, Greif *et al.* 2004) and in others (e.g., *Chaetomidium arxii* Benny) some putative external disruptive force is required to break apart the peridium along lines of weakness between plates and expose the ascospores (Benny, Samuelson and Kimbrough 1980). Booth's original description of *Thielavia leptodermus* (Booth 1961) included the observation that the cephalothecoid plates developed through a meristematic process in which the radiating cells in each plate arose from a central core of actively dividing cells, but he was unable to identify the suture lines (boundaries between meristematically expanding plates) that would accompany this process. Observations of cephalothecoid plate development in another sordariaceous

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Greif M and Currah RS 2006 Development and dehiscence of the cephalothecoid peridium in *Aporothielavia leptoderma* and a proposal to transfer the species to *Chaetomidium*. Mycological Research (Submitted March 2 2006; ref # Mycres-D-0600050)

species, i.e. *C. hypophloia* (Greif et al. 2004), suggest that meristematic growth is probably not a plausible explanation for plate ontogeny in *A. leptoderma* and that the suture lines Booth (1961) was unable to find would more likely be present as lines of weakness across hyphae rather than as abutments between plates.

Given the lack of definitive information on the structure and dehiscence of the cephalothecoid peridium of *A. leptoderma*, I studied the development of its cleistothecium using a combination of scanning electron, transmission electron, and light microscopy. I also tested the hypothesis that the cephalothecoid peridium is an adaptation for arthropod disruption of the peridium by observing, *in vitro*, the physical effects of visitation by three types of insects. My objectives were to determine the developmental sequence underlying the formation and disarticulation of the cephalothecoid plates in this species and to re-examine the morphological characteristics of *A. leptoderma* that would support maintaining *Aporothielavia* as a distinct and monotypic taxon.

MATERIALS AND METHODS:

Aporothielavia leptoderma (CBS 538.74, ex type) was grown at room temp and under ambient light conditions on corn meal agar (CMA, 17g Acumedia^{tm} corn meal media (Neogen Corp., Lansing, MI) and 1 l dH_20). Light (LM), and both scanning (SEM) and transmission electron (TEM) microscopy were used to follow the development of the cleistothecia.

For LM, material was stained with 1% lactofuchsin. For SEM, 5 mm disks of agar bearing immature and mature cleistothecia were fixed in buffered 2% glutaraldehyde for 4 hours, placed in phosphate buffer overnight at 5°C, and post-fixed in 2% OsO_4 for four hours at room temperature. Fixed material was dehydrated in an ethanol series, critical-point dried in a SeeVac dryer (SeeVac Inc., Hialeah, Florida) using carbon dioxide and then coated with gold using an Edwards S150 B gold coater and examined under a Hitachi S-2500 scanning electron microscope.

For TEM, samples were fixed in 2% glutaraldehyde for 5 hours at room temperature, washed three times with phosphate buffer, and post fixed in buffered 2% OsO_4 for 5 hours at room temperature. Blocks were put through a dehydration series in ethanol. At 75% ethanol 2% uranyl acetate was added for four hours at room temperature, after which the dehydration to 100% ethanol was continued. Dehydrated material was embedded in Spurr's resin, sectioned, and stained with 2% uranyl acetate and lead citrate. Sections placed on copper grids coated with formvar (3% w/v polyvinyl formaldehyde in ethylene dichloride) were viewed under a Hitachi H-7000 transmission electron microscope. Some sections prepared for TEM were heat fixed onto glass slides, stained with 1% toluidine blue, and viewed by LM.

To assess the validity of the supposition that arthropods play a role in cephalothecoid peridium disruption, dried ascomata were enclosed for 24 hours with each of three types of insect: fruit flies (*Drosophila melanogaster* Meigen, 3-4 mm in length), carpenter ants (*Camponotus nearcticus* Emery, 7-10 mm in length), and darkling beetles (*Upis ceramboides* Linnaeus, 17-19 mm in length). One insect was added to a single Petri plate containing 1 cm^2 of CMA on which mature ascomata had developed. Ten replicates each were made for the flies and ants, and three for the beetles. Interactions between ascomata and insects were examined periodically over a 24-hour period using the dissecting microscope. Following this, the plates were frozen (to kill the insects) and the ascomata examined for evidence of disarticulation.

RESULTS:

On CMA, colony diameter reached 52 mm after 7 days at room temp. Vegetative hyphae were hyaline, 1-2.4 μm wide, thin-walled and sparse. Cleistothecia appeared on and below the surface of the agar after approximately three weeks. Cleistothecia were initially hyaline, and when mature, 96-260 μm in diameter with dark brown peridia (Fig. 6.1).

Ascocarp initiation was preceded by the formation of a loose hyphal coil (2-4 μm across) that swelled to form a knot-like primordium 4-5 um in diameter (Fig. 6.2). Hyphae arising as branches from the base of the primordium, and originating from underlying or adjacent vegetative mycelium, grew over the surface of the primordium, elongated and branched repeatedly to form a structure resembling initially a ball of twine (Fig. 6.3-6.5). The peridium later arose through the coalescence of the outer layers of branched and interwoven hyphae. A thin mucilaginous layer enveloped the primordium through early stages of development (Fig. 6.4). Some branches arising from hyphae in the outer layer, instead of recurving over the surface of the developing cleistothecium, elongated and grew outwards to form the characteristic unbranched appendages (Fig. 6.6-6.7).

Thin sections of immature cleistothecia showed that the hyphae of the developing peridial layers were regularly septate and closely packed to form a tissue composed of 4-7 layers of roughly polygonal cells (Fig. 6.8-6.9). Cells of the outermost layer or two were thick-walled, angular in face view, and those of the underlying layers were thin-walled (Fig. 6.8). Within the centrum, eight-spored asci, 17-24 µm x 12-14.4 µm, each with a prominent stipe, developed asynchronously and were ovoid to clavate before the ascus wall evanesced (Fig. 6.10-6.11).

As the cleistothecia matured and increased in size, many of the angular cells making up the distinctive *textura angularis* of the outer layer of the peridium (Fig. 6.12) elongated to form a more or less regular series of rosette-like clusters, each of which had 5-12, radially disposed, hyphal segments or cells surrounding a central polygonal cell or cluster of polygonal cells (Fig. 6.12-6.15). Some radial cells from adjacent rosettes interdigitated as they elongated (Fig. 6.14). As maturation proceeded, the external flank along median portions of the radial cells became thin-walled and swelled outwards so that each plate became concave and was separated from adjacent plates by a more or less circular to polygonal ridge of knuckle-shaped swellings (Fig. 6.16). Each swelling was crowned with a knob-like protrusion that, in some instances, elongated to form a short hypha, 4-6 x 2 µm (Fig. 6.17-6.18). This pattern of elongation and swelling in the radially oriented cells created a contiguous series of concavities (each representing an incipient plate) over the surface of the cleistothecium (Fig. 6.18). TEM showed that the radially oriented cells contained cytoplasm at late ontogenetic stages and had a markedly thinner wall along the outer flank of the swollen area (Fig. 6.19).

Branches emerging from the outer flank of the elongated, knuckle-shaped peridial cells were fragile and broke away easily when specimens were manipulated (Fig. 6.20). When dry, the concave, rosette-like plates of the peridium disarticulated readily when touched with a probe, splitting apart across the thin-walled region of adjacent radial cells (Fig. 6.21-6.22). Appendages, arising singly from the center of some cephalothecoid plates, were smooth and thick-walled, septate, straight to wavy or slightly helical, 220-

400 µm x 2-2.8 µm, (3.3-5.8 µm at the base) (Fig. 6.23) and appeared early in the developmental sequence. These structures were sparse, with only four to eight visible on mature ascomata (Figs. 6.1, 6.23). At maturity, ascospores were ellipsoidal to slightly asymmetrical, dark brown to black, thick-walled, and 14.4-16.3 µm x 5.5-7.2 µm (Fig. 6.24-6.26); they germinated readily, producing a germ tube from a distinct apical germ pore (Fig. 6.25-6.26).

All three types of insects made direct contact with cleistothecia, either by touching or pushing against them with their legs or abdomen, or by walking over them. Cleistothecial appendages did not become entangled in the hairs, legs or antennae of the insects. Cleistothecia enclosed with the beetles were broken apart within 15 minutes through contact with either legs or abdomen, and peridial fragments were strewn across the surface of the agar (Fig. 6.27). Neither the flies nor the ants caused the peridium to disarticulate.

DISCUSSION:

My observations of the early stages of ascoma development in *Aporothielavia leptoderma* agree with observations reported briefly in Malloch and Cain (1973) and generally with reports describing the origin of initials and subsequent enveloping hyphae in other *Chaetomiaceae* (see Figueras and Guarro 1988). A knot-like primordium forms first and is then enveloped by branching and elongating hyphae that arise from its base and from underlying or adjacent vegetative mycelium. As the developing ascoma increases in size, the outer layers coalesce to produce a cohesive tissue of closely packed, septate hyphae that form a *textura angularis* that persists through to maturity in ostiolate species. Peridial hairs, characteristic of many *Chaetomiaceae*, differentiate early in this process. Ascal development was also similar to other cleistothecial *Chaetomiaceae* where asci develop asynchronously and deliquesce to release the ascospores.

The development of *Aporothielavia leptoderma* differs from most other *Chaetomiaceae* because the *textura angularis* differentiates to form a series of rosette-like clusters of radially oriented hyphal segments or cells that elongate and interdigitate with the hyphal segments of adjacent clusters to form a series of cephalothecoid plates. Cell elongation, rather than meristematic growth, was implicated in the development of the cephalothecoid plates of *Cryptendoxyla hypophloia* (Greif et al. 2004). This observation, however, disagrees with Booth's (1961) proposal that meristematic growth from a central cell or cell cluster produces the distinctive radial pattern exhibited by the cephalothecoid plates in this species, and is inconsistent with similar accounts of plate development for other species, i.e. *Cephalotheca sulfurea* Fuckel and *Fragosphaeria purpurea* Shear (Chesters 1934).

Booth (1961) reported that dehiscence lines ("sutures") were not present in the peridium of *A. leptoderma* but may have been looking for the appressed borders between meristematic plates, such as those described by Chesters (1934) in *Cephalotheca sulfurea.* When cleistothecia are mature, dehiscence lines are clearly present in the peridium of *A. leptoderma* but these form as a result of thinning of the walls of inflated, radiating cells of individual rosettes making up the cephalothecoid plates rather than as a consequence of the separation of abutted adjacent plates. Each inflated cell, which contains cytoplasm and is living even during later stages in peridium ontogeny, appears to be initiating a lateral branch but this aborts as the cell matures or, in some cases, extends to 4-6 µm. In mature cleistothecia many of these short branches detached during specimen preparation, resulting in a row of perforations indicating the position of the incipient dehiscence lines. During drying or when physically disrupted, the peridium of *A. leptoderma* breaks into irregular sections, each comprising one or more plates, along these lines of weakness so that the dehiscing peridium looks torn or cracked.

An active peridial dehiscence mechanism, as found in the somewhat similar cleistothecial species, *Cryptendoxyla hypophloia*, is not present in *A. leptoderma*. In *C. hypophloia*, the hyphal segments making up the outer layer of the peridium have annular thickenings that allow the hyphae to contract. Contraction causes the peridial plates to recurve and split apart when the mature ascomata dry out, effectively exposing the ascospores. This process is reversible because an increase in humidity causes the plates to return to their original shape and, as a result, the ascoma closes (Greif et al. 2004). The plates and retractable hyphal segments in *C. hypophloia* do not originate as radiating clusters in a *textura angularis*. In addition, they differentiate much earlier during ascoma development than the plates of *A. leptoderma*. Even though both of these cephalothecoid taxa are in the *Sordariomycetidae* (Huhndorf et al. 2004), differences in morphology and development strongly suggest that the plates making up the peridia of *C. hypophloia* and *A. leptoderma* arose independently in this lineage. This hypothesis is further supported by phylogenetic comparisons based on LSU and SSU rDNA (Suh and Blackwell 1999, Huhndorf et al. 2004).

Benny et al. (1980) speculated that the mature cleistothecia of *Chaetomidium arxii*, which are morphologically similar to *A. leptoderma*, could be torn open easily by "passing objects", presumably microfauna, getting entangled in the peridial appendages and causing the peridium to come apart along the dehiscence lines. There are fewer peridial appendages in *A. leptoderma* compared to *C. arxii,* but the role these played in dehiscence when mature cleistothecia were enclosed with insects was negligible. My results suggest that dehiscence was dependent more on the size of the insect making contact with the peridium than interactions of the appendages with the animals. The larger-bodied beetles were able to break open the cleistothecia but the smaller insects had no effect; this suggests that in nature visitation by relatively large arthropods, such as various *Coleoptera*, could be an important initial stage in ascospore liberation.

Dispersal of ascospores may also occur through contact with arthropods, although it is also possible that dispersal by abiotic agents such as wind or water may occur. To my knowledge *A. leptoderma* is known only from Booth's (1961) original collection of isolates from soil in the UK, and as a result, the substrate or habitat preferences of this species are unknown. Other cephalothecoid taxa such as species of *Cryptendoxyla* and *Cephalotheca* have been found in habitats protected from wind and rain and would need some type of animate dispersal vector to move propagules from one site to the next (Chesters 1934, Malloch and Cain 1970). A prediction of this sort for *Cryptendoxyla hypophloia* was recently supported by Greif et al. (2004) who isolated *C. hypophloia* from live trapped insects.

The pattern of peridial development in *A. leptoderma* shares many similarities with *Chaetomidium arxii,* the first cephalothecoid species studied using ultra-structural techniques (Benny et al. 1980). In both species, the peridium is made up of plates which have swollen, elongate cells radiating from a central cell or cell cluster, and similar lines of weakness that develop across them that allow the peridium to rupture. Ascospores in both are single-celled, dematiaceous, and possess a single apical or subapical germ pore

(Benny et al. 1980). *A. leptoderma* and *C. arxii* are morphologically closely related species and apparently congeneric although they do differ in some respects; the appendages of *A. leptoderma*, at 220-400 µm, are shorter and less numerous (4-8 per ascoma) that those of *C. arxii* which has more than twenty, each of which is generally longer than 380 µm. The ascospores are also similar although narrower in *A. leptoderma* at 14.4-16.3 µm x 5.5-7.2 µm compared to 10.7-19.1 x 7.6-12.7 µm in *C. arxii* (Benny 1980).

Malloch and Cain (1973) erected *Aporothielavia* for *T. leptodermus* because they did not see the germ pores that were a consistent feature in other species of *Thielavia*. In a subsequent revision of *Thielavia*, Von Arx (1975) moved species with non-ostiolate ascomata bearing straight to wavy appendages, and having clavate/stipitate evanescent asci, and single celled, brown ascospores with a single germ pore, to *Chaetomidium* but did not, or neglected to argue for the transfer of *A. leptoderma* to this genus. Eleven species are currently accommodated in *Chaetomidium* and five of these have cephalothecoid peridia (*C. arxii, C. cephalothecoides* (Malloch and Benny) Von Arx, *C. galaicum* Stchigel and Guarro, *C. khodense* Cano, Guarro, and El Shafie, and *C. megasporum* Doveri, Guarro, Cacialli, and Caroti) (Malloch and Benny 1973, Benny 1980, Cano et al. 1993, Silva and Hanlin 1996, Guarro et al. 1997, Doveri et al. 1998, Stchigel et al. 2004). Molecular studies using the LSU rDNA show some affinity between *A. leptoderma* and *C. cephalothecoides* (as *Thielavia cephalothecoides*) (Untereiner et al. 2001, Huhndorf et al. 2004, Miller and Huhndorf 2004) and that their closest relatives are at least among the *Chaetomiaceae*. It is unclear if the cephalothecoid species of *Chaetomidium* share a recent common ancestor or if this peridial type has arisen independently several times in the lineage. The widespread occurrence of cephalothecoid peridia in taxonomically distant groups of ascomycetes suggests that caution should be used in the interpretation of its phylogenetic significance (Malloch and Cain 1970, Suh and Blackwell 1999). However, it seems superfluous to continue to maintain *Aporothielavia* as a distinct, monotypic taxon given the unarguable presence of a germ pore in its ascospores and its morphological similarity to *Chaetomidium arxii* and other cephalothecoid species in that genus. I therefore propose the following new combination as a more appropriate name.

Chaetomidium leptodermum (Booth) Greif and Currah, comb. nov.

≡ *Aporothielavia leptoderma* (Booth) Malloch and Cain, Mycologia 65:1074. 1973.

≡ *Thielavia leptodermus* Booth, Mycological Papers, No. 83:3. 1961.

Figs. 6.1.-6.11. Stages in cleistothecium development in *Aporothielavia leptoderma.*

Fig. 6.1. Culture on corn meal agar after 30 days showing mature, black, globose cleistothecia and smaller, pale, immature cleistothecia (arrow) (Stereomicroscope). Bar = 200 µm.

Fig. 6.2. A knot-like primordium developing from a vegetative hypha (SEM). Bar = 3 µm

Fig. 6.3. A primordium enlarging through branching and elongation of appressed hyphae (*) (SEM). Bar = 5 µm.

Fig. 6.4. Hyphae arising from base of the primordium (*) and from nearby vegetative hyphae contribute to the enlarging primordium: A thin mucilaginous layer coats the young primordium (SEM). Bar = 15 µm.

Fig. 6.5. Outer layers of hyphae branch and elongate so that the young ascoma resembles a ball of twine (SEM). Bar = 6 µm.

Fig. 6.6. Some branches extend laterally to form peridial appendages (arrow) (SEM). Bar = 12 µm.

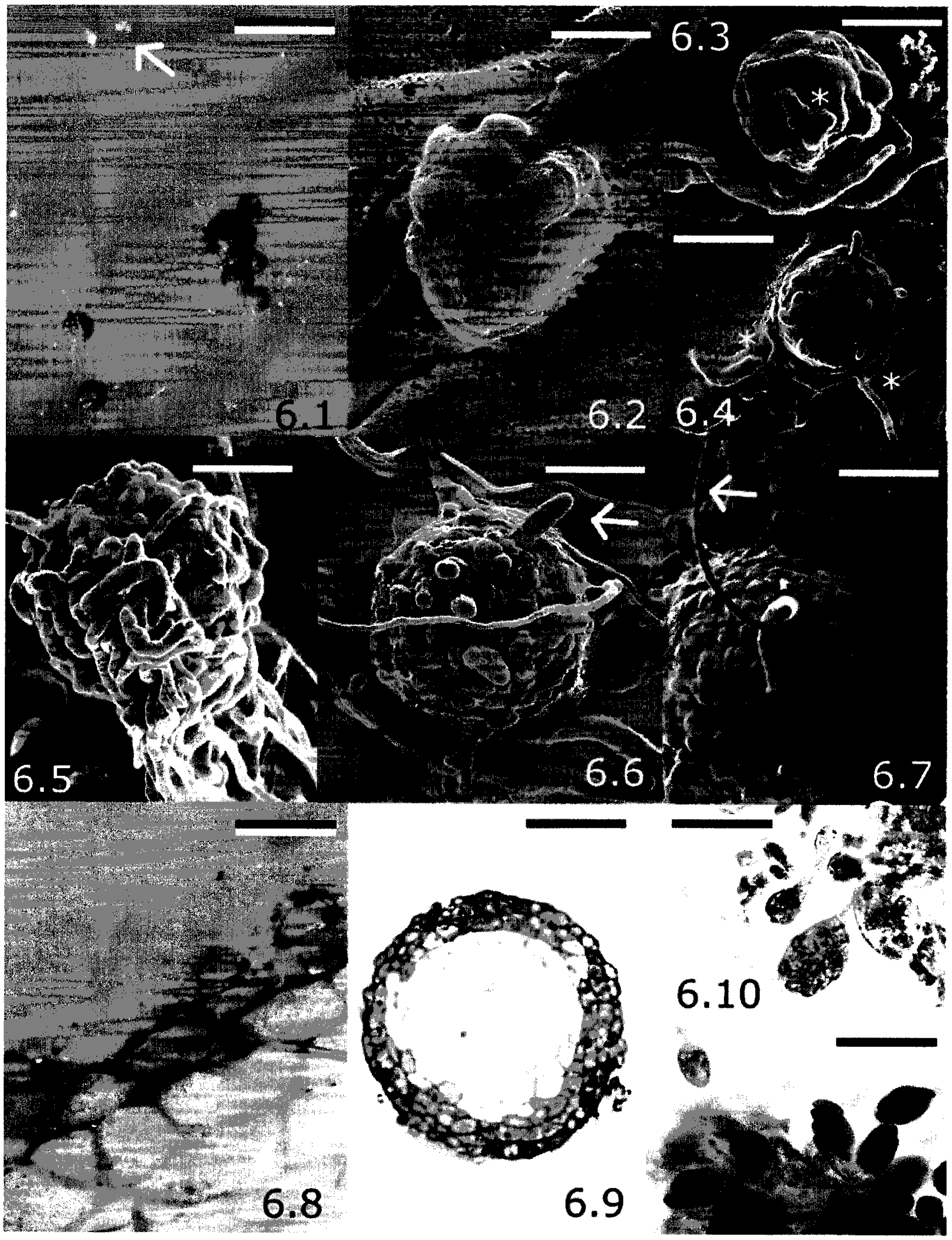
Fig. 6.7. An immature, globose, cleistothecium with a peridium composed of tightly packed, polygonal cells and an elongated appendage (arrow) (SEM). Bar = 38 µm.

Fig. 6.8. A section of a developing cleistothecium showing that the peridium is composed of regularly septate hyphae. Hyphae of the outer layer have thick, electron-dense dark walls; those of the inner layer have thin, electron-light walls (TEM). Bar = 8 µm.

Fig. 6.9. Cross section of the cleistothecium showing a branching hypha in the developing peridium (LM). Bar = 40 µm.

Fig. 6.10. Ascus development is asynchronous (LM). Bar = 20µm.

Fig. 6.11. Maturing, broadly clavate asci with prominent stipes each containing eight, pigmented single-celled ascospores (LM). Bar = 25 µm.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Figs. 6.12.-6.19. Stages in the development and maturation of the peridium of *Aporothielavia leptoderma.*

Fig. 6.12. The peridium forms a *textura angularis* when the cleistothecium is young but cells continue to elongate as the ascoma matures (SEM). Bar = 20 µm.

Fig. 6.13. As peridial cells elongate, peridial plates become recognizable (*) (SEM). Bar = 20 µm.

Fig. 6.14. Some opposing peridial cells from adjacent cephalothecoid plates interdigitate as they elongate (arrow) (SEM). Thinning in the cell wall, in the medial region of the elongating cells, indicates the location of the developing dehiscence line (SEM). Bar = 14 µm.

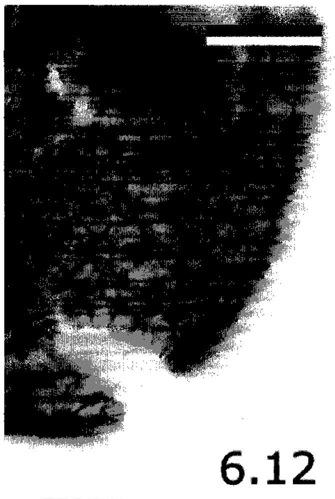
Fig. 6.15. Fully elongated peridial cells form rosette-like clusters with a cell or group of cells at their centre (*) (SEM). Bar = 20 µm.

Fig. 6.16. Elongating peridial cells beginning to form swollen, knuckle-shaped ridges (arrow) (SEM). Bar = 15 µm.

Fig. 6.17. Ridges between mature plates are pronounced and crowned with small knob-like protrusions (arrow) (SEM). Bar = 4.5 µm.

Fig. 6.18. In mature peridia, some of these knob-like protrusions continue to develop into short branches. Elongation and swelling of the radially oriented cells create a contiguous series of concavities, each representing an incipient plate (SEM). Bar = 36 µm.

Fig. 6.19. A section though a radially oriented, elongated cell shows that it contains cytoplasm and has a markedly thinner wall where the peak of the swollen region develops (arrow). Thin-walled areas of adjacent cells delineate the dehiscence line (TEM). Bar = 2 µm.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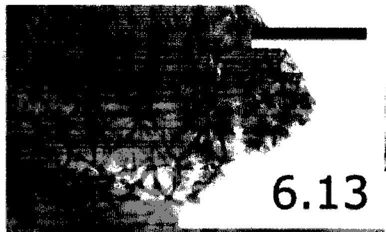
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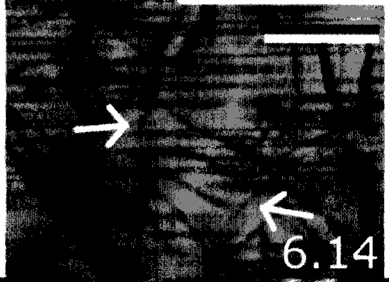
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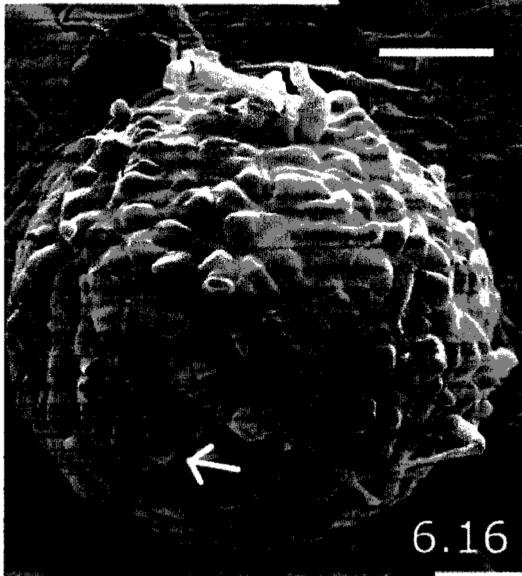
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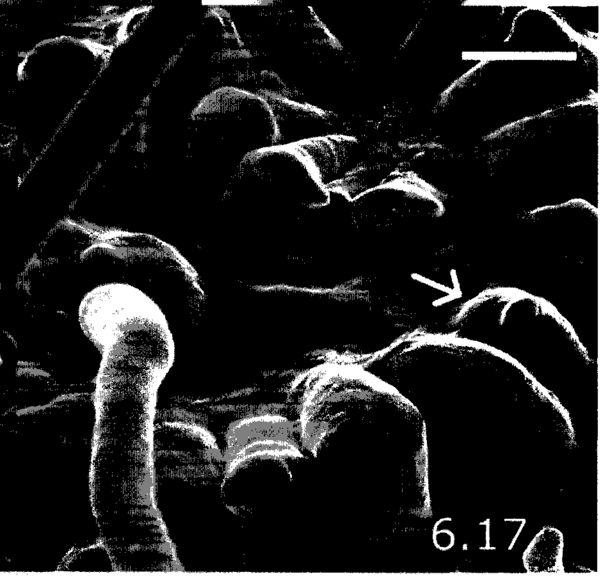
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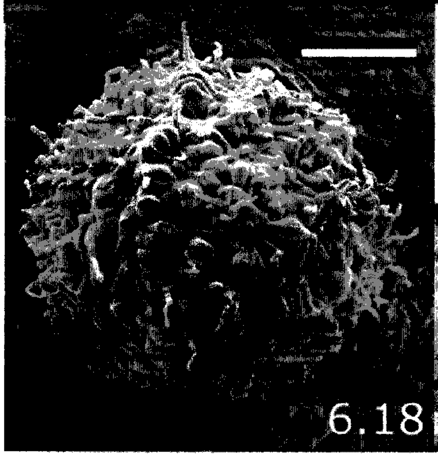
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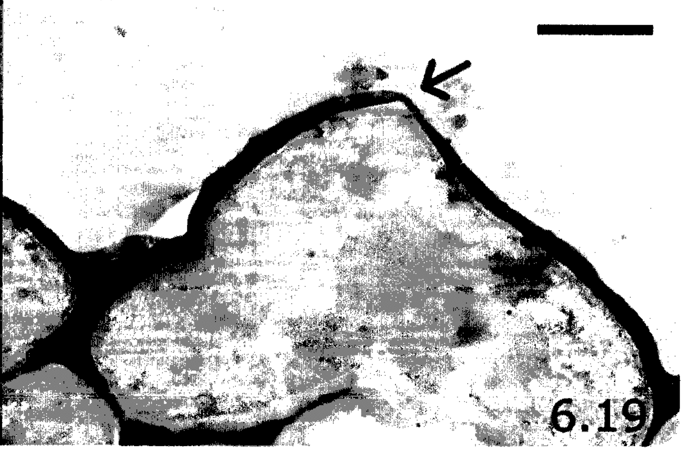
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Figs. 6.20.-6.27. Structure and dehiscence of the mature cleistothecium in *Aporothielavia leptoderma.*

Fig. 6.20. In mature peridia many of the short hyphae emerging from the elongated, knuckle-shaped peridial cells detach during fixation, leaving a series of perforations running along the dehiscence line (SEM). Bar = 3 µm.

Fig. 6.21. Dehiscence lines, located at the apex of the knuckle-shaped cells, begin to rupture as the peridium dries (arrow) (SEM). Bar = 12 µm.

Fig. 6.22. Close-up of a completely ruptured dehiscence line. Desiccation can cause the peridial plates to disarticulate from each other (SEM). Bar = 4.5 µm.

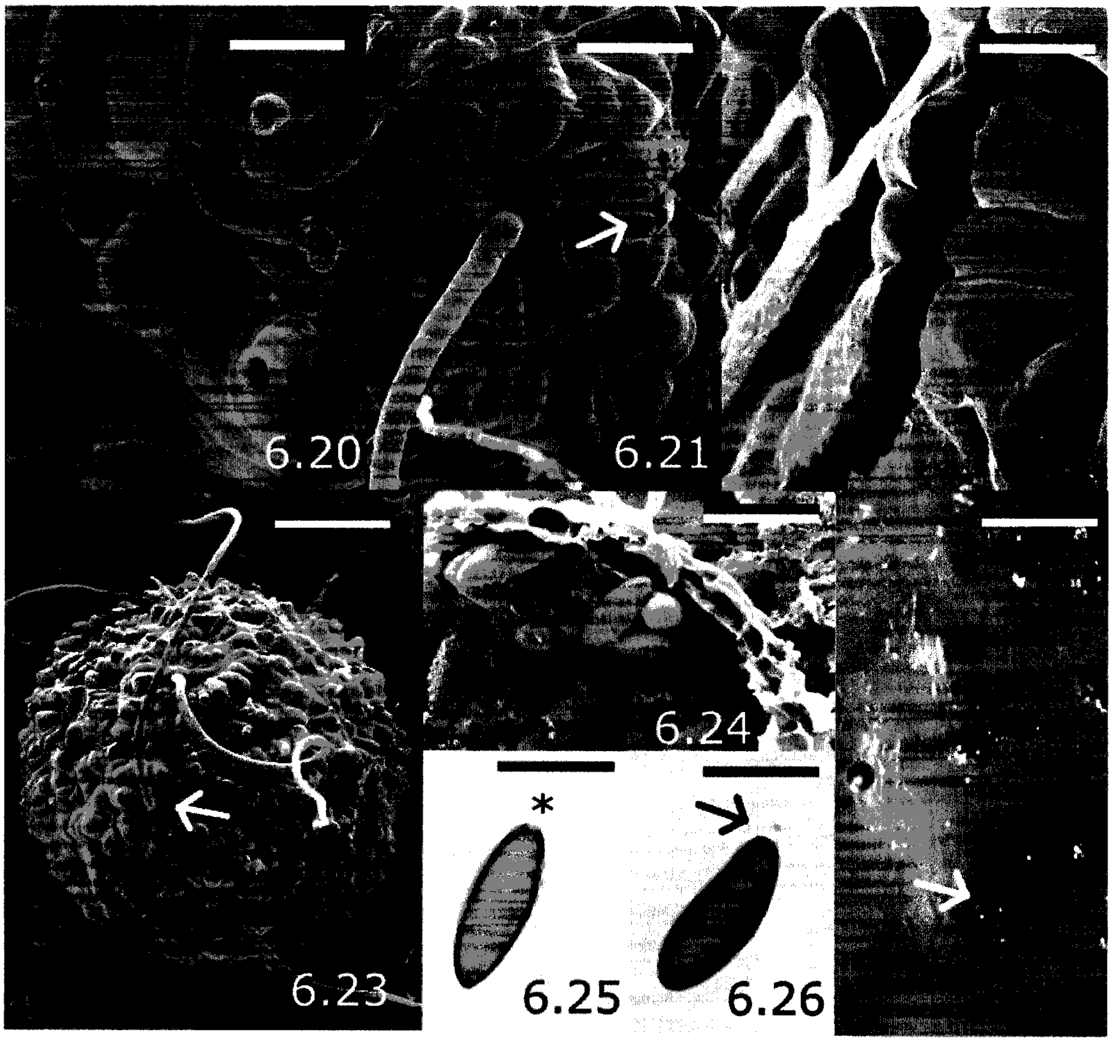
Fig. 6.23. A mature cleistothecium. The ridges across the medial portion of elongated cells are pronounced and delineate the cephalothecoid plates. A small number of plates have smooth-walled peridial appendages arising from their centre (arrow) (SEM). Bar = 30 µm.

Fig. 6.24. A peridium ruptured with a probe and containing mature ascospores. Asci have evanesced (SEM). Bar = 12.5 µm.

Fig. 6.25. A mature, single celled pigmented ascospore with an apical germ pore (*) (LM). Bar = 10 µm.

Fig. 6.26. A germinating ascospore. Arrow indicates emerging hyphal tip (LM). Bar = 10 µm.

Fig. 6.27. Ascomata after exposure to darkling beetles for 15 minutes. Cleistothecia have been torn open (*) and liberated peridial plates are strewn across the agar (arrow) (Stereomicroscope). Bar = 550 µm.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Chapter 7

Morphology and development of *Catinella olivacea*: an apothecioid loculoascomycete[1].

INTRODUCTION:

Catinella olivacea (Batsch) Boudier produces clusters of distinctive, flattened, dark olivaceous apothecia, up to 1.5 cm across, with a vertically furrowed, ochraceous margin (Boudier 1907, Breitenbach and Kränzlin 1981, Spooner and Legon 1999). The fungus is easily identified and probably common but reports are infrequent because apothecia are usually found only on the underside of moist, well-decayed logs of hardwood species, or in places where the wood is covered by moss or soil (Pomerleau 1980, Strödel 1984, Keizer 1990, Spooner and Legon 1999). The forcibly ejected ascospores of apothecial fungi are generally assumed to be dispersed by wind, but air movement in these cryptic and protected habitats would be minimal and probably insufficient to transfer propagules of *C. olivacea* to new habitats. Some reliance on microfaunal cohabitants might explain how the fungus is dispersed from one rotting log to the next, but adaptations for this type of dispersal strategy are not evident in published descriptions of this species.

Boudier (1907) erected the genus *Catinella* to accommodate *Peziza olivacea* Batsch and, since then, its identity and taxonomic position have been the subject of some disagreement. The asci of *C. olivacea* appear inoperculate and each contains a uniseriate file of eight, darkly pigmented, one-celled ascospores. The hymenium is supported within a blackish-olive, discoid receptacle that has an excipulum of large, thin-walled, deeply pigmented, subangular to globose cells. These characteristics, plus an ionomidotic reaction (dark brown-purple colour change) of the excipular tissues in KOH and ascal tips that do not stain blue in iodine, supported its disposition in the Dermateaceae, a family in the Helotiales having darkly pigmented apothecia (Durand 1922, Seaver 1961, Korf 1973, Nannfeldt 1932 in Dennis 1977, Eriksson et al. 2004). It has also been

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[1] A version of this chapter has been submitted as:

Greif MD, CFC Gibas, A Tsuneda and RS Currah 2006 Ascoma development and phylogeny of an apothecioid dothideomycete, *Catinella olivacea*. American Journal of Botany (Submitted April 24 2006; ref # 2006-235) suggested that the taxon might be more appropriately disposed in the Leotiaceae, also a member of the Helotiales (Spooner and Legon 1999), presumably because of the presence of a gelatinous layer that overlies the hymenium. Clements and Shear (1931) list the taxon as a synonym of the genus *Karschia* Körb., an genus with similar, darkly pigmented ascomata, septate ascospores and having uncertain affinities within the Dothideomycetes (Eriksson et al. 2004). The discoid ascomata, i.e., apothecia, of the Helotiales, an order accommodated in the Leotiomycetes (Eriksson et al. 2004), and the apothecioid ascostromata of some taxa (e.g. Patellariales) in the Dothideomycetes can be superficially similar to each other but exhibit a fundamentally different pattern of development (Korf 1973, Kutorga and Hawksworth 1997). However, *C. olivacea* is apparently known only from specimens collected in natural habitats, i.e., it has never been cultured, and there are no detailed reports of the developmental characteristics that would contribute to a clarification of its taxonomic position or provide some understanding of its reproductive strategies.

Recent collections of *C. olivacea* found growing within cavities inside moist, decaying aspen logs allowed me to prepare cultures that I used to make a detailed study of the development of the ascomata of this species and that served as a source of DNA for the examination of its phylogenetic affinities within the Ascomycota. My objectives were to clarify the taxonomic position of *C. olivacea* and to find evidence that might support my hypothesis that the species is dispersed from its cryptic environments by microfauna.

MATERIALS AND METHODS:

Mature ascomata of *Catinella olivacea* were collected in July 2003 and September 2005 from wet, rotting logs of *Populus tremuloides* Michx. (aspen), 2 km east of Elk Island National Park, in the southern boreal forest region of central Alberta. Pure cultures were prepared by germinating ascospores on malt extract agar (MEA, 15g/L sterile distilled water Difco™ malt extract, BD Biosciences, Mississauga, Ontario, Canada) and corn meal agar (CMA, 17g/L sterile distilled water Acumedia™ corn meal medium, Neogen Corp., Lansing, Michigan, USA). Blocks of aspen wood, 5 x 5 x 2 cm, sterilized by autoclaving twice, were inoculated with mycelia from pure culture and incubated in Pyrex deep culture plates (containing sterilized perlite covered with a sheet of filter paper) under ambient light and temperature on the laboratory bench or under black light with a 12 h light:dark photoperiod, and monitored weekly for ascomata formation. Material was moistened monthly with sterile water. MEA and CMA plates were incubated at room temperature and observed daily to record cultural characteristics. Cultures on MEA were deposited in the University of Alberta Microfungus Collection and Herbarium (UAMH 10679). For observation under a light microscope (LM), fungal material (i.e., germinating ascospores, young ascomata, and sections of mature ascomata cut by hand with a razor blade) were mounted in lacto-fuchsin (0.1 g acid fuchsin in 100 mL 85% lactic acid), or were pre-treated in 10% KOH and mounted in Melzer's reagent for observation and imaging using a Canon "powershot" A75 digital camera (Canon Canada Inc., Mississauga, Ontario, Canada).

For observation under a scanning electron microscope (SEM), ascomata at various developmental stages on agar media and on wood blocks were excised, placed in phosphate buffer (pH 7.0), and fixed in glutaraldehyde in buffer for 2 h. Samples were rinsed in buffer and immersed in 2% tannic acid - 2% guanidine hydrochloride solution for 3 h. Some ascomata at this stage in fixation were sectioned with a razor blade. All fungal material (sectioned and unsectioned) was rinsed in distilled water and post-fixed in 2% OsO_4 for 12 h at 5°C. Fixed material was dehydrated in an ethanol series, taken to amyl acetate, and critical point dried in a Polaron E-3000 dryer using carbon dioxide. Dried samples were coated with gold and examined using a Hitachi S-510 scanning electron microscope.

DNA sequences for the small subunit of the nuclear ribosomal DNA region (SSU) were obtained from mature ascomata. DNA extraction was done following the method described by Cubero et al. (1999) with some modification. Approximately 100 mg of fungal tissue was ground in 2X CTAB extraction buffer (10% CTAB, NaCl, 0.25 M EDTA, 1 M Tris-HCl pH 8.0, 2% PVP, and dH_2O). After incubation for 3 h at 65°C, genomic DNA was extracted using a chloroform:isoamyl alcohol (24:1 v/v) solution. Crude DNA was purified using a QIAquick DNA purification kit (Qiagen Inc., Mississauga, Ontario, Canada). Amplification of the SSU region was done using the primers NS1 and NS8 (White et al. 1990). PCR was run for 30 cycles in a PE GeneAmp

9700 thermal cycler (Applied Biosystems, Foster City, California, USA) set to the following parameters: denaturation at 94°C for 1 min, annealing at 55°C for 1 min, extension at 72°C for 2 min, then final extension at 74°C for 7 min followed by a cool down stage at 4°C for 10 min. The amplicon was purified using the QIAquick DNA purification kit and DNA concentration was determined using the Nanodrop ND-1000 (Nanodrop Technologies, Wilmington, Delaware, USA). Cycle sequencing was done using primers NS1, NS2, NS3, NS4, NS6, NS7 and NS8 (White et al., 1990) and BigDye terminator cycle sequencing kit (Applied Biosystems, Foster City, California, USA). The amplicons were run on an ABI 377 automated DNA sequencer (Amersham Pharmacia Biotech Inc., Piscataway, New Jersey, USA). A consensus sequence was constructed and edited using Sequencher version 4.0.2 (Gene Codes Corp., Ann Arbor, Michigan, USA). The newly determined sequence, 1700 bp in length, was then subjected to a BLAST search (Altschul et al. 1997) comparing *C. olivacea* with published sequences submitted to GenBank (www.ncbi.nlm.nih.gov).

The SSU sequence of *C. olivacea* was manually aligned by eye with 30 SSU sequences of species retrieved from GenBank (www.ncbi.nlm.nih.gov) representing the Helotiales, Patellariales, Dothideales, Pleosporales, Hysteriales, Tubeufiaceae, Jahnulales, Chaetothyriomycetes, Eurotiales, Sordariales, and Pezizales using Se-Al v2.0a11 Carbon (Rambaut 2002). *Saccharomyces cerevisiae* Meyen ex E.C. Hansen was used as an outgroup. A heuristic search was done using parsimony as the optimality criterion. Gaps were treated as missing data. Starting trees were obtained at random via stepwise addition with tree-bisection-reconnection as the branch-swapping algorithm. Confidence in the branches of the resulting trees was evaluated by bootstrap analysis (Felsenstein 1985) using 100 replicates.

RESULTS:

Mature, liberated ascospores were single-celled, guttulate, melanized, minutely verrucose, navicular to cypriform, slightly swollen and pointed at one end, narrower and rounded at the other, 7.6-9.6 x 3.6-4.6 μm (Fig. 7.1). Within 7-14 days on MEA, ascospores swelled until they were more or less spherical, 10-12 μm in diameter, and the outer wall became deeply pigmented and coarsely roughened to verrucose (Fig. 7.2).

After the formation of one or two cross walls within the swollen ascospore (Fig. 7.3), germ tubes emerged from one or more cells (Fig. 7.4). Germ tubes elongated through a combination of tip growth and meristematic division to form short segments of rough-walled hyphae, three to four cells in length and 5-6 µm in diameter (Figs. 7.4-7.5). Smooth, pale brown hyphae, 4-6 µm in diameter arose from the tips of these segments and became septate, broader (6-8 µm), and olivaceous as they matured (Fig. 7.6).

Growth on CMA, MEA and on wood blocks in moist chambers was sparse and consisted of deeply melanized sub-surface and surface hyphae. An anamorph was absent but ascomata developed on CMA and in moist chambers approximately three months after inoculation. The first indication of ascoma formation was the appearance of a small cluster of short, sub-globose branches from the side of a hyphal segment delimited by two sets of paired septa (Fig. 7.7). Meristematic division within the branches and cell enlargement led to the formation of a dense, stromatic mass 60-200 µm in diameter and composed of polygonal cells (Fig 7.8). The stromatic mass gave rise to numerous broad, closely septate and lightly pigmented hyphae (Fig. 7.9) that branched and anastomosed as they grew outwards (Fig. 7.10). This radial proliferation resulted in the formation of a globose mass of densely interwoven hyphae that was 300-500 µm in diameter and green to orange-brown. The abundant, free, clavate hyphal tips, 6-10 µm thick, formed a uniform tomentum over its surface (Figs. 7.10-7.11).

A minute pore appeared on the upper surface of the tomentum, revealing a single cavity containing the developing hymenium within the primordial ascoma (Figs. 7.12-7.14). The remnants of the tomentum surrounding the pore persisted as the ascoma flattened against the surface of the substrate to form a disk and remained as a prominent yellowish to ochre margin bearing numerous vertical fissures (Figs. 7.13-7.16). In culture, mature ascomata were 1-2 mm in diameter (Figs. 7.15-7.16). Straight, broad and sparingly branched, darkly pigmented and cuticularized hyphae arose from the base of the ascoma, where they were 8-10 µm thick, and radiated outwards, into and across the substrate (Figs. 7.12-7.14, 7.16) tapering to 4.8-7.2 µm at their apices (Fig. 7.17).

The newly exposed hymenium arose from a layer of globose cells that formed the outer excipulum, which was 120-160 µm thick (Figs. 7.17-7.18). The hymenium consisted of numerous slender, septate, sterile filaments, 70-105 x 0.7-1.6 µm, with slightly swollen apices (Figs. 7.18-7.20). As the hymenial layer matured, an outer amorphous layer surrounding the tips of the sterile filaments appeared to dissolve and lift away from the wall (Fig. 7.20). A darkly pigmented, viscous liquid accumulated on the surface of the hymenium and formed a pseudoepithecial layer, up to 50 µm thick (Figs. 7.21-7.22). Interspersed among the filaments were clavate asci, 62-84 x 4.8-6 µm, that in places protruded through the pseudoepithecial layer (Figs. 7.20-7.22). Ascus apices had markedly thickened walls, a prominent ocular chamber (Figs. 7.23-7.24), and remained unstained with Melzer's reagent. Eight, uniseriate ascospores were contained per ascus (Figs. 7.22-7.23, 7.25) and were released through a broad bivalvate slit across the ascus apex (Fig. 7.26). Numerous ascospores remained entrapped in the gel of the pseudoepithecial layer (Fig. 7.27). Others landed close to the perimeter (within 1-2 mm) of the ascoma where they formed a halo (Fig. 7.28) of dark-colored droplets (Fig. 7.29).

Phylogenetic analysis.

The sequence alignment matrix consisted of *Catinella olivacea* and 30 species of fungi in 11 orders of ascomycetes. The alignment, including gaps, consisted of 1815 characters, 1272 of which were constant, 244 were parsimony-uninformative, and 299 were parsimony-informative. Maximum parsimony analysis yielded four most-parsimonious trees (MPT) which differed slightly from each other in the position of taxa within the clade comprising the Helotiales. The tree length was 1048 steps, the consistency index (CI) was 0.66, the homoplasy index (HI) was 0.34, and the retention index (RI) was 0.652 (Fig. 7.30). Tree topology roughly correlated with previously recognized relationships both at order and family levels (Berbee 1996, Silva and Hanlin 1999, Lindemuth et al. 2001, Spatafora et al. 1995, Lumbsch et al. 2005). Most major orders had high bootstrap support. The Dothideomycetes formed two clades, with one comprising members of the Dothideales, Jahnulales, Tubeufiaceae, Hysteriales and *C. olivacea*. The second clade consisted of the Pleosporales and Patellariales, which together formed a strongly supported clade (97% support), and the Chaetothyriomycetes and Eurotiales. *Catinella olivacea* grouped with Jahnulales, Tubeufiaceae and Hysteriales, but support for this clade was poor (58% bootstrap support). The Helotiales formed a poorly supported clade that grouped with the Sordariales. The Pezizales were basal in relation to the rest of the taxa in the tree.

DISCUSSION:

Morphological and developmental characters observed by LM and SEM and phylogenetic analysis of the SSU gene indicate that *C. olivacea* is dothideomycetous and does not have affinities with the Helotiales, as others have suggested (Seaver 1961, Korf 1973, Nannfeldt 1932 in Dennis 1977, Spooner and Legon 1999). This erroneous placement was based on a misinterpretation of several ambiguous morphological characters and a lack of data concerning the development of the apothecioid ascomata of this species.

Single-celled ascospores are less common than septate ones in the Dothideomycetes (Eriksson 1981, Sivanesan 1983, Barr 1987, Barr and Huhndorf 2001) but the melanized, minutely verrucose walls, previously alluded to by Strödel (1990), and clear evidence of meristematic growth during germination are more indicative of a relationship with this class than with the Leotiomycetes. Ascomata arose from mycelia derived from single germinating ascospores, indicating that the fungus is homothallic, and did not involve the prior formation of an ascogonial coil. Instead, ascomata developed following a pattern typical among Dothideomycetes in which the tissues that will enclose the ascogenous system form before the appearance of gametangia and ascogenous initials (Luttrell 1973, Eriksson 1981, Barr 1987, Barr and Huhndorf 2001, Lindemuth et al. 2001). In contrast, ascoma formation among inoperculate and true perithecial taxa is initiated by the formation of an ascogonial coil (from which asci eventually arise) that is then enveloped by fungal tissue derived from adjacent vegetative hyphae (Emmons 1932, Greif et al. 2004, Tsuneda and Currah 2004).

The majority of Dothideomycetes are unilocular (Barr 1987) and fruiting bodies of many apothecioid taxa in the Myriangiales, Hysteriales, and Dothideales develop a pore or vertical slit that helps facilitate exposure of the hymenium and release of ascospores (Luttrell 1973, Eriksson 1981). In *C. olivacea*, the marginal tissue surrounding the initial pore persisted to form the distinctive fissured, ochraceous margin composed of textura prismatica-like excipulum, sensu Kutorga and Hawksworth (1997), as the fruiting body took on its characteristic apothecioid form similar to the ascomata produced by taxa in the Patellariales (Bezerra and Kimbrough 1982, Kutorga and Hawksworth 1997). The prominent cuticularized "anchoring hyphae" radiating from the base of the excipulum is a feature also reported in some taxa in the Patellariales (Kutorga and Hawksworth 1997). The anchoring hyphae in *C. olivacea* may represent vestiges of subicular tissue that is more prominent in other dothideomycete taxa (Dennis 1977, Eriksson 1981), but their function is unknown.

The apparently unitunicate ascus and non-blueing reaction in the ascal tip were important in classifying *C. olivacea* as an inoperculate taxon (Durand 1922, Korf 1973, Keizer 1990, Spooner and Legon 1999). Asci with a single wall-layer do occur in some Dothideomycetes (Eriksson 1981, Barr and Huhndorf 2001) but their apices differ from those of unitunicates in the Leotiomycetes. The earlier supposition, that there was a non-blueing apical plug or pore, was a misinterpretation of the narrow ocular chamber (or "nasse apicale" sensu Chadefaud 1960 in Luttrell 1973). This structure, along with the prominent bivalvate split that develops across the ascus apex during dehiscence, are strong indicators of affiliation with bitunicate taxa (Eriksson 1981, Eriksson et al. 2004). Without a second ascal wall layer, ascospore ejection does not involve a "jack-the-box" mechanism common to most other Dothideomycetes (Barr 1987, Eriksson 1981).

Depictions of the sterile filaments (i.e., "paraphyses") in Dennis (1977, see plate 28, Fig. M) show that an outer layer or coating on the apex of these structures lifts away from tip as the hymenium matures. My SEM observations confirm this phenomenon and, further, show that as this outer layer sloughs off it contributes to the formation of the amorphous, brown, gelatinous pseudoepithecium. The production of pseudoepithecial gels in other taxa has been suggested as a water retention mechanism to aid in spore maturation and ejection (Ingold 1959, Moore 1965), and as a type of antifreeze (Sherwood 1981). Given the types of habitats in which *C. olivacea* is found, protection from desiccation is not likely a function for this material. Both the sticky spore droplets that accumulate in the vicinity of mature ascomata and the gel-spore matrix that accumulates on the surface of the hymenium may be an adaptation favouring dispersal by passing microfauna. Fungi that are adapted for such cryptic habitats often exhibit a range of morphological mechanisms that utilize arthropods and other animals for spore dispersal. For example, the Myxotrichaceae (Helotiales), common on decaying wood (Currah 1985, Lumley et al. 2001), produce burr-like fruiting bodies that are capable of attaching to arthropods (Greif and Currah 2003). Many species of *Ophiostoma*, a taxon that occurs in excavated beetle galleries in conifers, produce elongate perithecia that exude ascospores in slimy droplets that adhere to passing arthropods. Discoid, dung-inhabiting species in the Pezizales also produce spores enveloped in a gelatinous outer layer, ostensibly to facilitate attachment to arthropods for dispersal (Pfister and Kimbrough 2001). Isolation of *C. olivacea* from cohabiting arthropods would provide support for my hypothesis concerning the function of the pseudoepithecial layer and surrounding spore-rich droplets. The apparent absence of an anamorph would make the successful transfer of meiotic propagules critical to the survival and dispersal of this species.

Parsimony analysis of the SSU sequence of *C. olivacea* (Fig. 30) supported the taxonomic affinities suggested by morphological and developmental characters, placing it within the clade represented by the Jahnulales, Hysteriales, and Tubeufiaceae. In this analysis, *C. olivacea* was affiliated with the Dothideomycetes, and was not closely associated with the taxa representing the Helotiales or Leotiales, or with the apothecioid taxon Patellariales (Boudier 1907, Durrand 1922, Nannfeldt 1932 in Dennis 1977, Korf 1973). It is unclear where the species belongs within the Dothideomycetes. *C. olivacea* does not appear to have morphological affinities with the Jahnulales or Tubeufiaceae because teleomorphs in these two taxa produce perithecioid ascomata and septate ascospores (Scheuer 1991, Pang et al. 2002). Teleomorphs in the Hysteriales also produce septate ascospores, and have elongate hysterothecia in which the hymenium is exposed through an apical slit rather than an expanding pore (Barr and Huhndorf 2001, Kirk et al. 2001).

Clements and Shear (1931) and others (e.g., Dennis 1977) have previously noted similarities between *C. olivacea* and the type species of *Karschia*, a taxon that is listed as incertae sedis in the Dothideomycetes (Eriksson et al. 2004). *Karschia lignyota* (Fr.) Sacc. has flat, stalkless, olive-black ascomata, cylindrical-clavate, melanized ascospores, asci with thickened apices, paraphyses that produce a brownish gel, and similar proclivities to fruit on damp, rotten wood. It differs in having two-celled ascospores, in an irregular biseriate pattern, in asci that turn blue at the apices in iodine (Dennis 1977). Nevertheless, the relationship between these two species should be re-examined if DNA sequences and fertile cultures could be obtained.

In conclusion, the morphological, developmental and molecular characters reported here show that *C. olivacea* is not a member of any taxon within the Leotiomycetes and that it would be most appropriately disposed in the Dothideomycetes, although affinities with other taxa within this class remain unresolved. The production of a sticky pseudoepithecial mass of ascospores and the formation of sticky multi-spored droplets in the vicinity of mature ascomata suggest that microfauna would likely play an important role in the dispersal of this fungus.

Fig. 7.1-7.15 Germinating ascospores and the ascoma development in *C. olivacea*.

Fig. 7.1. Liberated mature ascospores were single-celled, melanized, minutely verrucose, navicular to cypriform, slightly swollen and pointed at one end and narrower and rounded at the other. Bar = 10 µm.

Fig. 7.2. Germinating ascospore. Upon germination, ascospores swelled, changing shape from ellipsoidal to spherical. The outer cell wall also became coarsely roughened. Bar = 18 µm.

Fig. 7.3. Germinating ascospore divided by a cross wall. Bar = 18 µm.

Fig. 7.4. Germ tubes developing from germinated ascospore. Bar = 12 µm.

Fig. 7.5. Germ tubes elongated through a combination of tip growth and meristematic division to form short segments of rough-walled, hyphae. Bar = 16 µm.

Fig. 7.6. Smooth, light brown, elongating hypha (arrow) and matured, thick-walled, darkly olivaceous, septate hyphae. Bar = 30 µm.

Fig. 7.7. The formation of short, sub-globose branches from the side of a hyphal segment delimited by two sets of paired septa (arrows) was the first indication of ascoma development. Bar = 30 µm.

Fig. 7.8. Stroma composed of a dense cluster of polygonal cells derived from meristematically dividing, sub-globose branches. Bar = 30 µm.

Fig. 7.9. Numerous broad, closely septate, and lightly pigmented hyphae developed from the ascoma. Bar = 40 µm.

Fig. 7.10. Hyphae on the surface of the ascoma anastomosed with each other and formed a compact tomentum (arrow). Bar = 30 µm.

Fig. 7.11. Newly formed (arrow) and expanding ascoma as observed under a dissection microscope. Bar = 500 µm.

Fig. 7.12. Pore formed on the apical surface of the mature ascoma. Bar = 400 µm.

Fig. 7.13. Single unilocular cavity contained the developing hymenium. Bar = 400 µm.

Fig. 7.14. Apothecioid ascoma. The elevated remnants of the tomentum formed an ochre-yellow ring around the periphery of the ascoma. Bar = 800 µm.

Fig. 7.15. Mature apothecioid ascoma with upturned margin and applanate surface. Bar = 1 mm.

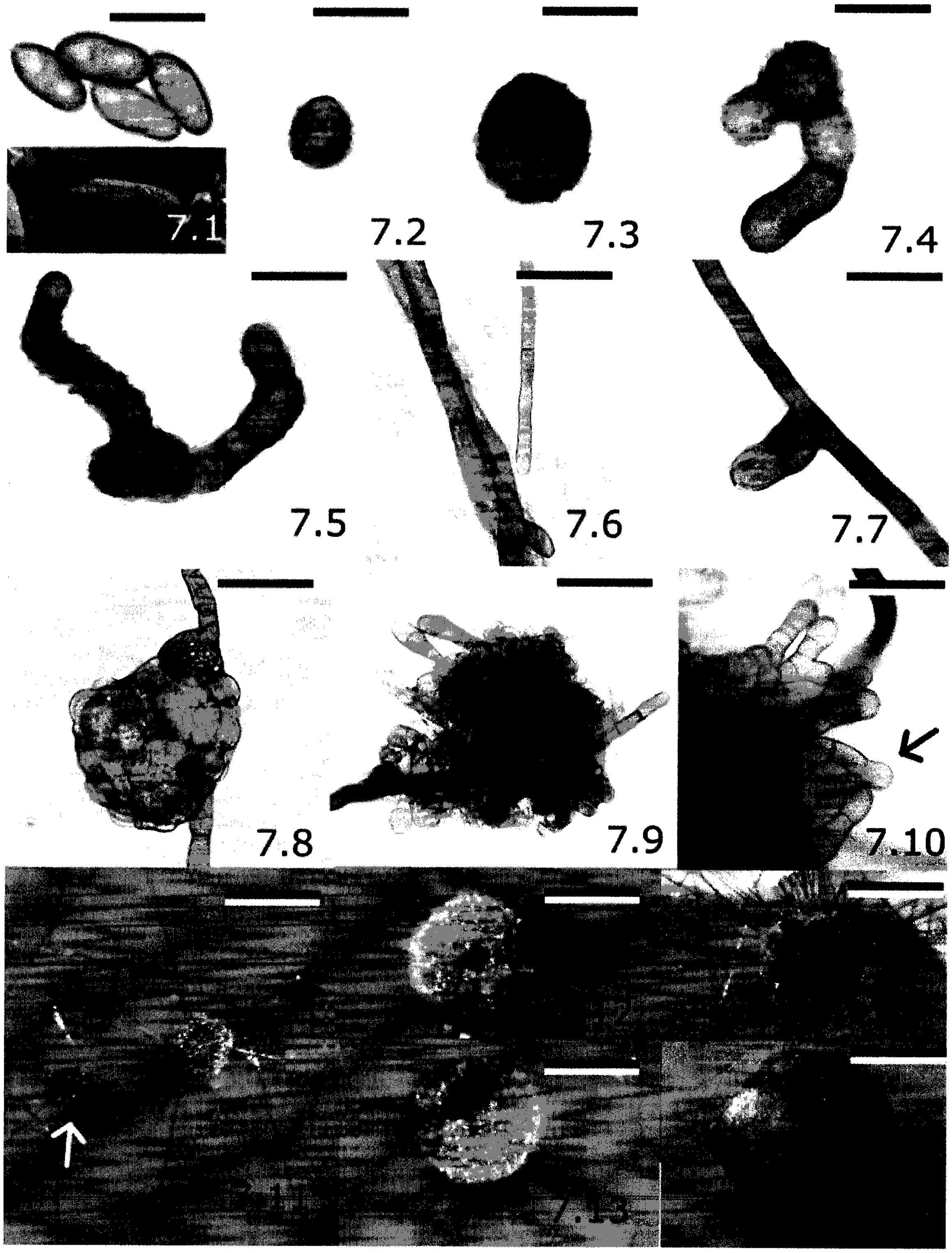
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Fig. 7.16 – 7.22. Anchoring hyphae and development of the hymenium in *C. olivacea*.

Fig. 7.16. SEM of a mature apothecioid ascoma. Straight, broad, and sparingly branched anchoring hyphae emerged from the underside of fruiting structure (arrow). Bar = 600 µm.

Fig. 7.17. Hand section through a maturing ascoma showing the origin and disposition of anchoring hyphae. Bar = 150 um.

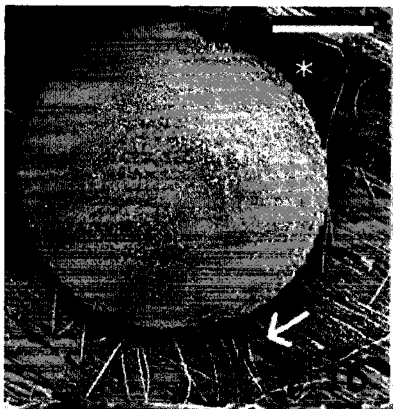
Fig. 7.18. Sectioned disk under SEM. The hymenium, composed of sterile filaments and asci (*), supported within an excipulum composed of globose cells (arrow). Bar = 90 µm.

Fig. 7.19. Sterile filaments developed from the sides of the developing margin of the hymenium as the ascoma expanded. Bar = 30 µm.

Fig. 7.20. Tips of the sterile filaments surrounded by an outer amorphous layer. On some filaments this layer appeared to dissolve and lift away (*). Arrow indicates ascal tips that emerged through pseudoepithecial gel. Bar = 10 µm.

Fig. 7.21. Section of a mature ascoma. The hymenium was covered by a dark pseudoepithecium (arrow). Bar = 80 µm.

Fig. 7.22. Section through the hymenial layer and overlying pseudoepithecium showing numerous liberated ascospores caught in the gel. Bar = 30 µm.



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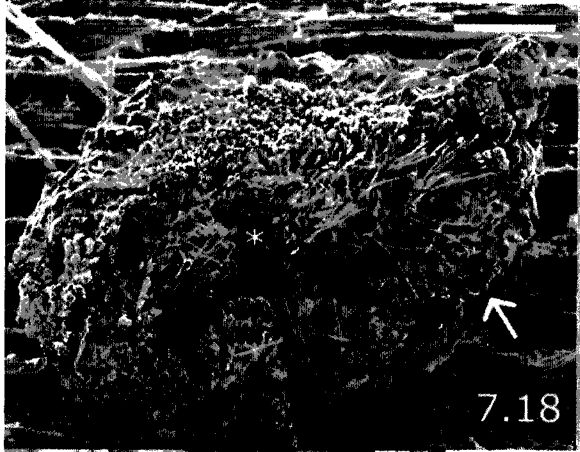

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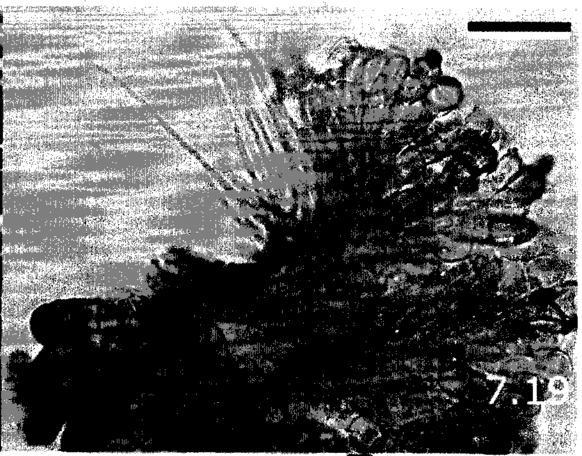

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Figs. 7.23 - 7.29. Ultra-structural details of the asci and pseudoepithecium.

Fig. 7.23. Ascus with a single wall layer and a thickened apex. Bar = 17 µm.

Fig. 7.24. Composite view of ascal tips under high magnification. Ocular chambers in tips were clearly visible. Bar = 7 µm.

Fig. 7.25. SEM of a mature ascus prior to dehiscence (arrow). Bar = 5 µm.

Fig. 7.26. Several asci showing a broad, bivalvate slit across the tip of the ascus (arrows). Bar = 6 µm.

Fig. 7.27. Surface view of mature ascoma under SEM. The gelatinous pseudoepithecium trapped large numbers of ascospores (arrow). Ascus visible protruding above the pseudoepithecium (*). Bar = 9 µm.

Fig. 7.28. Mature apothecioid ascoma with a dark halo of discharged ascospores (arrow). Bar = 2 mm.

Fig. 7.29. Close-up of the dark coloured droplets of gel and ascospores. Bar = 750 µm.


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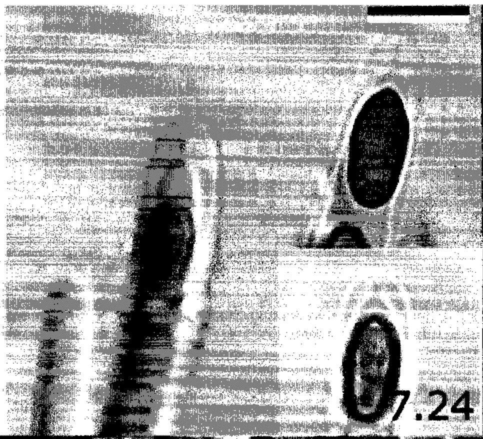
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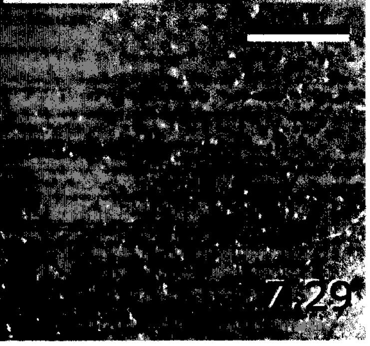
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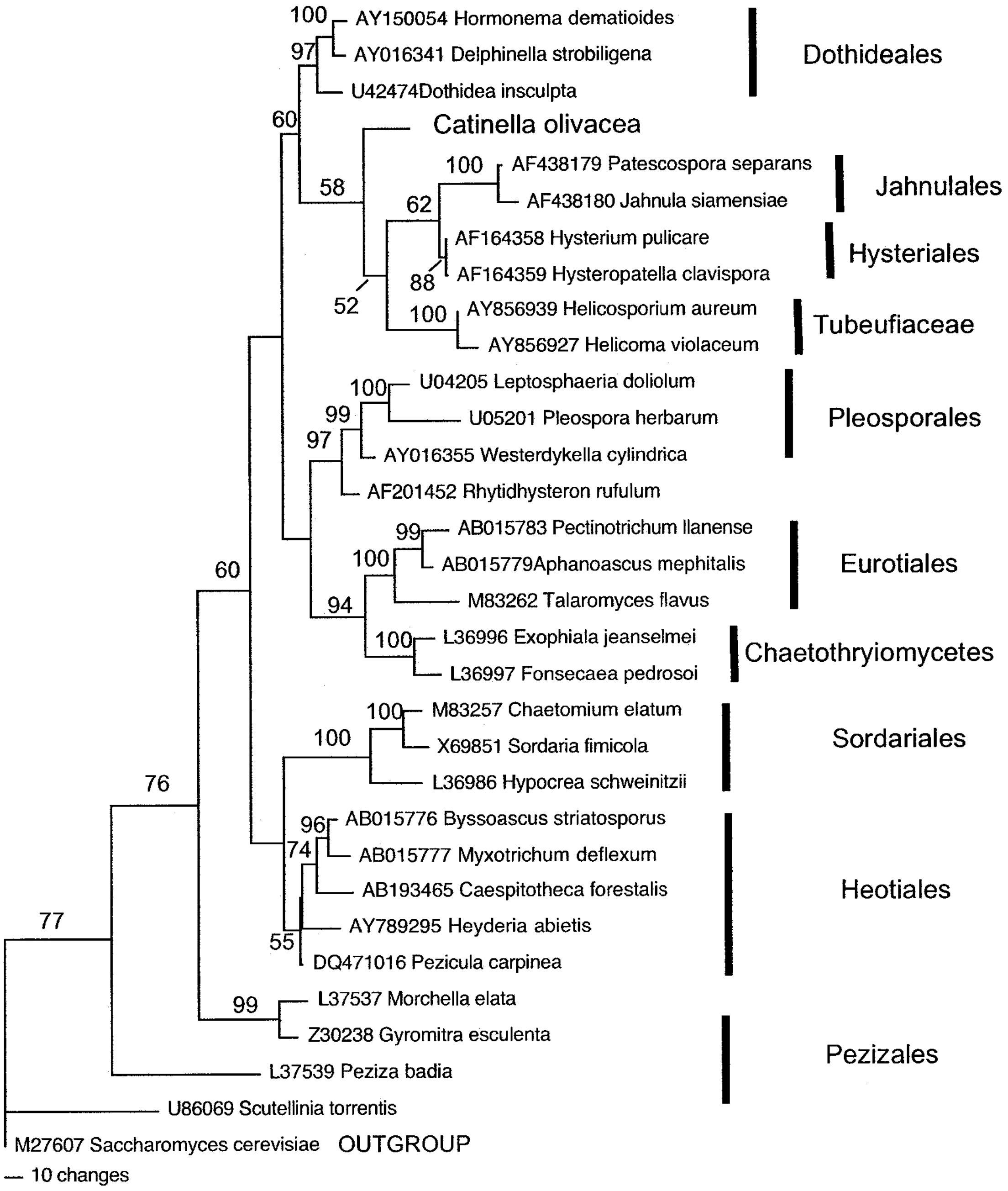
Fig. 7.30. One of four most-parsimonious trees showing the position of *Catinella olivacea* among discomycete and dothideomycete taxa based on SSU rDNA sequence data. *C. olivacea* is in a clade containing the Tubeufiaceae, Hysteriales, and Jahnulales. Genbank accession numbers are listed beside species. Bootstrap values >50% are shown above branches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AY150054 Hormonema dematioides
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AY016341 Delphinella strobiligena
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Dothideales
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Catinella olivacea
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AF438179 Patescospora separans
AF438180 Jahnula siamensiae
Jahnulales
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AF164358 Hysterium pulicare
AF164359 Hysteropatella clavispora
Hysteriales
88
52
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AY856939 Helicosporium aureum
AY856927 Helicoma violaceum
Tubeufiaceae
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U04205 Leptosphaeria doliolum
99
U05201 Pleospora herbarum
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AY016355 Westerdykella cylindrica
Pleosporales
AF201452 Rhytidhysteron rufulum
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AB015783 Pectinotrichum llanense
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AB015779Aphanoascus mephitalis
Eurotiales
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M83262 Talaromyces flavus
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Chaetothryiomycetes
100
M83257 Chaetomium elatum
100
X69851 Sordaria fimicola
Sordariales
L36986 Hypocrea schweinitzii
76
96
AB015776 Byssoascus striatosporus
74
AB015777 Myxotrichum deflexum
AB193465 Caespitotheca forestalis
Heotiales
77
AY789295 Heyderia abietis
55
DQ471016 Pezicula carpinea
99
L37537 Morchella elata
Z30238 Gyromitra esculenta
Pezizales
L37539 Peziza badia
U86069 Scutellinia torrentis
M27607 Saccharomyces cerevisiae
OUTGROUP
— 10 changes

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Chapter 8

General Discussion and Conclusions

Interactions between arthropods and fungal saprobes are poorly understood. Most available information on arthropod dispersal of fungal saprobes have either come from studies surveying the saprophytic fungi on a small set of arthropods, or have focused on particular arthropod or fungal species. Additionally, while the reproductive architecture of many saprophytic fungi suggests adaptations for arthropod dispersal, there are very little available developmental data on fungal fruiting bodies and on how mechanisms that facilitate spore transport by biotic agents might function. The aim of this thesis was to investigate the dispersal of fungi by arthropods, with an explicit focus on fungal saprobes, and to examine potential mechanisms that aid in spore liberation and attachment.

In my second chapter, I report the results of a survey of the saprophytic fungi associated with a general arthropod population. Traps set up with baits representative of cryptic habitats (coyote dung, moose dung, brown-rotted wood, and white-rotted wood) captured 1696 arthropods from which 1687 fungal isolates were recovered using cycloheximide-amended corn meal agar. At the outset of this survey, I hypothesised that arthropods are involved in the transport of substrate specific fungi between cryptic habitats. Many genera recovered, such as *Beauveria, Cladosporium*, and *Penicillium* were ubiquitous on all arthropods associated with all bait types, but some taxa, such as *Myxotrichum*, *Geomyces,* and *Auxarthron* were predominately recovered from arthropods attracted to bait types representative of habitats these fungal genera have been associated with (Currah 1985). A new species of *Leptographium* was also discovered and mainly occurred on arthropods attracted to dung. Principal component analyses comparing bait type and arthropods, and bait type and fungi, suggest that different suites of arthropods were recovered from specific bait types, and that the cycloheximide-resistant fungi on these arthropods varied depending on bait. While tentative, these results reveal that, at my survey site, arthropods are dispersing a wide range of fungal saprobes including a sub-set of select suites of fungi to particular substrate types.

This survey is the first to take the approach of isolating fungi from a robust population of arthropods rather than focusing on specific arthropod or insect taxa. By using baited traps, this survey also more clearly shows the potential of arthropods to transmit viable propagules. This surveying methodology provides a complex data set that can be mined to examine various phenomena in addition to questions about general dispersal, such as the dispersal of specific fungal species by a population of arthropods (i.e. per order), or fungal species richness associated with particular arthropod families, genera, species, or functional groups. While time consuming, continuing this approach of wide scale sampling is essential if we are to understand better the extent to which fungal saprobes depend on arthropods for dispersal. Modifying the methods used in this thesis (i.e., using larger bait samples, more traps, different selective media) in future studies will help in improving pattern resolution between fungi, arthropods, and substrates. Molecular techniques, such as large-scale PCR analysis (O'Brien et al. 2005), can allow for more robust data sets by potentially sequencing and identifying all fungi present without a loss of diversity due to either selective media eliminating certain species, or favouring fast-growing taxa at the expense of poor competitors. Perhaps the most interesting finding from this survey, aside from the new species of *Leptographium*, was the isolation of fungal species predicted to be dispersed by arthropods (Currah 1985, Greif and Currah 2003, Chesters 1934, Malloch and Cain 1970). The isolation of species in the Myxotrichaceae, Onygenaceae, and Arthrodermataceae, as well *C. hypophloia*, confirmed predictions that gymnothecial and cephalothecoid taxa respectively are dispersed by arthropods.

Chapter three described a new species of *Leptographium* obtained during my research and is illustrative of the spin-off benefits of conducting wide ranging surveys of arthropod-associated fungi. The genus *Leptographium* contains 52 species which are defined by dematiaceous conidiophores bearing a brush-like head of conidiogenous cells, and annellidic spore production. *Leptographium piriforme* is unique in having short stipes, curved conidia, pear-shaped cells, and an optimum growth temperature of 35°C. The high growth optimum and isolation from a wide variety of arthropods associated with animal dung implies a possible coprophilous aspect to its life history, which is remarkable since the genus *Leptographium* has not previously been associated with vertebrates or their dung. Future work should focus on attempting to isolate this fungus directly from animal dung and woody substrates to determine the lifecycle of *L. piriforme* and the role this fungus plays in the ecosystem. The production of pear-shaped cells was the most intriguing morphological feature of this fungus. Casual observations on mites revealed a possible nutritive role of these structures similar to that of gongylidia in *Leucoagaricus gongylophorus*, and may serve to prolong contact between arthropod and fungus and promote spore contact, although such an association at this point is only speculative. Studies on the chemical composition of the contents of the pear-shaped cells, and the response of arthropods to these structures, will provide a better understanding of the possible function of these novel vegetative structures.

The subsequent chapters in my thesis examined possible mechanisms for spore attachment in the reproductive architecture of a number of fungal saprobes associated with cryptic substrates. There have been very few studies on the development of these fruiting types (Chesters 1934, Benny et al. 1980, Bezerra and Kimbrough 1981, Tsuneda and Currah 2004), and there is no information available on how these particular peridial types react when exposed to abiotic or biotic elements. A combination of ultra-structural techniques in combination with observations of how these structures behave when exposed to arthropods have provided unprecedented insight into how these fruiting bodies develop, and allowed for more accurate predictions of how these fungi are dispersed. In chapter four, I investigated the ability of gymnothecia to attach to the bodies of arthropods. Currah (1985) predicted that the burr-like construction of the gymnothecium was an adaptation for arthropod dispersal with the appendages on the surface of the gymnothecium latching onto the arthropod appendages. Exposure of gymnothecia of *Myxotrichum deflexum* and *Auxarthron conjugatum* to live flesh flies, followed by ultra-structural observations confirmed that gymnothecia can attach to arthropods, but the mechanism of attachment was unexpected and contrary to previous predictions. The cage-like construction of the gymnothecium allowed setae on the surface of the arthropod to pass through and impale the gymnothecium. Impalement, not gymnothecial appendages, secured the gymnothecium onto the arthropod. By being able to secure the entire fruiting body onto the exoskeleton of passing arthropods, fungi in these taxa can exploit the mobility of these animals and be actively dispersed to fresh substrates. Further tests of this hypothesis will depend on observations of gymnothecia on arthropods caught in the wild.

In chapters five and six, I investigated the development of the cephalothecoid peridia of two taxa (*Cryptendoxyla hypophloia* and *Aporothielavia leptoderma* respectively) and related morphological characters of the peridium to dispersal. Previous reports on cephalothecoid taxa stated that the peridium was generated through meristematic cellular divisions which accounted for the characteristic radiating plates (Chesters 1934, Booth 1961, Malloch and Cain 1970). Prior to my research into cephalothecoid taxa, there was only one paper examining the development of this peridial type using ultra-structural techniques (Benny et al. 1980). My findings showed peridial development in both taxa was through branching and elongation of hyphal tips rather than by meristematic growth. The construction of the cephalothecoid peridium allowed the cleistothecium to be ruptured easily. With *C. hypophloia*, which is reported to occur under bark (Malloch and Cain 1970), rupturing was speculated to coincide with dry environmental conditions which would bring liberated spores into contact with arthropods seeking shelter to avoid desiccation. In the case of *A. leptoderma*, rupturing appeared to be dependant on mechanical disruption due to contact with large, robust arthropods. The most interesting findings for *C. hypophloia* were the irregular cell wall thickenings in the peridial plates, and how the plates contracted fully when dried allowing exposure of the ascospores. The most interesting finding from the study on *A. leptoderma* was its congeneric status with *Chaetomidium* according to its morphology and development. Future work investigating the phylogeny of *Chaetomidium* and *A. leptoderma* will confirm the generic relationship of this particular cephalothecoid species. These studies on cephalothecoid peridia represent a new direction for this fruiting body type where both the function and development of the peridium is taken into account. Future investigations of other cephalothecoid fungi, such as the stalked cleistothecium of *Batistia annulipes*, or on the genus *Cercophora*, which has a partially cephalothecoid perithecium, will provide new insight into how such this peridial type has arisen in diverse fungal taxa. Additionally, this research can be used to determine the frequency with which this peridial character has evolved and the extent to which morphological and developmental characters mirror phylogeny.

Finally, chapter seven examined the development and phylogenetic placement of *Catinella olivacea*. Collections of this fungus have been made from cavities in wet, decorticated aspen, and other similar substrates protected from abiotic vectors (Pomerleau 1980, Keizer 1990, Breitenbach and Kränzlin 1981, Strödel 1984). The cryptic habitat, and reproductive architecture of this fungus suggested a possible reliance on animal vectors for dispersal. Sections of the mature fruiting body and scanning electron micrographs revealed the pseudoepithecium to be a matrix of gel and trapped mature ascospores. Additionally, ejected spores formed a halo of droplets circumscribing the mature ascomata. The gel-spore matrix and spore droplets are superficially similar to spore droplets produced by taxa in the Ophiostomatales, an order vectored by arthropods. To test the biotic dispersal potential of this fungus, examination of exoskeleton bound propagules from arthropods found co-habiting on substrates with *C. olivacea*, using similar methodology used by Lilleskov and Bruns (2005), can be performed to test if ascospores can physically attach to visiting arthropods. Developmental characters and SSU sequence data were instrumental in confirming the affiliation of *C. olivacea* with the Dothideomycetes rather than with the Helotiales. Prior to this research, *C. olivacea* was placed in the Helotialian family Dermataceae. However, my results were unable to determine ordinal and familial level taxonomic positions for this fungus. Since comparable developmental characters are lacking for most Dothideomycete taxa, determining the proper phylogeny of *C. olivacea* may be better determined by molecular anaylsis combining SSU with additional gene regions such as ITS and ß-tubulin.

The results of this thesis show that arthropods are involved in the transport of many saprophytic fungal species, including fungi specialized for specific substrates. Some saprophytic taxa in turn produce fruiting structures with mechanisms that facilitate, or at least encourage, spore attachment and dispersal by arthropods. The most important findings in this thesis are without a doubt the developmental observations on the various fruiting types and their wider implications for understanding the evolution of reproductive architectures within the Ascomycota. All three types of fruiting structures examined in this study (gymnothecia, cephalothecoid cleistothecia, and apothecioid fruiting bodies) are convergent between different fungal taxa and are representative of the selective pressure put upon these fungi to maximize dispersal. Given the current trend in mycology towards molecular research, both in funding and training, these findings show that traditional mycological techniques, such as isolating and identifying fungal species, ultra-structural analyses, and actually observing the response of fungal structures to abiotic and biotic factors, can still provide relevant information concerning life cycles, dispersal, and phylogeny.

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GLOSSARY:

Anastomosis: The fusion of two or more vegetative hyphae.

Anamorph: The asexual phase in a fungal lifecycle.

Angiosperms: The flowering plants.

Anther(s): The reproductive structure in flowers that is the site of pollen production.

Apothecium (*pl.* apothecia): A type of fruiting body produced by some fungi in the Ascomycota. An apothecium is disk-shaped, with the asci fully exposed to the environment.

Arthroconidia: Conidia derived from the fragmentation of vegetative hyphae.

Arthropoda: A phylum in the Kingdom Animalia. This phylum in home to the small aquatic and terrestrial invertebrates including insects, spiders, mites, and scorpions.

Ascus (*pl.* Asci): A specialized cell found in ascomycete fruiting bodies that produce the ascospores through meiosis. Asci can be of a variety of shapes from clavate to cylindrical, and can release spores through specialized pores, or through tears in the ascal membrane.

Ascogenous cell: A cell that gives rise to an ascus.

Ascomycota: A phylum in the Kingdom Fungi defined by the production of asci, specialized cells that are the site of meiospores formation.

Ascospores: Spores produced through meiosis within the ascus.

Basidiomycota: A phylum in the Kingdom Fungi defined by the production of basidia, specialized cells that are site of meiospores formation.

Biodiversity: The number and variety of organisms in an area.

Bitunicate asci. Asci with two distinct wall layers. The outer layer, or ectotunica, is brittle, while the inner layer or endotunica, is flexible. A "jack in the box" mechanism", where the outer layer breaks and the inner layer expands, ejects the spores.

Brown rot: Wood decay where the cellulose component of the cell wall is broken down and removed, leaving behind the brown coloured lignins.

Cellulose: A linear carbohydrate molecule composed of chain of glucose molecules.

Centrum: The portion inside an ascomycete fruiting body that consists of the asci and other sterile tissue.

Cephalothecoid peridium: A peridium composed of plates of cells. Each plate is referred to as a cephalothecoid plate.

Cleistothecium (*pl.* cleistothecia): A fruiting body found in certain ascomycetes that lacks an opening for spore release.

Conidia: An asexual spore.

Coprophilous: Literally translated as dung loving.

Crozier: A structure that precedes the formation of an ascus.

Cycloheximide: A chemical compound that inhibits cytosol synthesis in some fungi.

Cytoplasm: The internal fluid portion of a cell.

Dehiscence: See evanescent.

Discomycete: A fungus that produces apothecia.

Dothideales: An order in the Loculoascomycetes. This order is characterized by the production of apothecioid fruiting bodies derived from stromatic tissue.

Ecology: The relationship between organisms and their environment.

Entomopathogen: A fungal pathogen of arthropods.

Evanescent: Of short duration. When applied to asci, refers to an ascus that breaks down to release spores.

Evolution: Decent with modifications, or changes in allele frequency over time.

Exoskeleton: The outer layer found in arthropods. The exoskeleton provides both protection from the elements, and anchorage points for muscle tissue to facilitate movement.

Gametangium (*pl.* gametangia): A structure that produces gametes.

Gymnothecium (*pl.* gymnothecia): See reticuloperidium.

Herbaceous plants: A vascular plant that does not develop persistent woody tissue, does not produce secondary xylem or phloem.

Hydrophobic: Repellent to water.

Hypha (*pl.* Hyphae): a elongated cellular filament typical in fungi.

Inoperculate: A type of ascus that opens via an irregular tearing of the tip.

In-vitro: Artificial, performed in a lab or other setting.

Incompositoperidium: A type of reticuloperidium where the peridial hyphae form a loose mesh surrounding the asci. The peridial hyphae are very fragile and disarticulate upon contact.

Keratin: A recalcitrant protein found in hair, skin, feathers, horn, and nails.

Laboulbeniales: An order in the Ascomycota that produce morphologically distinct reduced thalli that are exclusively found on the exoskeletons of arthropods.

Leptosporangiate ferns: Ferns defined by the production of sporangia from a single cell in the epidermis.

Meristematic growth: The production of new cells through cell division.

Mycangium: An invagination on certain insects used to maintain and transport fungal spores to fresh substrates.

Ocular chamber: A distinctive dimple in the thickened apex of a bitunicate ascus. Also known as a nasse apicale.

Ontogeny: The origin and development of an organism from zygote to maturity.

Onygenales: An order consisting of three families; the Arthrodermataceae, Onygenacea, and Gymnoascaceae. These families produce burr-like fruiting structures known as gymnothecia.

Ophiostomatales: An order consisting of two families in the Ascomycota. Defined as producing perithecia, sometimes cleistothecia, pigmented or hyaline. Asci formed in chains, ascospores small and hyaline.

Paraphysis (*pl.* Paraphyses): A sterile filament produced in a hymenium in the fruiting bodies of some fungi in the Ascomycota.

Peridium: The outer cellular layer of a fungal fruiting body.

Perithecium (*pl.* Perithecia): A flask-shaped fruiting body with a ostiole, or opening to allow spore release, produced by certain fungi in the Ascomycota.

Phoretic: A term used to describe mites that are vectored to various substrates by arthropods.

Phylogeny: The evolution of and relationship between a group of organisms over time.

Reticuloperidium: A peridium composed of loosely interwoven thick walled hyphae.

Rhinoentomophthoromycosis: A sub-cutaneous infection caused by fungi in the Entomophthorales.

Setae: Stout appendages found on the surface of arthropod exoskeleton.

Saprophyte: An organism that obtains nutrients from dead or dying material.

Sordariales: An order in the ascomycetes containing 7 families. Produces either perithecia or cleistothecia, paraphyses present or absent, asci clavate or cylindrical, ascospores dark, single celled, with a germ pore.

Sorus (*pl.* **Sori**): A fruiting structure containing spores found in certain fungi and non flowering plants.

Teleomorph: The lifecycle of a fungus that encompasses sexual reproduction.

Thallus: A vegetative body or mass of hyphae.

Ubiquitous: Common, present everywhere.

Unitunicate asci: Asci with only one visible wall layer. See also bitunicate asci.

Vector: An agent capable of dispersing or transmitting viable spores from one location to another.

White rot: Wood decay where the lignin component of the cell was is broken down and removed, leaving behind the white coloured cellulose.

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Appendix 1: Deposition numbers for collected arthropods.

Personal identifier/plate number	Accession number	Arthropod order	Personal identifier/ plate number	Accession number	Arthropod order
C1	UASM90001	Diptera	M295	UASM90828	Hemiptera
C2	UASM90002	Diptera	M296	UASM90829	Hemiptera
C3	UASM90003	Coleoptera	M297	UASM90830	Diptera
C4	UASM90004	Hymenoptera	M298	UASM90831	Diptera
C5	UASM90005	Diptera	M299	UASM90832	Hymenoptera
C6	UASM90006	Diptera	M300	UASM90833	Diptera
C7	UASM90007	Coleoptera	M301	UASM90834	Araneae
C8	UASM90008	Hymenoptera	M302	UASM90835	Diptera
C9	UASM90009	Diptera	M303	UASM90836	Diptera
C10	UASM90010	Araneae	M304	UASM90837	Araneae
C11	UASM90011	Diptera	M305	UASM90838	Hymenoptera
C12	UASM90012	Araneae	M306	UASM90839	Diptera
C13	UASM90013	Diptera	M307	UASM90840	Diptera
C14	UASM90014	Coleoptera	M308	UASM90841	Diptera
C15	UASM90015	Coleoptera	M309	UASM90842	Diptera
C16	UASM90016	Hymenoptera	M310	UASM90843	Diptera
C18	UASM90017	Hemiptera	M311	UASM90844	Coleoptera
C19	UASM90018	Araneae	M312	UASM90845	Diptera
C20	UASM90019	Coleoptera	M313	UASM90846	Araneae
C21	UASM90020	Coleoptera	M314	UASM90847	Araneae
C22	UASM90021	Araneae	M315	UASM90848	Diptera
C23	UASM90022	Lepidoptera	M316	UASM90849	Hemiptera
C24	UASM90023	Diptera	M317	UASM90850	Diptera
C25	UASM90024	Lepidoptera	M318	UASM90851	Araneae
C26	UASM90025	Lepidoptera	M319	UASM90852	Diptera
C27	UASM90026	Hymenoptera	M320	UASM90853	Coleoptera
C28	UASM90027	Lepidoptera	M321	UASM90854	Diptera
C29	UASM90028	Hymenoptera	M322	UASM90855	Diptera
C30	UASM90029	Coleoptera	M323	UASM90856	Diptera
C31	UASM90030	Coleoptera	M324	UASM90857	Araneae
C32	UASM90031	Coleoptera	M325	UASM90858	Acari
C33	UASM90032	Hymenoptera	M326	UASM90859	Acari
C34	UASM90033	Coleoptera	M327	UASM90860	Araneae
C35	UASM90034	Coleoptera	M328	UASM90861	Hymenoptera
C36	UASM90035	Araneae	M329	UASM90862	Hymenoptera
C37	UASM90036	Araneae	M330	UASM90863	Hymenoptera
C38	UASM90037	Acari	M331	UASM90864	Diptera
C39	UASM90038	Araneae	M332	UASM90865	Coleoptera
C40	UASM90039	Coleoptera	M333	UASM90866	Diptera
C41	UASM90040	Araneae	M334	UASM90867	Diptera
C42	UASM90041	Neuroptera	M335	UASM90868	Opilione
C43	UASM90042	Araneae	M336	UASM90869	Hymenoptera
C44	UASM90043	Diptera	M337	UASM90870	Diptera
C45	UASM90044	Araneae	M338	UASM90871	Araneae

C46	UASM90045	Diptera	M339	UASM90872	Hymenoptera
C47	UASM90046	Hymenoptera	M340	UASM90873	Diptera
C48	UASM90047	Hemiptera	M341	UASM90874	Diptera
C49	UASM90048	Diptera	M342	UASM90875	Opilione
C50	UASM90049	Coleoptera	M343	UASM90876	Diptera
C51	UASM90050	Diptera	M344	UASM90877	Diptera
C52	UASM90051	Araneae	M345	UASM90878	Diptera
C53	UASM90052	Araneae	M346	UASM90879	Hymenoptera
C54	UASM90053	Araneae	M347	UASM90880	Diptera
C55	UASM90054	Coleoptera	M348	UASM90881	Diptera
C57	UASM90055	Coleoptera	M349	UASM90882	Diptera
C58	UASM90056	Hymenoptera	M350	UASM90883	Lepidoptera
C59	UASM90057	Hymenoptera	B1	UASM90884	Diptera
C60	UASM90058	Hymenoptera	B2	UASM90885	Hymenoptera
C61	UASM90059	Diptera	B3	UASM90886	Araneae
C62	UASM90060	Coleoptera	B4	UASM90887	Diptera
C63	UASM90061	Hemiptera	B5	UASM90888	Diptera
C64	UASM90062	Diptera	B6	UASM90889	Araneae
C65	UASM90063	Diptera	B7	UASM90890	Hymenoptera
C66	UASM90064	Hymenoptera	B8	UASM90891	Hemiptera
C67	UASM90065	Araneae	B9	UASM90892	Araneae
C68	UASM90066	Araneae	B10	UASM90893	Diptera
C69	UASM90067	Diptera	B11	UASM90894	Araneae
C70	UASM90068	Diptera	B12	UASM90895	Araneae
C71	UASM90069	Hemiptera	B13	UASM90896	Araneae
C72	UASM90070	Coleoptera	B14	UASM90897	Hymenoptera
C73	UASM90071	Diptera	B15	UASM90898	Diptera
C74	UASM90072	Araneae	B16	UASM90899	Araneae
C75	UASM90073	Coleoptera	B17	UASM90900	Araneae
C76	UASM90074	Coleoptera	B18	UASM90901	Diptera
C77	UASM90075	Pscoptera	B19	UASM90902	Hymenoptera
C78	UASM90076	Diptera	B20	UASM90903	Araneae
C79	UASM90077	Diptera	B21	UASM90904	Coleoptera
C80	UASM90078	Hymenoptera	B22	UASM90905	Araneae
C81	UASM90079	Hemiptera	B24	UASM90906	Araneae
C82	UASM90080	Hymenoptera	B25	UASM90907	Hymenoptera
C83	UASM90081	Hemiptera	B26	UASM90908	Hemiptera
C84	UASM90082	Diptera	B27	UASM90909	Hymenoptera
C85	UASM90083	Coleoptera	B28	UASM90910	Lepidoptera
C86	UASM90084	Hymenoptera	B29	UASM90911	Coleoptera
C87	UASM90085	Araneae	B30	UASM90912	Lepidoptera
C88	UASM90086	Lepidoptera	B31	UASM90913	Diptera
C89	UASM90087	Hymenoptera	B32	UASM90914	Hymenoptera
C90	UASM90088	Araneae	B33	UASM90915	Diptera
C91	UASM90089	Diptera	B34	UASM90916	Araneae
C92	UASM90090	Lepidoptera	B35	UASM90917	Coleoptera
C93	UASM90091	Araneae	B37	UASM90918	Lepidoptera
C94	UASM90092	Diptera	B38	UASM90919	Araneae
C95	UASM90093	Hemiptera	B39	UASM90920	Diptera
C96	UASM90094	Acari	B40	UASM90921	Araneae

C97	UASM90095	Acari	B41	UASM90922	Hemiptera
C98	UASM90096	Coleoptera	B42	UASM90923	Araneae
C99	UASM90097	Diptera	B43	UASM90924	Araneae
C100	UASM90098	Hymenoptera	B45	UASM90925	Hemiptera
C101	UASM90099	Acari	B46	UASM90926	Lepidoptera
C102	UASM90100	Araneae	B47	UASM90927	Araneae
C103	UASM90101	Diptera	B48	UASM90928	Lepidoptera
C104	UASM90102	Diptera	B49	UASM90929	Acari
C105	UASM90103	Hemiptera	B50	UASM90930	Hemiptera
C106	UASM90104	Diptera	B51	UASM90931	Araneae
C107	UASM90105	Hymenoptera	B52	UASM90932	Diptera
C108	UASM90106	Hemiptera	B53	UASM90933	Coleoptera
C109	UASM90107	Hemiptera	B54	UASM90934	Coleoptera
C110	UASM90108	Diptera	B55	UASM90935	Coleoptera
C111	UASM90109	Diptera	B56	UASM90936	Coleoptera
C112	UASM90110	Coleoptera	B57	UASM90937	Coleoptera
C113	UASM90111	Araneae	B58	UASM90938	Coleoptera
C114	UASM90112	Diptera	B59	UASM90939	Coleoptera
C115	UASM90113	Diptera	B60	UASM90940	Coleoptera
C116	UASM90114	Acari	B61	UASM90941	Coleoptera
C117	UASM90115	Acari	B62	UASM90942	Coleoptera
C118	UASM90116	Coleoptera	B63	UASM90943	Coleoptera
C119	UASM90117	Araneae	B64	UASM90944	Coleoptera
C121	UASM90118	Hemiptera	B65	UASM90945	Araneae
C122	UASM90119	Diptera	B66	UASM90946	Hymenoptera
C123	UASM90120	Diptera	B67	UASM90947	Diptera
C124	UASM90121	Diptera	B68	UASM90948	Diptera
C125	UASM90122	Diptera	B69	UASM90949	Pscoptera
C126	UASM90123	Araneae	B70	UASM90950	Coleoptera
C127	UASM90124	Diptera	B71	UASM90951	Araneae
C128	UASM90125	Araneae	B72	UASM90952	Lepidoptera
C129	UASM90126	Araneae	B73	UASM90953	Araneae
C130	UASM90127	Hemiptera	B74	UASM90954	Araneae
C131	UASM90128	Araneae	B75	UASM90955	Araneae
C132	UASM90129	Diptera	B76	UASM90956	Hymenoptera
C133	UASM90130	Diptera	B77	UASM90957	Hemiptera
C134	UASM90131	Diptera	B78	UASM90958	Diptera
C135	UASM90132	Diptera	B79	UASM90959	Pscoptera
C136	UASM90133	Hymenoptera	B80	UASM90960	Acari
C137	UASM90134	Diptera	B81	UASM90961	Hymenoptera
C138	UASM90135	Coleoptera	B82	UASM90962	Diptera
C138b	UASM90136	Coleoptera	B83	UASM90963	Diptera
C138c	UASM90137	Coleoptera	B84	UASM90964	Diptera
C139	UASM90138	Hymenoptera	B85	UASM90965	Coleoptera
C140	UASM90139	Trichoptera	B86	UASM90966	Araneae
C141	UASM90140	Acari	B87	UASM90967	Acari
C142	UASM90141	Coleoptera	B88	UASM90968	Hemiptera
C143	UASM90142	Diptera	B89	UASM90969	Araneae
C144	UASM90143	Diptera	B90	UASM90970	Hymenoptera
C145	UASM90144	Diptera	B91	UASM90971	Araneae

C146	UASM90145	Acari	B92	UASM90972	Araneae
C147	UASM90146	Hymenoptera	B93	UASM90973	Araneae
C148	UASM90147	Diptera	B94	UASM90974	Araneae
C149	UASM90148	Hymenoptera	B95	UASM90975	Hymenoptera
C150	UASM90149	Hymenoptera	B96	UASM90976	Diptera
C151	UASM90150	Araneae	B97	UASM90977	Pscoptera
C152	UASM90151	Hemiptera	B98	UASM90978	Acari
C153	UASM90152	Araneae	B99	UASM90979	Acari
C154	UASM90153	Coleoptera	B100	UASM90980	Diptera
C155	UASM90154	Diptera	B101	UASM90981	Araneae
C156	UASM90155	Diptera	B102	UASM90982	Diptera
C157	UASM90156	Acari	B103	UASM90983	Diptera
C158	UASM90157	Diptera	B104	UASM90984	Hemiptera
C159	UASM90158	Hymenoptera	B105	UASM90985	Araneae
C161	UASM90160	Araneae	B106	UASM90986	Diptera
C163	UASM90161	Diptera	B107	UASM90987	Diptera
C164	UASM90162	Coleoptera	B108	UASM90988	Hemiptera
C165	UASM90163	Hymenoptera	B109	UASM90989	Neuroptera
C166	UASM90164	Araneae	B110	UASM90990	Araneae
C168	UASM90165	Hymenoptera	B111	UASM90991	Diptera
C169	UASM90166	Acari	B112	UASM90992	Araneae
C170	UASM90167	Hymenoptera	B113	UASM90993	Acari
C171	UASM90168	Araneae	B114	UASM90994	Hemiptera
C172	UASM90169	Hemiptera	B115	UASM90995	Coleoptera
C173	UASM90170	Hymenoptera	B116	UASM90996	Hemiptera
C174	UASM90171	Hymenoptera	B117	UASM90997	Araneae
C175	UASM90172	Diptera	B118	UASM90998	Araneae
C176	UASM90173	Diptera	B119	UASM90999	Coleoptera
C177	UASM90174	Coleoptera	B120	UASM91000	Diptera
C178	UASM90175	Hymenoptera	B121	UASM91001	Hymenoptera
C179	UASM90176	Hemiptera	B122	UASM91002	Diptera
C180	UASM90177	Hemiptera	B123	UASM91003	Hemiptera
C181	UASM90178	Diptera	B124	UASM91004	Hymenoptera
C182	UASM90179	Coleoptera	B125	UASM91005	Araneae
C183	UASM90180	Araneae	B126	UASM91006	Araneae
C184	UASM90181	Coleoptera	B127	UASM91007	Diptera
C185	UASM90182	Coleoptera	B128	UASM91008	Hymenoptera
C186	UASM90183	Diptera	B129	UASM91009	Acari
C187	UASM90184	Lepidoptera	B133	UASM91010	Trichoptera
C190	UASM90185	Coleoptera	B134	UASM91011	Hemiptera
C191	UASM90186	Diptera	B135	UASM91012	Diptera
C192	UASM90187	Hemiptera	B136	UASM91013	Araneae
C193	UASM90188	Diptera	B137	UASM91014	Acari
C194	UASM90189	Hemiptera	B138	UASM91015	Hymenoptera
C195	UASM90190	Hemiptera	B139	UASM91016	Diptera
C196	UASM90191	Diptera	B140	UASM91017	Hemiptera
C197	UASM90192	Hymenoptera	B141	UASM91018	Hymenoptera
C198	UASM90193	Hymenoptera	B142	UASM91019	Diptera
C199	UASM90194	Diptera	B143	UASM91020	Diptera
C200	UASM90195	Diptera	B144	UASM91021	Hemiptera

C201	UASM90196	Diptera	B145	UASM91022	Diptera
C202	UASM90197	Araneae	B146	UASM91023	Araneae
C203	UASM90198	Hymenoptera	B147	UASM91024	Hymenoptera
C204	UASM90199	Acari	B148	UASM91025	Diptera
C205	UASM90200	Coleoptera	B149	UASM91026	Acari
C206	UASM90201	Coleoptera	B150	UASM91027	Diptera
C207	UASM90202	Coleoptera	B151	UASM91028	Diptera
C208	UASM90203	Coleoptera	B152	UASM91029	Araneae
C209	UASM90204	Lepidoptera	B153	UASM91030	Diptera
C210	UASM90205	Hymenoptera	B154	UASM91031	Diptera
C211	UASM90206	Araneae	B155	UASM91032	Araneae
C212	UASM90207	Acari	B156	UASM91033	Hymenoptera
C213	UASM90208	Diptera	B157	UASM91034	Hymenoptera
C214	UASM90209	Coleoptera	B158	UASM91035	Diptera
C215	UASM90210	Acari	B159	UASM91036	Acari
C216	UASM90211	Coleoptera	B160	UASM91037	Diptera
C217	UASM90212	Araneae	B161	UASM91038	Araneae
C218	UASM90213	Araneae	B162	UASM91039	Coleoptera
C219	UASM90214	Hemiptera	B163	UASM91040	Araneae
C220	UASM90215	Hymenoptera	B164	UASM91041	Diptera
C221	UASM90216	Acari	B165	UASM91042	Araneae
C222	UASM90217	Hymenoptera	B166	UASM91043	Coleoptera
C224	UASM90218	Araneae	B167	UASM91044	Araneae
C225	UASM90219	Hymenoptera	B168	UASM91045	Opilione
C226	UASM90220	Diptera	B169	UASM91046	Hymenoptera
C227	UASM90221	Acari	B170	UASM91047	Acari
C228	UASM90222	Diptera	B171	UASM91048	Coleoptera
C229	UASM90223	Lepidoptera	B172	UASM91049	Coleoptera
C230	UASM90224	Araneae	B173	UASM91050	Diptera
C231	UASM90225	Diptera	B174	UASM91051	Diptera
C232	UASM90226	Diptera	B175	UASM91052	Hymenoptera
C233	UASM90227	Hymenoptera	B176	UASM91053	Coleoptera
C234	UASM90228	Hymenoptera	B177	UASM91054	Araneae
C235	UASM90229	Acari	B178	UASM91055	Araneae
C236	UASM90230	Diptera	B179	UASM91056	Opilione
C237	UASM90231	Diptera	B180	UASM91057	Lepidoptera
C238	UASM90232	Araneae	B181	UASM91058	Hymenoptera
C239	UASM90233	Araneae	B182	UASM91059	Collembola
C240	UASM90234	Hymenoptera	B183	UASM91060	Diptera
C241	UASM90235	Diptera	B184	UASM91061	Acari
C242	UASM90236	Hymenoptera	B185	UASM91062	Hymenoptera
C243	UASM90237	Hymenoptera	B186	UASM91063	Hymenoptera
C244	UASM90238	Diptera	B187	UASM91064	Acari
C245	UASM90239	Diptera	B188	UASM91065	Araneae
C246	UASM90240	Diptera	B189	UASM91066	Araneae
C247	UASM90241	Diptera	B190	UASM91067	Hymenoptera
C248	UASM90242	Diptera	B191	UASM91068	Diptera
C249	UASM90243	Diptera	B192	UASM91069	Diptera
C250	UASM90244	Hemiptera	B193	UASM91070	Coleoptera
C251	UASM90245	Hymenoptera	B194	UASM91071	Hymenoptera

C252	UASM90246	Coleoptera	B195	UASM91072	Collembola
C253	UASM90247	Araneae	B196	UASM91073	Collembola
C254	UASM90248	Coleoptera	B197	UASM91074	Araneae
C255	UASM90249	Hemiptera	B198	UASM91075	Collembola
C256	UASM90250	Diptera	B199	UASM91076	Collembola
C257	UASM90251	Coleoptera	B200	UASM91077	Diptera
C258	UASM90252	Diptera	B201	UASM91078	Araneae
C259	UASM90253	Hymenoptera	B202	UASM91079	Acari
C260	UASM90254	Hemiptera	B203	UASM91080	Araneae
C261	UASM90255	Acari	B204	UASM91081	Diptera
C262	UASM90256	Coleoptera	B206	UASM91082	Diptera
C263	UASM90257	Hymenoptera	B207	UASM91083	Diptera
C264	UASM90258	Hymenoptera	B208	UASM91084	Diptera
C265	UASM90259	Coleoptera	B209	UASM91085	Hymenoptera
C266	UASM90260	Araneae	B210	UASM91086	Diptera
C267	UASM90261	Coleoptera	B211	UASM91087	Hemiptera
C268	UASM90262	Diptera	B212	UASM91088	Araneae
C269	UASM90263	Diptera	B213	UASM91089	Araneae
C270	UASM90264	Diptera	B214	UASM91090	Acari
C271	UASM90265	Diptera	B215	UASM91091	Hemiptera
C272	UASM90266	Acari	B216	UASM91092	Acari
C273	UASM90267	Diptera	B217	UASM91093	Coleoptera
C274	UASM90268	Acari	B218	UASM91094	Araneae
C275	UASM90269	Diptera	B219	UASM91095	Acari
C276	UASM90270	Collembola	B220	UASM91096	Collembola
C277	UASM90271	Araneae	B221	UASM91097	Hymenoptera
C278	UASM90272	Coleoptera	B222	UASM91098	Hymenoptera
C279	UASM90273	Diptera	B223	UASM91099	Araneae
C280	UASM90274	Diptera	B224	UASM91100	Hemiptera
C281	UASM90275	Diptera	B225	UASM91101	Diptera
C282	UASM90276	Acari	B226	UASM91102	Coleoptera
C283	UASM90277	Diptera	B227	UASM91103	Diptera
C284	UASM90278	Hemiptera	B228	UASM91104	Acari
C285	UASM90279	Hymenoptera	B229	UASM91105	Araneae
C286	UASM90280	Hymenoptera	B230	UASM91106	Collembola
C287	UASM90281	Hymenoptera	B231	UASM91107	Araneae
C288	UASM90282	Araneae	B232	UASM91108	Hymenoptera
C289	UASM90283	Collembola	B234	UASM91109	Araneae
C290	UASM90284	Diptera	B235	UASM91110	Coleoptera
C291	UASM90285	Coleoptera	B236	UASM91111	Hymenoptera
C292	UASM90286	Coleoptera	B237	UASM91112	Coleoptera
C293	UASM90287	Coleoptera	B238	UASM91113	Hymenoptera
C294	UASM90288	Diptera	B239	UASM91114	Diptera
C295	UASM90289	Coleoptera	B240	UASM91115	Diptera
C296	UASM90290	Acari	B241	UASM91116	Araneae
C297	UASM90291	Hymenoptera	B242	UASM91117	Collembola
C298	UASM90292	Araneae	B243	UASM91118	Araneae
C299	UASM90293	Hemiptera	B244	UASM91119	Hymenoptera
C300	UASM90294	Coleoptera	B245	UASM91120	Araneae
C301	UASM90295	Diptera	B246	UASM91121	Diptera

C302	UASM90296	Acari	B247	UASM91122	Acari
C303	UASM90297	Collembola	B248	UASM91123	Araneae
C304	UASM90298	Araneae	B249	UASM91124	Coleoptera
C305	UASM90299	Acari	B250	UASM91125	Hymenoptera
C306	UASM90300	Diptera	B251	UASM91126	Araneae
C307	UASM90301	Hymenoptera	B252	UASM91127	Collembola
C308	UASM90302	Diptera	B253	UASM91128	Diptera
C309	UASM90303	Diptera	B254	UASM91129	Hymenoptera
C310	UASM90304	Diptera	B255	UASM91130	Araneae
C311	UASM90305	Hymenoptera	B256	UASM91131	Acari
C312	UASM90306	Diptera	B257	UASM91132	Araneae
C313	UASM90307	Coleoptera	B258	UASM91133	Diptera
C314	UASM90308	Acari	B259	UASM91134	Coleoptera
C315	UASM90309	Diptera	B260	UASM91135	Araneae
C316	UASM90310	Diptera	B261	UASM91136	Araneae
C317	UASM90311	Lepidoptera	B262	UASM91137	Araneae
C318	UASM90312	Hymenoptera	B263	UASM91138	Hemiptera
C319	UASM90313	Hymenoptera	B264	UASM91139	Araneae
C320	UASM90314	Diptera	B265	UASM91140	Acari
C321	UASM90315	Diptera	B266	UASM91141	Araneae
C322	UASM90316	Diptera	B267	UASM91142	Hemiptera
C323	UASM90317	Hymenoptera	B269	UASM91143	Acari
C324	UASM90318	Coleoptera	B270	UASM91144	Collembola
C325	UASM90319	Hemiptera	B271	UASM91145	Collembola
C326	UASM90320	Araneae	B272	UASM91146	Diptera
C327	UASM90321	Araneae	B273	UASM91147	Diptera
C328	UASM90322	Diptera	B274	UASM91148	Acari
C329	UASM90323	Hymenoptera	B275	UASM91149	Araneae
C330	UASM90324	Coleoptera	B276	UASM91150	Acari
C331	UASM90325	Collembola	B277	UASM91151	Araneae
C332	UASM90326	Hymenoptera	B278	UASM91152	Lepidoptera
C333	UASM90327	Coleoptera	B279	UASM91153	Araneae
C334	UASM90328	Diptera	B280	UASM91154	Acari
C335	UASM90329	Diptera	B281	UASM91155	Collembola
C336	UASM90330	Araneae	B282	UASM91156	Hymenoptera
C337	UASM90331	Diptera	B283	UASM91157	Hymenoptera
C338	UASM90332	Coleoptera	B284	UASM91158	Hymenoptera
C339	UASM90333	Collembola	B285	UASM91159	Araneae
C340	UASM90334	Collembola	B287	UASM91160	Diptera
C341	UASM90335	Diptera	B288	UASM91161	Acari
C342	UASM90336	Hymenoptera	B289	UASM91162	Lepidoptera
C343	UASM90337	Coleoptera	B290	UASM91163	Collembola
C344	UASM90338	Hemiptera	B291	UASM91164	Hymenoptera
C345	UASM90339	Collembola	B292	UASM91165	Hemiptera
C346	UASM90340	Acari	B293	UASM91166	Acari
C347	UASM90341	Hymenoptera	B294	UASM91167	Araneae
C348	UASM90342	Diptera	B295	UASM91168	Hymenoptera
C349	UASM90343	Acari	B296	UASM91169	Diptera
C350	UASM90344	Araneae	B297	UASM91170	Araneae
C351	UASM90345	Coleoptera	B298	UASM91171	Collembola

C352	UASM90346	Hymenoptera	B299	UASM91172	Araneae
C353	UASM90347	Acari	B300	UASM91173	Diptera
C354	UASM90348	Araneae	B301	UASM91174	Hymenoptera
C355	UASM90349	Araneae	B302	UASM91175	Coleoptera
C356	UASM90350	Acari	B303	UASM91176	Hymenoptera
C358	UASM90351	Araneae	B304	UASM91177	Diptera
C359	UASM90352	Hymenoptera	B305	UASM91178	Acari
C360	UASM90353	Diptera	B306	UASM91179	Diptera
C361	UASM90354	Diptera	B307	UASM91180	Araneae
C362	UASM90355	Coleoptera	B308	UASM91181	Coleoptera
C363	UASM90356	Diptera	B309	UASM91182	Collembola
C364	UASM90357	Acari	B310	UASM91183	Hymenoptera
C365	UASM90358	Coleoptera	B311	UASM91184	Acari
C366	UASM90359	Coleoptera	B312	UASM91185	Hemiptera
C367	UASM90360	Acari	B313	UASM91186	Hymenoptera
C368	UASM90361	Pscoptera	B314	UASM91187	Hymenoptera
C369	UASM90362	Lepidoptera	B315	UASM91188	Coleoptera
C370	UASM90363	Araneae	B316	UASM91189	Acari
C371	UASM90364	Lepidoptera	B317	UASM91190	Coleoptera
C372	UASM90365	Coleoptera	B318	UASM91191	Diptera
C373	UASM90366	Diptera	B319	UASM91192	Diptera
C374	UASM90367	Coleoptera	B320	UASM91193	Hymenoptera
C375	UASM90368	Hymenoptera	B322	UASM91194	Araneae
C376	UASM90369	Araneae	B323	UASM91195	Coleoptera
C377	UASM90370	Diptera	B324	UASM91196	Diptera
C378	UASM90371	Hymenoptera	B325	UASM91197	Diptera
C379	UASM90372	Acari	B326	UASM91198	Diptera
C380	UASM90373	Araneae	B327	UASM91199	Hymenoptera
C381	UASM90374	Acari	B328	UASM91200	Araneae
C382	UASM90375	Acari	B329	UASM91201	Araneae
C383	UASM90376	Hymenoptera	B330	UASM91202	Hymenoptera
C384	UASM90377	Coleoptera	B331	UASM91203	Araneae
C385	UASM90378	Lepidoptera	B332	UASM91204	Diptera
C386	UASM90379	Hymenoptera	B333	UASM91205	Diptera
C387	UASM90380	Diptera	B334	UASM91206	Acari
C388	UASM90381	Hymenoptera	B335	UASM91207	Hemiptera
C389	UASM90382	Araneae	B336	UASM91208	Coleoptera
C390	UASM90383	Acari	B337	UASM91209	Collembola
C391	UASM90384	Coleoptera	B338	UASM91210	Collembola
C392	UASM90385	Araneae	B339	UASM91211	Coleoptera
C393	UASM90386	Araneae	B340	UASM91212	Acari
C394	UASM90387	Acari	B341	UASM91213	Opilione
C395	UASM90388	Acari	B342	UASM91214	Araneae
C397	UASM90389	Diptera	B343	UASM91215	Hymenoptera
C398	UASM90390	Hymenoptera	B344	UASM91216	Hymenoptera
C399	UASM90391	Diptera	B345	UASM91217	Diptera
C400	UASM90392	Diptera	B346	UASM91218	Araneae
C401	UASM90393	Collembola	B347	UASM91219	Coleoptera
C402	UASM90394	Araneae	B348	UASM91220	Diptera
C403	UASM90395	Diptera	B349	UASM91221	Araneae

C404	UASM90396	Acari	B350	UASM91222	Acari
C405	UASM90397	Hemiptera	B351	UASM91223	Collembola
C406	UASM90398	Hymenoptera	B352	UASM91224	Acari
C407	UASM90399	Hemiptera	B353	UASM91225	Lepidoptera
C408	UASM90400	Acari	B354	UASM91226	Araneae
C409	UASM90401	Diptera	B355	UASM91227	Araneae
C410	UASM90402	Diptera	B356	UASM91228	Hymenoptera
C411	UASM90403	Acari	B357	UASM91229	Diptera
C412	UASM90404	Coleoptera	B358	UASM91230	Diptera
C413	UASM90405	Diptera	B359	UASM91231	Coleoptera
C414	UASM90406	Coleoptera	B360	UASM91232	Diptera
C415	UASM90407	Acari	B361	UASM91233	Diptera
C416	UASM90408	Acari	B362	UASM91234	Acari
C417	UASM90409	Coleoptera	B363	UASM91235	Araneae
C418	UASM90410	Hymenoptera	B364	UASM91236	Araneae
C419	UASM90411	Diptera	B365	UASM91237	Araneae
C420	UASM90412	Diptera	B366	UASM91238	Hymenoptera
C421	UASM90413	Diptera	B367	UASM91239	Hymenoptera
C422	UASM90414	Araneae	B368	UASM91240	Diptera
C423	UASM90415	Araneae	B369	UASM91241	Diptera
C424	UASM90416	Diptera	B370	UASM91242	Diptera
C425	UASM90417	Acari	W1	UASM91243	Araneae
C426	UASM90418	Hymenoptera	W2	UASM91244	Coleoptera
C427	UASM90419	Coleoptera	W3	UASM91245	Araneae
C428	UASM90420	Acari	W4	UASM91246	Hemiptera
C429	UASM90421	Lepidoptera	W5	UASM91247	Hymenoptera
C430	UASM90422	Hymenoptera	W6	UASM91248	Hymenoptera
C431	UASM90423	Diptera	W7	UASM91249	Araneae
C432	UASM90424	Diptera	W8	UASM91250	Araneae
C433	UASM90425	Diptera	W9	UASM91251	Araneae
C434	UASM90426	Araneae	W10	UASM91252	Araneae
C435	UASM90427	Hymenoptera	W11	UASM91253	Lepidoptera
C436	UASM90428	Diptera	W12	UASM91254	Hymenoptera
C437	UASM90429	Diptera	W13	UASM91255	Hemiptera
C438	UASM90430	Hymenoptera	W14	UASM91256	Hymenoptera
C439	UASM90431	Coleoptera	W15	UASM91257	Araneae
C440	UASM90432	Diptera	W16	UASM91258	Araneae
C441	UASM90433	Hymenoptera	W17	UASM91259	Pscoptera
C442	UASM90434	Diptera	W18	UASM91260	Diptera
C443	UASM90435	Diptera	W19	UASM91261	Coleoptera
C444	UASM90436	Diptera	W20	UASM91262	Diptera
C445	UASM90437	Diptera	W22	UASM91263	Hemiptera
C446	UASM90438	Diptera	W23	UASM91264	Araneae
C447	UASM90439	Acari	W24	UASM91265	Coleoptera
C448	UASM90440	Acari	W25	UASM91266	Coleoptera
C449	UASM90441	Acari	W27	UASM91267	Araneae
C450	UASM90442	Diptera	W29	UASM91268	Diptera
C451	UASM90443	Hymenoptera	W30	UASM91269	Araneae
C452	UASM90444	Acari	W31	UASM91270	Araneae
C453	UASM90445	Coleoptera	W32	UASM91271	Araneae

C454	UASM90446	Diptera	W33	UASM91272	Araneae
C455	UASM90447	Hymenoptera	W34	UASM91273	Araneae
C456	UASM90448	Diptera	W35	UASM91274	Araneae
C457	UASM90449	Diptera	W36	UASM91275	Diptera
C458	UASM90450	Diptera	W37	UASM91276	Araneae
C459	UASM90451	Hemiptera	W38	UASM91277	Diptera
C460	UASM90452	Hymenoptera	W39	UASM91278	Diptera
C461	UASM90453	Diptera	W40	UASM91279	Diptera
C462	UASM90454	Diptera	W41	UASM91280	Araneae
C463	UASM90455	Hymenoptera	W42	UASM91281	Araneae
C464	UASM90456	Diptera	W43	UASM91282	Araneae
C465	UASM90457	Diptera	W44	UASM91283	Diptera
C466	UASM90458	Hymenoptera	W45	UASM91284	Coleoptera
C467	UASM90459	Diptera	W46	UASM91285	Diptera
C468	UASM90460	Diptera	W47	UASM91286	Diptera
C469	UASM90461	Diptera	W48	UASM91287	Diptera
C470	UASM90462	Acari	W50	UASM91288	Diptera
C471	UASM90463	Coleoptera	W51	UASM91289	Diptera
C472	UASM90464	Hymenoptera	W52	UASM91290	Araneae
C473	UASM90465	Hemiptera	W53	UASM91291	Araneae
C474	UASM90466	Hymenoptera	W54	UASM91292	Diptera
C475	UASM90467	Araneae	W55	UASM91293	Neuroptera
C476	UASM90468	Hemiptera	W56	UASM91294	Hymenoptera
C477	UASM90469	Diptera	W57	UASM91295	Acari
C478	UASM90470	Diptera	W58	UASM91296	Araneae
C479	UASM90471	Coleoptera	W59	UASM91297	Araneae
C480	UASM90472	Diptera	W60	UASM91298	Araneae
C481	UASM90473	Lepidoptera	W61	UASM91299	Diptera
C482	UASM90474	Hymenoptera	W62	UASM91300	Diptera
C483	UASM90475	Diptera	W63	UASM91301	Acari
C484	UASM90476	Diptera	W64	UASM91302	Araneae
C485	UASM90477	Acari	W65	UASM91303	Araneae
C486	UASM90478	Araneae	W66	UASM91304	Araneae
C487	UASM90479	Diptera	W67	UASM91305	Diptera
C488	UASM90480	Araneae	W68	UASM91306	Diptera
C489	UASM90481	Araneae	W69	UASM91307	Trichoptera
C490	UASM90482	Diptera	W70	UASM91308	Diptera
C491	UASM90483	Araneae	W71	UASM91309	Acari
C492	UASM90484	Diptera	W72	UASM91310	Araneae
C493	UASM90485	Lepidoptera	W73	UASM91311	Araneae
C494	UASM90486	Araneae	W74	UASM91312	Hemiptera
C495	UASM90487	Acari	W75	UASM91313	Acari
C496	UASM90488	Diptera	W76	UASM91314	Araneae
C497	UASM90489	Acari	W77	UASM91315	Araneae
C498	UASM90490	Diptera	W78	UASM91316	Neuroptera
C499	UASM90491	Acari	W79	UASM91317	Acari
C501	UASM90492	Lepidoptera	W80	UASM91318	Araneae
C502	UASM90493	Diptera	W81	UASM91319	Diptera
C503	UASM90494	Araneae	W82	UASM91320	Diptera
C504	UASM90495	Hymenoptera	W83	UASM91321	Acari

C505	UASM90496	Diptera	W84	UASM91322	Hemiptera
C506	UASM90497	Coleoptera	W85	UASM91323	Araneae
C507	UASM90498	Araneae	W88	UASM91324	Diptera
C508	UASM90499	Coleoptera	W89	UASM91325	Acari
C509	UASM90500	Diptera	W90	UASM91326	Araneae
C510	UASM90501	Diptera	W91	UASM91327	Acari
C511	UASM90502	Hymenoptera	W92	UASM91328	Araneae
C512	UASM90503	Coleoptera	W93	UASM91329	Acari
C513	UASM90504	Diptera	W94	UASM91330	Acari
C514	UASM90505	Acari	W95	UASM91331	Acari
C515	UASM90506	Collembola	W96	UASM91332	Araneae
C516	UASM90507	Diptera	W97	UASM91333	Acari
C517	UASM90508	Opilione	W98	UASM91334	Diptera
C518	UASM90509	Lepidoptera	W99	UASM91335	Diptera
C519	UASM90510	Diptera	W100	UASM91336	Diptera
C520	UASM90511	Diptera	W101	UASM91337	Araneae
C521	UASM90512	Hymenoptera	W102	UASM91338	Acari
C522	UASM90513	Diptera	W103	UASM91339	Araneae
C523	UASM90514	Diptera	W104	UASM91340	Araneae
C524	UASM90515	Araneae	W105	UASM91341	Neuroptera
C525	UASM90516	Diptera	W106	UASM91342	Diptera
C526	UASM90517	Hymenoptera	W107	UASM91343	Araneae
C527	UASM90518	Araneae	W108	UASM91344	Diptera
C528	UASM90519	Araneae	W109	UASM91345	Hemiptera
C529	UASM90520	Coleoptera	W110	UASM91346	Lepidoptera
C530	UASM90521	Diptera	W111	UASM91347	Diptera
C531	UASM90522	Diptera	W112	UASM91348	Diptera
C532	UASM90523	Acari	W113	UASM91349	Coleoptera
C533	UASM90524	Araneae	W114	UASM91350	Araneae
C534	UASM90525	Diptera	W115	UASM91351	Diptera
C535	UASM90526	Diptera	W116	UASM91352	Hymenoptera
C536	UASM90527	Hymenoptera	W117	UASM91353	Diptera
C537	UASM90528	Hymenoptera	W118	UASM91354	Diptera
C538	UASM90529	Araneae	W119	UASM91355	Acari
C539	UASM90530	Araneae	W120	UASM91356	Hemiptera
C540	UASM90531	Diptera	W121	UASM91357	Diptera
M1	UASM90532	Coleoptera	W122	UASM91358	Hymenoptera
M2	UASM90533	Diptera	W123	UASM91359	Diptera
M3	UASM90534	Diptera	W124	UASM91360	Hymenoptera
M4	UASM90535	Araneae	W125	UASM91361	Diptera
M6	UASM90536	Diptera	W126	UASM91362	Pscoptera
M7	UASM90537	Araneae	W127	UASM91363	Diptera
M8	UASM90538	Araneae	W128	UASM91364	Lepidoptera
M9	UASM90539	Araneae	W129	UASM91365	Coleoptera
M10	UASM90540	Diptera	W130	UASM91366	Coleoptera
M11	UASM90541	Hymenoptera	W131	UASM91367	Araneae
M12	UASM90542	Diptera	W132	UASM91368	Acari
M13	UASM90543	Araneae	W133	UASM91369	Araneae
M14	UASM90544	Diptera	W134	UASM91370	Araneae
M15	UASM90545	Diptera	W135	UASM91371	Araneae

M16	UASM90546	Hemiptera	W136	UASM91372	Diptera
M17	UASM90547	Diptera	W137	UASM91373	Pscoptera
M18	UASM90548	Hemiptera	W138	UASM91374	Lepidoptera
M19	UASM90549	Araneae	W139	UASM91375	Diptera
M20	UASM90550	Araneae	W140	UASM91376	Araneae
M21	UASM90551	Araneae	W141	UASM91377	Araneae
M22	UASM90552	Hemiptera	W142	UASM91378	Hymenoptera
M23	UASM90553	Hymenoptera	W143	UASM91379	Diptera
M24	UASM90554	Araneae	W145	UASM91380	Diptera
M25	UASM90555	Lepidoptera	W146	UASM91381	Diptera
M26	UASM90556	Lepidoptera	W148	UASM91382	Diptera
M27	UASM90557	Araneae	W149	UASM91383	Diptera
M28	UASM90558	Acari	W150	UASM91384	Coleoptera
M29	UASM90559	Coleoptera	W151	UASM91385	Hymenoptera
M30	UASM90560	Araneae	W152	UASM91386	Araneae
M31	UASM90561	Araneae	W153	UASM91387	Diptera
M32	UASM90562	Acari	W154	UASM91388	Acari
M33	UASM90563	Hemiptera	W155	UASM91389	Diptera
M34	UASM90564	Araneae	W156	UASM91390	Collembola
M35	UASM90565	Diptera	W157	UASM91391	Diptera
M36	UASM90566	Lepidoptera	W158	UASM91392	Diptera
M37	UASM90567	Diptera	W159	UASM91393	Diptera
M37a	UASM90568	Coleoptera	W160	UASM91394	Diptera
M38	UASM90569	Araneae	W161	UASM91395	Araneae
M38a	UASM90570	Acari	W162	UASM91396	Araneae
M39	UASM90571	Coleoptera	W163	UASM91397	Collembola
M39a	UASM90572	Araneae	W164	UASM91398	Lepidoptera
M40	UASM90573	Coleoptera	W165	UASM91399	Coleoptera
M41	UASM90574	Diptera	W166	UASM91400	Diptera
M41a	UASM90575	Araneae	W167	UASM91401	Acari
M42	UASM90576	Hymenoptera	W168	UASM91402	Hymenoptera
M42a	UASM90577	Diptera	W169	UASM91403	Diptera
M43	UASM90578	Hemiptera	W170	UASM91404	Diptera
M43a	UASM90579	Hemiptera	W171	UASM91405	Hemiptera
M44	UASM90580	Hemiptera	W172	UASM91406	Diptera
M45	UASM90581	Hemiptera	W173	UASM91407	Hymenoptera
M46	UASM90582	Diptera	W174	UASM91408	Araneae
M47	UASM90583	Araneae	W175	UASM91409	Diptera
M48	UASM90584	Hymenoptera	W176	UASM91410	Acari
M49	UASM90585	Acari	W177	UASM91411	Coleoptera
M50	UASM90586	Hemiptera	W178	UASM91412	Collembola
M51	UASM90587	Acari	W179	UASM91413	Acari
M52	UASM90588	Araneae	W180	UASM91414	Diptera
M53	UASM90589	Araneae	W181	UASM91415	Hymenoptera
M54	UASM90590	Hymenoptera	W182	UASM91416	Araneae
M55	UASM90591	Coleoptera	W183	UASM91417	Diptera
M56	UASM90592	Diptera	W184	UASM91418	Araneae
M58	UASM90593	Hemiptera	W185	UASM91419	Diptera
M59	UASM90594	Araneae	W186	UASM91420	Araneae
M60	UASM90595	Diptera	W187	UASM91421	Araneae

M61	UASM90596	Acari	W188	UASM91422	Araneae
M62	UASM90597	Acari	W189	UASM91423	Diptera
M63	UASM90598	Hymenoptera	W190	UASM91424	Araneae
M64	UASM90599	Araneae	W191	UASM91425	Araneae
M65	UASM90600	Araneae	W192	UASM91426	Hymenoptera
M66	UASM90601	Diptera	W193	UASM91427	Hymenoptera
M67	UASM90602	Coleoptera	W194	UASM91428	Collembola
M68	UASM90603	Diptera	W195	UASM91429	Araneae
M69	UASM90604	Diptera	W196	UASM91430	Acari
M70	UASM90605	Hymenoptera	W197	UASM91431	Collembola
M71	UASM90606	Diptera	W198	UASM91432	Coleoptera
M72	UASM90607	Hemiptera	W199	UASM91433	Hemiptera
M73	UASM90608	Diptera	W200	UASM91434	Diptera
M74	UASM90609	Diptera	W201	UASM91435	Acari
M75	UASM90610	Hymenoptera	W202	UASM91436	Collembola
M76	UASM90611	Diptera	W203	UASM91437	Hymenoptera
M77	UASM90612	Hemiptera	W204	UASM91438	Diptera
M78	UASM90613	Hymenoptera	W205	UASM91439	Araneae
M79	UASM90614	Diptera	W206	UASM91440	Araneae
M80	UASM90615	Acari	W207	UASM91441	Acari
M81	UASM90616	Araneae	W208	UASM91442	Acari
M82	UASM90617	Araneae	W209	UASM91443	Collembola
M83	UASM90618	Diptera	W210	UASM91444	Araneae
M84	UASM90619	Diptera	W211	UASM91445	Acari
M85	UASM90620	Coleoptera	W212	UASM91446	Acari
M86	UASM90621	Diptera	W213	UASM91447	Araneae
M87	UASM90622	Diptera	W214	UASM91448	Diptera
M88	UASM90623	Diptera	W215	UASM91449	Diptera
M89	UASM90624	Hymenoptera	W216	UASM91450	Araneae
M90	UASM90625	Araneae	W217	UASM91451	Collembola
M91	UASM90626	Hymenoptera	W218	UASM91452	Acari
M92	UASM90627	Hemiptera	W219	UASM91453	Araneae
M93	UASM90628	Hemiptera	W220	UASM91454	Hemiptera
M94	UASM90629	Hymenoptera	W221	UASM91455	Araneae
M95	UASM90630	Diptera	W222	UASM91456	Acari
M96	UASM90631	Diptera	W223	UASM91457	Collembola
M97	UASM90632	Diptera	W224	UASM91458	Acari
M98	UASM90633	Diptera	W225	UASM91459	Hymenoptera
M99	UASM90634	Acari	W226	UASM91460	Collembola
M100	UASM90635	Araneae	W227	UASM91461	Araneae
M101	UASM90636	Hemiptera	W228	UASM91462	Araneae
M102	UASM90637	Diptera	W229	UASM91463	Diptera
M103	UASM90638	Diptera	W230	UASM91464	Acari
M104	UASM90639	Acari	W231	UASM91465	Coleoptera
M105	UASM90640	Araneae	W232	UASM91466	Acari
M106	UASM90641	Hemiptera	W233	UASM91467	Coleoptera
M107	UASM90642	Araneae	W234	UASM91468	Araneae
M108	UASM90643	Diptera	W235	UASM91469	Araneae
M110	UASM90644	Diptera	W236	UASM91470	Opilione
M111	UASM90645	Coleoptera	W237	UASM91471	Collembola

M112	UASM90646	Diptera	W238	UASM91472	Acari
M113	UASM90647	Hemiptera	W239	UASM91473	Acari
M114	UASM90648	Diptera	W240	UASM91474	Coleoptera
M115	UASM90649	Diptera	W242	UASM91475	Coleoptera
M116	UASM90650	Diptera	W243	UASM91476	Acari
M117	UASM90651	Diptera	W244	UASM91477	Araneae
M118	UASM90652	Diptera	W245	UASM91478	Acari
M119	UASM90653	Hemiptera	W246	UASM91479	Hemiptera
M120	UASM90654	Hymenoptera	W247	UASM91480	Araneae
M121	UASM90655	Acari	W248	UASM91481	Acari
M122	UASM90656	Diptera	W249	UASM91482	Acari
M123	UASM90657	Diptera	W251	UASM91483	Acari
M124	UASM90658	Acari	W252	UASM91484	Acari
M125	UASM90659	Acari	W253	UASM91485	Collembola
M127	UASM90660	Diptera	W254	UASM91486	Diptera
M128	UASM90661	Acari	W255	UASM91487	Diptera
M129	UASM90662	Hemiptera	W256	UASM91488	Diptera
M130	UASM90663	Diptera	W258	UASM91489	Diptera
M131	UASM90664	Diptera	W259	UASM91490	Hemiptera
M132	UASM90665	Araneae	W260	UASM91491	Acari
M133	UASM90666	Hemiptera	W261	UASM91492	Acari
M134	UASM90667	Araneae	W262	UASM91493	Araneae
M135	UASM90668	Hymenoptera	W263	UASM91494	Acari
M136	UASM90669	Diptera	W264	UASM91495	Araneae
M137	UASM90670	Diptera	W265	UASM91496	Araneae
M138	UASM90671	Diptera	W266	UASM91497	Collembola
M139	UASM90672	Araneae	W267	UASM91498	Diptera
M140	UASM90673	Araneae	W268	UASM91499	Diptera
M141	UASM90674	Hemiptera	W269	UASM91500	Hymenoptera
M142	UASM90675	Hymenoptera	W270	UASM91501	Diptera
M143	UASM90676	Hemiptera	W271	UASM91502	Diptera
M144	UASM90677	Araneae	W272	UASM91503	Collembola
M145	UASM90678	Hymenoptera	W273	UASM91504	Acari
M146	UASM90679	Hymenoptera	W274	UASM91505	Acari
M147	UASM90680	Hemiptera	W275	UASM91506	Araneae
M148	UASM90681	Lepidoptera	W276	UASM91507	Araneae
M149	UASM90682	Diptera	W277	UASM91508	Diptera
M150	UASM90683	Acari	W278	UASM91509	Acari
M151	UASM90684	Diptera	W279	UASM91510	Araneae
M152	UASM90685	Diptera	W280	UASM91511	Araneae
M153	UASM90686	Diptera	W281	UASM91512	Araneae
M154	UASM90687	Hymenoptera	W282	UASM91513	Hymenoptera
M155	UASM90688	Araneae	W283	UASM91514	Hymenoptera
M156	UASM90689	Diptera	W284	UASM91515	Diptera
M157	UASM90690	Diptera	W285	UASM91516	Diptera
M158	UASM90691	Diptera	W286	UASM91517	Diptera
M159	UASM90692	Diptera	W287	UASM91518	Araneae
M160	UASM90693	Hemiptera	W288	UASM91519	Hemiptera
M161	UASM90694	Araneae	W289	UASM91520	Diptera
M162	UASM90695	Araneae	W290	UASM91521	Araneae

M163	UASM90696	Hymenoptera	W291	UASM91522	Diptera
M164	UASM90697	Araneae	W292	UASM91523	Araneae
M165	UASM90698	Acari	W293	UASM91524	Acari
M166	UASM90699	Araneae	W294	UASM91525	Acari
M167	UASM90700	Hymenoptera	W295	UASM91526	Araneae
M168	UASM90701	Hymenoptera	W296	UASM91527	Acari
M169	UASM90702	Araneae	W297	UASM91528	Diptera
M170	UASM90703	Diptera	W298	UASM91529	Araneae
M171	UASM90704	Diptera	W299	UASM91530	Diptera
M172	UASM90705	Hemiptera	W300	UASM91531	Araneae
M173	UASM90706	Opilione	W301	UASM91532	Diptera
M174	UASM90707	Diptera	W302	UASM91533	Diptera
M175	UASM90708	Hemiptera	W303	UASM91534	Acari
M176	UASM90709	Hymenoptera	W304	UASM91535	Coleoptera
M177	UASM90710	Araneae	W306	UASM91536	Araneae
M178	UASM90711	Hymenoptera	W307	UASM91537	Coleoptera
M179	UASM90712	Hymenoptera	W308	UASM91538	Araneae
M180	UASM90713	Hemiptera	W309	UASM91539	Diptera
M181	UASM90714	Diptera	W310	UASM91540	Araneae
M182	UASM90715	Diptera	W311	UASM91541	Acari
M183	UASM90716	Diptera	W312	UASM91542	Coleoptera
M184	UASM90717	Diptera	Ct1	UASM91543	Diptera
M185	UASM90718	Diptera	Ct2	UASM91544	Araneae
M186	UASM90719	Diptera	Ct3	UASM91545	Araneae
M187	UASM90720	Hymenoptera	Ct4	UASM91546	Araneae
M188	UASM90721	Hymenoptera	Ct5	UASM91547	Araneae
M189	UASM90722	Acari	Ct6	UASM91548	Coleoptera
M190	UASM90723	Acari	Ct7	UASM91549	Araneae
M191	UASM90724	Diptera	Ct8	UASM91550	Lepidoptera
M192	UASM90725	Araneae	Ct9	UASM91551	Araneae
M193	UASM90726	Araneae	Ct10	UASM91552	Araneae
M194	UASM90727	Hemiptera	Ct11	UASM91553	Coleoptera
M195	UASM90728	Opilione	Ct12	UASM91554	Araneae
M196	UASM90729	Acari	Ct13	UASM91555	Acari
M197	UASM90730	Hemiptera	Ct14	UASM91556	Coleoptera
M198	UASM90731	Araneae	Ct15	UASM91557	Araneae
M199	UASM90732	Diptera	Ct16	UASM91558	Araneae
M200	UASM90733	Diptera	Ct17	UASM91559	Diptera
M201	UASM90734	Diptera	Ct18	UASM91560	Coleoptera
M202	UASM90735	Hemiptera	Ct19	UASM91561	Araneae
M203	UASM90736	Hemiptera	Ct20	UASM91562	Lepidoptera
M204	UASM90737	Hymenoptera	Ct21	UASM91563	Araneae
M205	UASM90738	Diptera	Ct22	UASM91564	Araneae
M206	UASM90739	Hymenoptera	Ct23	UASM91565	Acari
M207	UASM90740	Diptera	Ct24	UASM91566	Araneae
M208	UASM90741	Coleoptera	Ct25	UASM91567	Araneae
M209	UASM90742	Acari	Ct26	UASM91568	Coleoptera
M210	UASM90743	Araneae	Ct27	UASM91569	Coleoptera
M211	UASM90744	Diptera	Ct28	UASM91570	Diptera
M212	UASM90745	Hymenoptera	Ct29	UASM91571	Diptera

M213	UASM90746	Diptera	Ct30	UASM91572	Hymenoptera
M214	UASM90747	Hymenoptera	Ct31	UASM91573	Diptera
M215	UASM90748	Araneae	Ct32	UASM91574	Acari
M216	UASM90749	Hymenoptera	Ct33	UASM91575	Diptera
M217	UASM90750	Coleoptera	Ct34	UASM91576	Diptera
M218	UASM90751	Diptera	Ct35	UASM91577	Acari
M219	UASM90752	Diptera	Ct36	UASM91578	Hemiptera
M220	UASM90753	Diptera	Ct37	UASM91579	Hymenoptera
M221	UASM90754	Hymenoptera	Ct38	UASM91580	Araneae
M222	UASM90755	Hymenoptera	Ct39	UASM91581	Araneae
M223	UASM90756	Hymenoptera	Ct40	UASM91582	Araneae
M224	UASM90757	Araneae	Ct41	UASM91583	Diptera
M225	UASM90758	Diptera	Ct42	UASM91584	Hemiptera
M226	UASM90759	Coleoptera	Ct43	UASM91585	Araneae
M227	UASM90760	Araneae	Ct44	UASM91586	Hemiptera
M228	UASM90761	Araneae	Ct45	UASM91587	Araneae
M229	UASM90762	Araneae	Ct46	UASM91588	Hymenoptera
M230	UASM90763	Acari	Ct47	UASM91589	Diptera
M231	UASM90764	Araneae	Ct48	UASM91590	Acari
M232	UASM90765	Hymenoptera	Ct49	UASM91591	Araneae
M233	UASM90766	Diptera	Ct50	UASM91592	Araneae
M234	UASM90767	Diptera	Ct51	UASM91593	Diptera
M235	UASM90768	Hymenoptera	Ct52	UASM91594	Hymenoptera
M236	UASM90769	Hymenoptera	Ct53	UASM91595	Hymenoptera
M237	UASM90770	Araneae	Ct56	UASM91596	Araneae
M238	UASM90771	Diptera	Ct57	UASM91597	Acari
M239	UASM90772	Lepidoptera	Ct58	UASM91598	Araneae
M240	UASM90773	Hymenoptera	Ct59	UASM91599	Coleoptera
M241	UASM90774	Acari	Ct60	UASM91600	Acari
M242	UASM90775	Diptera	Ct61	UASM91601	Araneae
M243	UASM90776	Diptera	Ct62	UASM91602	Diptera
M244	UASM90777	Hymenoptera	Ct63	UASM91603	Araneae
M245	UASM90778	Araneae	Ct64	UASM91604	Hemiptera
M246	UASM90779	Araneae	Ct65	UASM91605	Hymenoptera
M247	UASM90780	Hymenoptera	Ct66	UASM91606	Collembola
M248	UASM90781	Diptera	Ct67	UASM91607	Araneae
M249	UASM90782	Diptera	Ct68	UASM91608	Hymenoptera
M250	UASM90783	Diptera	Ct69	UASM91609	Diptera
M251	UASM90784	Diptera	Ct70	UASM91610	Hymenoptera
M252	UASM90785	Diptera	Ct71	UASM91611	Diptera
M253	UASM90786	Diptera	Ct72	UASM91612	Hymenoptera
M254	UASM90787	Coleoptera	Ct73	UASM91613	Araneae
M255	UASM90788	Hymenoptera	Ct74	UASM91614	Coleoptera
M256	UASM90789	Coleoptera	Ct75	UASM91615	Diptera
M257	UASM90790	Acari	Ct76	UASM91616	Acari
M258	UASM90791	Acari	Ct77	UASM91617	Diptera
M259	UASM90792	Araneae	Ct78	UASM91618	Collembola
M260	UASM90793	Hymenoptera	Ct79	UASM91619	Araneae
M261	UASM90794	Diptera	Ct80	UASM91620	Araneae
M262	UASM90795	Diptera	Ct81	UASM91621	Acari

M263	UASM90796	Hemiptera	Ct82	UASM91622	Hymenoptera
M264	UASM90797	Diptera	Ct83	UASM91623	Diptera
M265	UASM90798	Diptera	Ct84	UASM91624	Hymenoptera
M266	UASM90799	Araneae	Ct85	UASM91625	Hymenoptera
M267	UASM90800	Coleoptera	Ct86	UASM91626	Acari
M268	UASM90801	Diptera	Ct87	UASM91627	Diptera
M269	UASM90802	Diptera	Ct88	UASM91628	Diptera
M270	UASM90803	Diptera	Ct89	UASM91629	Araneae
M271	UASM90804	Hymenoptera	Ct90	UASM91630	Hymenoptera
M272	UASM90805	Hymenoptera	Ct91	UASM91631	Araneae
M273	UASM90806	Hymenoptera	Ct92	UASM91632	Diptera
M274	UASM90807	Diptera	Ct93	UASM91633	Lepidoptera
M275	UASM90808	Diptera	Ct94	UASM91634	Araneae
M276	UASM90809	Acari	Ct95	UASM91635	Diptera
M277	UASM90810	Araneae	Ct96	UASM91636	Coleoptera
M278	UASM90811	Araneae	Ct97	UASM91637	Acari
M279	UASM90812	Acari	Ct98	UASM91638	Acari
M280	UASM90813	Coleoptera	Ct99	UASM91639	Araneae
M281	UASM90814	Hymenoptera	Ct100	UASM91640	Hemiptera
M282	UASM90815	Diptera	Ct101	UASM91641	Hemiptera
M283	UASM90816	Diptera	Ct102	UASM91642	Araneae
M284	UASM90817	Lepidoptera	Ct103	UASM91643	Acari
M285	UASM90818	Diptera	Ct104	UASM91644	Hymenoptera
M286	UASM90819	Diptera	Ct105	UASM91645	Diptera
M287	UASM90820	Araneae	Ct106	UASM91646	Coleoptera
M288	UASM90821	Diptera	Ct107	UASM91647	Hemiptera
M289	UASM90822	Araneae	Ct109	UASM91648	Araneae
M290	UASM90823	Pscoptera	Ct110	UASM91649	Araneae
M291	UASM90824	Diptera	Ct111	UASM91650	Lepidoptera
M292	UASM90825	Diptera	Ct112	UASM91651	Acari
M293	UASM90826	Acari	Ct113	UASM91652	Araneae
M294	UASM90827	Opilione	Ct114	UASM91653	Acari
			Ct115	UASM91654	Coleoptera

Appendix 2: Fungi identified from each original isolation plate.

Bait types; C = coyote dung, M = moose dung, B = brown-rotted wood, W= white-rotted wood, and Ct = fibreglass

Plate numbei	Trap number	Date	*Fungi*			
348	B1	Aug 20/03	*Verticillium lecanii*			
349	B1	Aug 20/03	*Verticillium lecanii*			
326	B1	Aug 6/03	*Beauveria bassiana*	*Penicillium* spp.		
325	B1	Aug 6/03	*Penicillium steckii*			
151	B1	Aug 7/02	*Beauvaria bassiana*	*Penicillium brevicompactum*		
150	B1	Aug 7/02	*Cladosporium cladosporiodies*	*Acremonium strictum*	*Penicillium steckii*	
152	B1	Aug 7/02	*Penicillium marquandii*			
97	B1	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
96	B1	July 10/02	*Cladosporium cladosporioides*			
273	B1	July 16/03	*Acremonium strictum*	*Penicillium janthinellum*		
272	B1	July 16/03	B/y			
243	B1	July 2/03	*Cladosporium sphaerospermum*			
133	B1	July 24/02	*Penicillium brevicompactum*			
134	B1	July 24/02	*Penicillium brevicompactum*			
135	B1	July 24/02	*Cladosporium sphaerospermum*	*Fusarium solani*	*Verticillium lecanii*	*Penicillium restrictum*
83	B1	July 3/02	No growth			
258	B1	July 9/03	*Cladosporium cladosporioides*			
259	B1	July 9/03	*Cladosporium cladosporioides*			
257	B1	July 9/03	B/y			
209	B1	June 11/03	No growth			
208	B1	June 11/03	No growth			
221	B1	June 25/03	B/y			
205	B1	June 4/03	B/y			
204	B1	June 4/03	*Acremonium fusidioides*	*Cladosporium sphareospermum*		
203	B1	June 4/03	*Beauveria bassiana*			
23	B1	June 5/02	*Penicillium* spp.			
190	B1	May 28/03	*Beauveria bassiana*	*Leptographium piriforme*	*Cladosporium sphaerospermum*	*Eupenicillium brefeldianum*
188	B1	May 28/03	*Beauveria bassiana*			
189	B1	May 28/03	*Beauveria bassiana*			
12	B1	May 29/02	*Cladosporium cladosporioides*			
173	B1	Sept 4/02	*Mucor hiemalis*	*Penicillium brevicompactum*		
174	B1	Sept 4/02	*Verticillium lecanii*	*Penicillium steckii*		
333	B10	Aug 13/03	*Penicillium steckii*			
334	B10	Aug 13/03	B/y			
353	B10	Aug 20/03	*Cladosporium cladosporioides*	*Verticillium lamellicola*		
354	B10	Aug 20/03	*Verticillium lamellicola*			
160	B10	Aug 21/02	No growth			

159	B10	Aug 21/02	No growth			
357	B10	Aug 27/03	*Cladosporium cladosporioides*			
358	B10	Aug 27/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Verticillium lamellicola*	
166	B10	Aug 28/02	*Cladosporium cladosporioides*			
165	B10	Aug 28/02	*Beauvaria bassiana*			
324	B10	Aug 6/03	*Verticillium psalliotae*	*Paecilomyces farinosus*	*Cladosporium cladosporioides*	*Penicillium steckii*
91	B10	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
116	B10	July 18/02	*Cladosporium cladosporioides*			
117	B10	July 18/02	*Penicillium steckii*			
127	B10	July 24/02	*Beauvaria bassiana*			
79	B10	July 3/02	*Cladosporium cladosporioides*			
319	B10	July 30/03	*Cladosporium cladosporioides*	*Acremonium butryi*	*Verticillium lamellicola*	*Penicillium steckii*
318	B10	July 30/03	*Verticillium lamellicola*	*Mucor hiemalis*		
317	B10	July 30/03	*Cladosporium cladosporioides*	*Penicillium steckii*		
316	B10	July 30/03	*Cladosporium cladosporioides*	*Penicillium* spp.		
142	B10	July 31/02	*Cladosporium cladosporioides*			
37	B10	June 12/01	*Penicillium* spp.	*Beauvaria bassiana*	*Oidiodendron periconioides*	
69	B10	June 19/02	No growth			
66	B10	June 19/02	*Phialophora americana*	*Beauvaria bassiana*		
68	B10	June 19/02	*Rhizopus stolonifer*			
67	B10	June 19/02	No growth			
224	B10	June 25/03	*Cladosporium cladosporioides*			
225	B10	June 25/03	*Cladosporium cladosporioides*			
200	B10	June 4/03	*Beauveria bassiana*			
201	B10	June 4/03	*Cladosporium cladosporioides*			
202	B10	June 4/03	No growth			
21	B10	June 5/02	*Penicillium* spp.			
15	B10	May 29/02	No growth			
338	B2	Aug 13/03	*Acermonium butyri*	*Penicillium steckii*		
337	B2	Aug 13/03	*Penicillium brevicompactum*			
351	B2	Aug 20/03	*Penicillium implicatum*			
350	B2	Aug 20/03	*Penicillium steckii*			
352	B2	Aug 20/03	*Penicillium steckii*			
322	B2	Aug 6/03	*Beauveria bassiana*			
109	B2	July 10/02	*Cladosporium sphaerospermum*	*Penicillium* sp. 1		
108	B2	July 10/02	*Cladosporium sphaerospermum*			
111	B2	July 10/02	*Cladosporium cladosporioides*	*Penicillium* spp.		
107	B2	July 10/02	*Beauvaria bassiana*			
110	B2	July 10/02	*Cladosporium cladosporioides*	*Penicillium steckii*		
281	B2	July 16/03	B/y			

279	B2	July 16/03	*Acremonium strictum*			
280	B2	July 16/03	*Cladosporium sphaerospermum*	*Beauveria bassiana*		
121	B2	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Cladosporium sphaerospermum*	
123	B2	July 18/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*		
122	B2	July 18/02	*Penicillium brevicompactum*	*Acremonium butyri*	*Acremonium strictum*	*Beauvaria bassiana*
252	B2	July 2/03	B/y			
251	B2	July 2/03	B/y			
298	B2	July 23/03	B/y			
297	B2	July 23/03	No growth			
138	B2	July 24/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium janthinellum*	
139	B2	July 24/02	*Cladosporium cladosporioides*			
136	B2	July 24/02	*Cladosporium sphaerospermum*			
137	B2	July 24/02	No growth			
140	B2	July 31/02	*Cladosporium cladosporioides*	*Penicillium steckii*		
270	B2	July 9/03	*Geomyces pannorus*	*Beauveria bassiana*	*Verticillium lecanii*	
267	B2	July 9/03	No growth			
266	B2	July 9/03	No growth			
269	B2	July 9/03	*Geomyces pannorus*			
268	B2	July 9/03	*Cladosporium sphaerospermum*			
206	B2	June 11/03	*Geomyces pannorus*			
35	B2	June 12/01	No growth			
46	B2	June 19/02	*Beauvaria bassiana*			
47	B2	June 19/02	*Beauvaria bassiana*			
230	B2	June 25/03	*Verticillium lecanii*	*Verticillium psalliotae*		
229	B2	June 25/03	No growth			
195	B2	June 4/03	*Oidiodendron griseum*			
8	B2	May 22/02	*Cladosporium cladosporiodies*	*Beauvaria bassiana*		
10	B2	May 22/02	No growth			
9	B2	May 22/02	*Cladosporium cladosporiodies*			
183	B2	May 28/03	No growth			
184	B2	May 28/03	No growth			
330	B3	Aug 13/03	*Beauveria bassiana*			
329	B3	Aug 13/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
343	B3	Aug 20/03	*Cladosporium cladosporioides*			
342	B3	Aug 20/03	No growth			
363	B3	Aug 27/03	*Cladosporium cladosporioides*			
365	B3	Aug 27/03	No growth			
364	B3	Aug 27/03	*Verticillium lamellicola*			
321	B3	Aug 6/03	*Verticillium lamellicola*			
147	B3	Aug 7/02	*Absidia glauca*			

92	B3	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
283	B3	July 16/03	No growth			
282	B3	July 16/03	No growth			
284	B3	July 16/03	No growth			
285	B3	July 16/03	No growth			
286	B3	July 16/03	No growth			
112	B3	July 18/02	*Beauvaria bassiana*			
113	B3	July 18/02	*Penicillium brevicompactum*			
241	B3	July 2/03	*Cladosporium sphaerospermum*			
301	B3	July 23/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Phialophora americana*	
300	B3	July 23/03	*Beauveria bassiana*			
299	B3	July 23/03	*Verticillium lamellicola*	*Penicillium steckii*		
129	B3	July 24/02	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*		
86	B3	July 3/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	*Acremonium fusidioides*	
87	B3	July 3/02	*Cladosporium cladosporioides*			
313	B3	July 30/03	B/y			
314	B3	July 30/03	*Cladosporium cladosporioides*	*Sagenomella diversispora*		
312	B3	July 30/03	No growth			
315	B3	July 30/03	No growth			
255	B3	July 9/03	*Cladosporium sphaerospermum*			
256	B3	July 9/03	*Cladosporium cladosporioides*			
207	B3	June 11/03	*Beauveria bassiana*			
42	B3	June 12/01	*Beauvaria bassiana*			
65	B3	June 19/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
223	B3	June 25/03	*Beauveria bassiana*	*Verticillium lecanii*	*Cladosporium sphaerospermum*	*Paecilomyces farinosus*
73	B3	June 26/02	*Beauvaria bassiana*			
22	B3	June 5/02	*Beauvaria bassiana*			
2	B3	May 15/02	No growth			
1	B3	May 15/02	No growth			
6	B3	May 22/02	*Beauvaria bassiana*			
180	B3	May 28/03	*Beauveria bassiana*			
18	B3	May 29/02	No growth			
347	B4	Aug 20/03	*Penicillium steckii*			
346	B4	Aug 20/03	*Penicillium steckii*			
366	B4	Aug 27/03	*Penicillium steckii*			
367	B4	Aug 27/03	*Penicillium steckii*			
369	B4	Aug 27/03	*Absidia glauca*	*Penicillium steckii*		
368	B4	Aug 27/03	*Penicillium steckii*			
370	B4	Aug 27/03	*Penicillium steckii*			
275	B4	July 16/03	*Verticillium psalliotae*			

274	B4	July 16/03	*Alternaria alternata*	*Penicillium steckii*			
242	B4	July 2/03	*Verticillium psalliotae*				
303	B4	July 23/03	*Penicillium steckii*				
306	B4	July 23/03	*Beauveria bassiana*	*Cladosporium cladosporioides*			
304	B4	July 23/03	*Cladosporium cladosporioides*	*Verticillium psalliotae*	*Penicillium steckii*		
302	B4	July 23/03	*Cladosporium sphaerospermum*	*Eupenicillium brefeldianum*	*Penicillium raistrickii*		
305	B4	July 23/03	*Verticillium psalliotae*	*Beauveria bassiana*			
128	B4	July 24/02	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*			
80	B4	July 3/02	*Cladosporium sphaerospermum*				
307	B4	July 30/03	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Penicillium steckii*		
141	B4	July 31/02	*Verticillium lecanii*	*Absidia glauca*			
260	B4	July 9/03	*Cladosporium cladosporioides*				
261	B4	July 9/03	No growth				
220	B4	June 11/03	*Verticillium psalliotae*	*Beauveria bassiana*			
217	B4	June 11/03	No growth				
218	B4	June 11/03	*Beauveria bassiana*				
219	B4	June 11/03	*Beauveria bassiana*				
36	B4	June 12/02	*Geomyces panorus*	*Cladosporium cladosporioides*	*Auxarthron conjugatum*	*Beauvaria bassiana*	*Absidia glauca*
53	B4	June 19/02	*Cryptendoxyla hypophloia*				
54	B4	June 19/02	No growth				
55	B4	June 19/02	No growth				
56	B4	June 19/02	No growth				
57	B4	June 19/02	No growth				
58	B4	June 19/02	No growth				
59	B4	June 19/02	No growth				
227	B4	June 25/03	No growth				
226	B4	June 25/03	B/y				
228	B4	June 25/03	B/y				
196	B4	June 4/03	*Beauveria bassiana*				
32	B4	June 5/02	*Beauvaria bassiana*				
33	B4	June 5/02	*Beauvaria bassiana*				
34	B4	June 5/02	*Beauvaria bassiana*				
182	B4	May 28/03	*Leptographium piriforme*	*Penicillium steckii*			
181	B4	May 28/03	No growth				
14	B4	May 29/02	No growth				
13	B4	May 29/02	No growth				
328	B5	Aug 13/03	*Penicillium brevicompactum*				
344	B5	Aug 20/03	*Verticillium psalliotae*	*Cladosporium cladosporioides*	*Penicillium steckii*		
345	B5	Aug 20/03	*Penicillium implicatum*				
162	B5	Aug 21/02	No growth				

161	B5	Aug 21/02	*Acremonium fusioides*	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*	*Beauvaria bassiana*
355	B5	Aug 27/03	*Penicillium janthinellum*			
164	B5	Aug 28/02	*Cladosporium cladosporioides*			
163	B5	Aug 28/02	No growth			
323	B5	Aug 6/03	*Penicillium steckii*			
148	B5	Aug 7/02	*Mucor hiemalis*			
149	B5	Aug 7/02	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
100	B5	July 10/02	*Beauvaria bassiana*	*Acremonium fusidioides*	*Geomyces pannorus*	
99	B5	July 10/02	No growth			
98	B5	July 10/02	*Verticillium lecanii*			
271	B5	July 16/03	*Cladosporium cladosporioides*	*Penicillium steckii*		
120	B5	July 18/02	*Cladosporium sphaerospermum*			
119	B5	July 18/02	*Absidia glauca*			
118	B5	July 18/02	*Paecilomyces farinosus*			
240	B5	July 2/03	No growth			
84	B5	July 3/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*		
85	B5	July 3/02	No growth			
309	B5	July 30/03	No growth			
263	B5	July 9/03	*Cladosporium sphaerospermum*			
264	B5	July 9/03	*Cladosporium cladosporioides*			
262	B5	July 9/03	No growth			
265	B5	July 9/03	*Cladosporium cladosporioides*	*Beauveria bassiana*		
39	B5	June 12/01	*Cladosporium sphaerospermum*			
38	B5	June 12/01	No growth			
236	B5	June 25/03	B/y			
235	B5	June 25/03	*Cladosporium cladosporioides*			
234	B5	June 25/03	B/y			
77	B5	June 26/02	No growth			
78	B5	June 26/02	*Cladosporium cladosporioides*			
28	B5	June 5/02	*Beauvaria bassiana*	*Auxarthron compactum*		
29	B5	June 5/02	*Beauvaria bassiana*			
7	B5	May 22/02	*Beauvaria bassiana*			
191	B5	May 28/03	*Beauveria bassiana*	*Phialophora americana*		
192	B5	May 28/03	*Verticillium lecanii*	*Beauveria bassiana*		
193	B5	May 28/03	*Beauveria bassiana*			
11	B5	May 29/02	No growth			
176	B5	Sept 4/02	No growth			
327	B6	Aug 13/03	*Penicillium brevicompactum*			
339	B6	Aug 20/03	*Penicillium steckii*			
360	B6	Aug 27/03	*Verticillium lamellicola*	*Penicillium brevicompactum*		

359	B6	Aug 27/03	*Verticillium lecanii*	*Alternaria alternata*	*Penicillium brevicompactum*
145	B6	Aug 7/02	*Cladosporium cladosporioides*		
106	B6	July 10/02	*Cladosporium cladosporioides*		
105	B6	July 10/02	No growth		
124	B6	July 18/02	No growth		
125	B6	July 18/02	*Cladosporium cladosporioides*		
126	B6	July 18/02	*Cladosporium cladosporioides*		
248	B6	July 2/03	B/y		
247	B6	July 2/03	B/y		
41	B6	June 12/01	No growth		
40	B6	June 12/01	*Penicillium steckii*		
51	B6	June 19/02	*Beauvaria bassiana*		
76	B6	June 26/02	*Beauvaria bassiana*		
74	B6	June 26/02	B/y		
75	B6	June 26/02	*Beauvaria bassiana*		
198	B6	June 4/03	B/y		
25	B6	June 5/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
24	B6	June 5/02	B/y		
3	B6	May 15/02	*Beauvaria bassiana*	*Scopulariopsis brevicaulis*	*Cladosporium cladosporiodies*
185	B6	May 28/03	*Beauveria bassiana*	*Cladosporium orchidis*	
186	B6	May 28/03	No growth		
187	B6	May 28/03	*Beauveria bassiana*		
16	B6	May 29/02	No growth		
179	B6	Sept 4/02	*Beauvaria bassiana*		
178	B6	Sept 4/02	No growth		
335	B7	Aug 13/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Verticillium lamellicola*
336	B7	Aug 13/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
340	B7	Aug 20/03	*Verticillium lecanii*	*Penicillium implicatum*	
157	B7	Aug 21/02	B/y		
361	B7	Aug 27/03	*Penicillium steckii*		
362	B7	Aug 27/03	*Paecilomyces farinosus*		
169	B7	Aug 28/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium implicatum*
171	B7	Aug 28/02	*Beauvaria bassiana*		
172	B7	Aug 28/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium* spp.
170	B7	Aug 28/02	No growth		
144	B7	Aug 7/02	B/y		
104	B7	July 10/02	*Cladosporium cladosporioides*		
103	B7	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporiodies*	
102	B7	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
101	B7	July 10/02	*Cladosporium cladosporioides*		

289	B7	July 16/03	No growth		
291	B7	July 16/03	No growth		
292	B7	July 16/03	No growth		
287	B7	July 16/03	No growth		
290	B7	July 16/03	No growth		
288	B7	July 16/03	No growth		
293	B7	July 16/03	No growth		
114	B7	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
115	B7	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
250	B7	July 2/03	No growth		
249	B7	July 2/03	No growth		
294	B7	July 23/03	B/y		
130	B7	July 24/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium brevicompactum*
131	B7	July 24/02	*Cladosporium cladosporioides*		
132	B7	July 24/02	No growth		
308	B7	July 30/03	*Penicillium frequetans*		
143	B7	July 31/02	B/y		
60	B7	June 19/02	*Beauvaria bassiana*		
61	B7	June 19/02	*Beauvaria bassiana*		
62	B7	June 19/02	*Beauvaria bassiana*		
64	B7	June 19/02	*Beauvaria bassiana*	*Penicillium steckii*	
63	B7	June 19/02	No growth		
238	B7	June 25/03	*Geomyces pannorus*		
239	B7	June 25/03	B/y		
237	B7	June 25/03	No growth		
70	B7	June 26/02	B/y		
199	B7	June 4/03	No growth		
194	B7	May 28/03	*Cladosporium sphaerospermum*	*Beauveria bassiana*	
175	B7	Sept 4/02	*Beauvaria bassiana*	*Penicillium implicatum*	
341	B8	Aug 20/03	*Beauveria bassiana*		
356	B8	Aug 27/03	*Verticillium lamellicola*	*Penicillium marquandii*	
168	B8	Aug 28/02	B/y		
167	B8	Aug 28/02	No growth		
320	B8	Aug 6/03	B/y		
156	B8	Aug 7/02	*Cladosporium cladosporioides*		
153	B8	Aug 7/02	No growth		
154	B8	Aug 7/02	No growth		
155	B8	Aug 7/02	B/y		
95	B8	July 10/02	No growth		
94	B8	July 10/02	*Beauvaria bassiana*		

244	B8	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
246	B8	July 2/03	B/y			
245	B8	July 2/03	*Cladosporium cladosporioides*			
295	B8	July 23/03	*Beauveria bassiana*	*Absidia glauca*		
296	B8	July 23/03	*Cladosporium cladosporioides*			
90	B8	July 3/02	*Beauvaria bassiana*			
88	B8	July 3/02	No growth			
89	B8	July 3/02	*Paecilomyces farinosus*	*Penicillium* spp.		
310	B8	July 30/03	*Verticillium lamellicola*	*Paecilomyces farinosus*		
311	B8	July 30/03	No growth			
254	B8	July 9/03	B/y			
215	B8	June 11/03	B/y			
213	B8	June 11/03	*Beauveria bassiana*			
212	B8	June 11/03	*Verticillium psalliotae*	*Cladosporium cladosporioides*		
216	B8	June 11/03	*Cladosporium cladosporioides*	*Paecilomyces farinosus*		
214	B8	June 11/03	No growth			
45	B8	June 12/01	B/y			
44	B8	June 12/01	*Beauvaria bassiana*			
43	B8	June 12/01	*Beauvaria bassiana*			
48	B8	June 19/02	*Cladosporium sphaerospermum*	*Alternaria alternata*	*Penicillium janthinellum*	
50	B8	June 19/02	B/y			
49	B8	June 19/02	*Alternaria alternata*	*Beauvaria bassiana*		
233	B8	June 25/03	No growth			
232	B8	June 25/03	*Cladosporium cladosporioides*	*Geomyces pannorus*	*Cladosporium sphaerospermum*	*Beauveria bassiana*
231	B8	June 25/03	*Penicillium marquandii*			
72	B8	June 26/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
71	B8	June 26/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*		
197	B8	June 4/03	No growth			
27	B8	June 5/02	*Verticillium pselliotae*			
26	B8	June 5/02	*Beauvaria bassiana*			
4	B8	May 15/02	No growth			
5	B8	May 15/02	No growth			
17	B8	May 29/02	B/y			
332	B9	Aug 13/03	*Penicillium steckii*			
331	B9	Aug 13/03	*Penicillium brevicompactum*	*Cladosporium cladosporioides*	*Verticillium lamellicola*	*Beauveria bassiana*
158	B9	Aug 21/02	No growth			
146	B9	Aug 7/02	B/y			
93	B9	July 10/02	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Beauvaria bassiana*	
278	B9	July 16/03	*Cladosporium cladosporioides*			
277	B9	July 16/03	*Cladosporium cladosporioides*	*Verticillium lamellicola*		

276	B9	July 16/03	*Ramichloridium schulzeri*	*Cladosporium sphaerospermum*		
81	B9	July 3/02	B/y			
82	B9	July 3/02	B/y			
253	B9	July 9/03	*No growth*			
211	B9	June 11/03	*Cladosporium cladosporioides*			
210	B9	June 11/03	*Beauveria bassiana*	*Eupenicillium brefeldianum*		
52	B9	June 19/02	*Beauvaria bassiana*			
222	B9	June 25/03	B/y			
30	B9	June 5/02	*Phialophora americana*	*Beauvaria bassiana*		
31	B9	June 5/02	No growth			
19	B9	May 29/02	*Geomyces pannorus*	*Phialophora americana*		
20	B9	May 29/02	*Verticillium lecanii*	*Beauvaria bassiana*		
177	B9	Sept 4/02	*Beauvaria bassiana*	*Verticillium lecanii*	*Penicillium steckii*	
521	C1	Aug 20/03	*Cladosporium cladosporioides*	*Absidia glauca*		
522	C1	Aug 20/03	*Cladosporium cladosporioides*	*Eupenicillium brefeldianum*		
523	C1	Aug 20/03	*Conidiobolus coronotus*			
203	C1	Aug 21/02	*Beauvaria bassiana*			
202	C1	Aug 21/02	No growth			
535	C1	Aug 27/03	*Cladosporium cladosporioides*			
225	C1	Aug 28/02	*Verticillium lecanii*	*Absidia corymtifera*		
226	C1	Aug 28/02	No growth			
487	C1	Aug 6/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
486	C1	Aug 6/03	No growth			
97	C1	July 10/02	*Cladosporium sphaerospermum*	*Beauvaria bassiana*		
421	C1	July 16/03	*Beauveria bassiana*	*Leptographium piriforme*	*Cladosporium sphaerospermum*	
420	C1	July 16/03	*Cladosporium sphaerospermum*			
419	C1	July 16/03	No growth			
422	C1	July 16/03	*Acremonium strictum*			
130	C1	July 18/02	*Cladosporium cladosporioides*			
129	C1	July 18/02	*Cladosporium cladosporioides*			
128	C1	July 18/02	*Penicillium brevicompactum*			
341	C1	July 2/03	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*		
446	C1	July 23/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	*Penicillium marquandii*	
445	C1	July 23/03	*Beauveria bassiana*	*Leptographium piriforme*	*Cladosporium cladosporioides*	*Penicillium marquandii*
444	C1	July 23/03	*Beauveria bassiana*	*Penicillium restrictum*		
443	C1	July 23/03	*Verticillium lamellicola*	*Verticillium lecanii*	*Penicillium marquandii*	
449	C1	July 23/03	*Cladosporium cladosporioides*	*Paecilomyces farinosus*	*Penicillium marquandii*	
447	C1	July 23/03	*Penicillium marquandii*			
448	C1	July 23/03	*Leptographium piriforme*	*Cladosporium cladosporioides*	*Penicillium marquandii*	
146	C1	July 24/02	B/Y			

92	C1	July 3/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
91	C1	July 3/02	*Penicillium* spp.			
476	C1	July 30/03	*Cladosporium cladosporioides*	*Beauveria bassiana*		
477	C1	July 30/03	*Beauveria bassiana*	*Mucor hiemalis*		
478	C1	July 30/03	*Cladosporium cladosporioides*	*Verticillium lamellicola*		
475	C1	July 30/03	*Verticillium psalliotae*	*Penicillium brevicompactum*	*Cladosporium cladosporioides*	*Beauveria bassiana*
380	C1	July 9/03	*Cladosporium sphaerospermum*	*Eupenicillium brefeldianum*		
381	C1	July 9/03	*Beauveria bassiana*			
306	C1	June 11/03	No growth			
304	C1	June 11/03	*B/y*			
305	C1	June 11/03	No growth			
46	C1	June 19/02	No growth			
45	C1	June 19/02	*Verticillium lecanii*			
319	C1	June 25/03	*Beauveria bassiana*			
318	C1	June 25/03	*Beauveria bassiana*			
320	C1	June 25/03	No growth			
321	C1	June 25/03	*Verticillium lecanii*	*Penicillium brevicompactum*		
64	C1	June 26/02	B/y			
65	C1	June 26/02	B/Y			
272	C1	June 4/03	*Cladosporium cladosporioides*	*Beauveria bassiana*		
5	C1	May 22/02	No growth			
6	C1	May 22/02	*Geomyces pannorus*			
7	C1	May 22/02	*Beauvaria bassiana*			
271	C1	June 4/03	B/y			
509	C10	Aug 13/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
510	C10	Aug 13/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Penicillium steckii*	
531	C10	Aug 20/03	*Aphanocladium aranearum*			
530	C10	Aug 20/03	*Cladosporium cladosporioides*	*Aphanocladium aranearum*		
532	C10	Aug 20/03	*Verticillium lecanii*			
219	C10	Aug 21/02	B/y			
214	C10	Aug 21/02	B/y			
216	C10	Aug 21/02	B/y			
217	C10	Aug 21/02	B/y			
218	C10	Aug 21/02	B/y			
215	C10	Aug 21/02	B/y			
540	C10	Aug 27/03	*Verticillium lecanii*			
539	C10	Aug 27/03	No growth			
234	C10	Aug 28/02	B/y			
237	C10	Aug 28/02	B/y			
236	C10	Aug 28/02	B/y			

238	C10	Aug 28/02	B/y		
235	C10	Aug 28/02	B/y		
501	C10	Aug 6/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Paecilomyces farinosus*
496	C10	Aug 6/03	*Cladosporium sphaerospermum*	*Aphanocladium aranearum*	*Penicillium marquandii*
480	C10	Aug 6/03	*Verticillium lamellicola*	*Beauveria bassiana*	
498	C10	Aug 6/03	*Verticillium psalliotae*		
494	C10	Aug 6/03	B/y		
500	C10	Aug 6/03	B/y		
497	C10	Aug 6/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	*Verticillium lamellicola*
495	C10	Aug 6/03	*Cladosporium sphaerospermum*	*Beauveria bassiana*	
499	C10	Aug 6/03	*Penicillium marquandii*		
176	C10	Aug 7/02	B/y		
177	C10	Aug 7/02	B/y		
110	C10	July 10/02	*Cladosporium cladosporiodies*		
111	C10	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
112	C10	July 10/02	*Beauvaria bassiana*		
410	C10	July 16/03	By		
412	C10	July 16/03	*Cladosporium cladosporioides*		
411	C10	July 16/03	*Cladosporium herbarum*		
140	C10	July 18/02	*Leptographium piriforme*	*Mucor hiemalis*	
139	C10	July 18/02	B/y		
136	C10	July 18/02	B/y		
134	C10	July 18/02	B/y		
135	C10	July 18/02	B/y		
137	C10	July 18/02	B/y		
138	C10	July 18/02	B/y		
138c	C10	July 18/02	No growth		
138b	C10	July 18/02	*Leptographium piriforme*		
352	C10	July 2/03	B/y		
353	C10	July 2/03	No growth		
432	C10	July 23/03	*Acremonium strictum*	*Verticillium lamellicola*	*Cladosporium cladosporioides*
433	C10	July 23/03	*Verticillium lamellicola*		
144	C10	July 24/02	B/y		
145	C10	July 24/02	B/y		
143	C10	July 24/02	B/y		
142	C10	July 24/02	B/y		
141	C10	July 24/02	B/y		
79	C10	July 3/02	*Cladosporium cladosporioides*		
78	C10	July 3/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
469	C10	July 30/03	B/y		

470	C10	July 30/03	*Cladosporium cladosporioides*		
294	C10	June 11/03	*Beauveria bassiana*		
295	C10	June 11/03	*Cladosporium cladosporioides*		
296	C10	June 11/03	*Cladosporium cladosporioides*		
28	C10	June 12/02	B/y		
29	C10	June 12/02	No growth		
30	C10	June 12/02	No growth		
51	C10	June 19/02	No growth		
50	C10	June 19/02	*Beauvaria bassiana*		
52	C10	June 19/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
309	C10	June 25/03	*Acremonium kiliense*	*Cladosporium cladosporioides*	
308	C10	June 25/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
71	C10	June 26/02	No growth		
73	C10	June 26/02	B/y		
70	C10	June 26/02	B/Y		
69	C10	June 26/02	No growth		
72	C10	June 26/02	*Beauvaria bassiana*		
270	C10	June 4/03	By		
269	C10	June 4/03	No growth		
15	C10	June 5/02	*Beauvaria bassiana*		
252	C10	May 28/03	*Beauveria bassiana*		
245	C10	Sept 4/02	B/y		
246	C10	Sept 4/02	B/y		
515	C2	Aug 13/03	No growth		
511	C2	Aug 13/03	*Ceratocystis sp.*		
513	C2	Aug 13/03	No growth		
512	C2	Aug 13/03	*Penicillium raistrickii*		
514	C2	Aug 13/03	*Penicillium raistrickii*		
526	C2	Aug 20/03	B/y		
525	C2	Aug 20/03	B/y		
524	C2	Aug 20/03	B/y		
188	C2	Aug 21/02	No growth		
189	C2	Aug 21/02	No growth		
222	C2	Aug 28/02	*Geomyces pannorus*		
223	C2	Aug 28/02	B/y		
490	C2	Aug 6/03	*Cladosporium sphaerospermum*	*Phialophora americana*	*Verticillium lamellicola*
488	C2	Aug 6/03	No growth		
489	C2	Aug 6/03	*Verticillium lamellicola*		
174	C2	Aug 7/02	No growth		
175	C2	Aug 7/02	*Paecilomyces farinosus*	*Cladosporium cladosporioides*	

96	C2	July 10/02	*Cladosporium cladosporioides*		
429	C2	July 16/03	*Cladosporium cladosporioides*		
426	C2	July 16/03	*Cladosporium cladosporioides*	*Geomyces pannorus*	
424	C2	July 16/03	No growth		
427	C2	July 16/03	B/y		
423	C2	July 16/03	B/y		
428	C2	July 16/03	*Cladosporium cladosporioides*		
425	C2	July 16/03	*Verticillium lamellicola*		
351	C2	July 2/03	*Arthroderma* sp.		
350	C2	July 2/03	No growth		
441	C2	July 23/03	*Cladosporium cladosporioides*	*Verticillium lecanii*	
440	C2	July 23/03	*Beauveria bassiana*		
442	C2	July 23/03	No growth		
439	C2	July 23/03	*Beauveria bassiana*	*Leptographium piriforme*	*Penicillium brevicompactum*
150	C2	July 24/02	*Beauvaria bassiana*	*Geomyces pannorus*	
151	C2	July 24/02	No growth		
89	C2	July 3/02	B/y		
90	C2	July 3/02	No growth		
467	C2	July 30/03	*Cladosporium cladosporioides*		
468	C2	July 30/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
162	C2	July 31/02	No growth		
388	C2	July 9/03	B/y		
391	C2	July 9/03	B/y		
389	C2	July 9/03	B/y		
390	C2	July 9/03	B/y		
288	C2	June 11/03	*Beauveria bassiana*	*Cladosporium sphaerospermum*	
26	C2	June 12/02	*Cladosporium cladosporiodies*	*Beauvaria bassiana*	
25	C2	June 12/02	*Geomyces pannorus*	*Cladosporium cladosporioides*	*Beauveria bassiana*
34	C2	June 19/02	*Arthroderma curreyi*	*Cladosporium cladosporioides*	
35	C2	June 19/02	*Cladosporium cladosporiodies*		
63	C2	June 26/02	No growth		
61	C2	June 26/02	*Cladosporium cladosporioides*		
62	C2	June 26/02	*Beauvaria bassiana*		
23	C2	June 5/02	*Beauvaria bassiana*		
24	C2	June 5/02	*Beauvaria bassiana*		
22	C2	June 5/02	*Geomyces pannorus*		
13	C2	May 29/02	No growth		
240	C2	Sept 4/02	*Arthroderma* sp.		
505	C3	Aug 13/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Eupenicillium brefeldianum*
506	C3	Aug 13/03	*Cladosporium cladosporioides*		

529	C3	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
528	C3	Aug 20/03	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*	
527	C3	Aug 20/03	No growth		
198	C3	Aug 21/02	No growth		
201	C3	Aug 21/02	No growth		
199	C3	Aug 21/02	No growth		
200	C3	Aug 21/02	No growth		
493	C3	Aug 6/03	*Cladosporium cladosporioides*		
492	C3	Aug 6/03	*Cladosporium cladosporioides*		
491	C3	Aug 6/03	*Penicillium marquandii*		
186	C3	Aug 7/02	No growth		
184	C3	Aug 7/02	No growth		
185	C3	Aug 7/02	B/y		
183	C3	Aug 7/02	*Cladosporium cladosporioides*		
114	C3	July 10/02	*Beauvaria bassiana*	*Acremonium fusioide*	
115	C3	July 10/02	*Acremonium strictum*	*Beauvaria bassiana*	
113	C3	July 10/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
116	C3	July 10/02	*Beauvaria bassiana*		
413	C3	July 16/03	*Acremonium strictum*		
414	C3	July 16/03	No growth		
415	C3	July 16/03	No growth		
133	C3	July 18/02	*Beauvaria bassiana*		
132	C3	July 18/02	*Beauvaria bassiana*		
131	C3	July 18/02	*Penicillium* spp.		
368	C3	July 2/03	*Leptographium piriforme*		
369	C3	July 2/03	*Leptographium piriforme*		
366	C3	July 2/03	B/y		
365	C3	July 2/03	*Leptographium piriforme*		
367	C3	July 2/03	*Leptographium piriforme*		
438	C3	July 23/03	*Beauveria bassiana*		
437	C3	July 23/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Leptographium piriforme*
95	C3	July 3/02	No growth		
94	C3	July 3/02	No growth		
93	C3	July 3/02	*Cladosporium cladosporioides*		
472	C3	July 30/03	*Cladosporium cladosporioides*	*Penicillium* spp.	
471	C3	July 30/03	*Penicillium brevicompactum*		
163	C3	July 31/02	*Beauvaria bassiana*	*Paecilomyces farinosus*	
378	C3	July 9/03	*Cladosporium cladosporioides*		
379	C3	July 9/03	*Leptographium piriforme*		
293	C3	June 11/03	B/y		

292	C3	June 11/03	*Beauveria bassiana*			
33	C3	June 12/02	*Cladosporium cladosporiodies*	*Cladosporium sphaeospermum*		
32	C3	June 12/02	*Cladosporium cladosporiodies*			
42	C3	June 19/02	*Cladosporium cladosporioides*			
41	C3	June 19/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*		
312	C3	June 25/03	*Leptographium piriforme*			
313	C3	June 25/03	*Leptographium piriforme*			
314	C3	June 25/03	B/y			
67	C3	June 26/02	*Beauvaria bassiana*			
268	C3	June 4/03	*Cladosporium cladosporioides*			
19	C3	June 5/02	*Beauvaria bassiana*			
265	C3	May 28/03	*Phialophora americana*	*Beauveria bassiana*		
9	C3	May 29/02	No growth			
517	C4	Aug 20/03	*Cladosporium sphaerospermum*	*Verticillium lecanii*		
194	C4	Aug 21/02	*Beauvaria bassiana*			
192	C4	Aug 21/02	*Paecilomyces farinosus*	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Penicillium steckii*
193	C4	Aug 21/02	*Cladosporium cladosporioides*			
228	C4	Aug 28/02	B/y			
227	C4	Aug 28/02	B/y			
172	C4	Aug 7/02	*Cladosporium cladosporioides*	*Chalara fusidioides*		
105	C4	July 10/02	No growth			
106	C4	July 10/02	*Cladosporium sphaerospermum*			
407	C4	July 16/03	*Polyscytalum pustulans*			
409	C4	July 16/03	B/y			
408	C4	July 16/03	*Cladosporium sphaerospermum*			
120	C4	July 18/02	*Homiactis candida*			
121	C4	July 18/02	B/y			
359	C4	July 2/03	*Cladosporium cladosporioides*			
363	C4	July 2/03	*Beauveria bassiana*			
361	C4	July 2/03	*Cladosporium cladosporioides*			
360	C4	July 2/03	*Cladosporium sphaerospermum*	*Beauveria bassiana*		
362	C4	July 2/03	*Cladosporium cladosporioides*			
358	C4	July 2/03	*Cladosporium sphaerospermum*			
364	C4	July 2/03	B/y			
430	C4	July 23/03	*Cladosporium cladosporioides*			
152	C4	July 24/02	B/y			
80	C4	July 3/02	*Myxotrichum deflexum*	*Penicillium* spp.		
81	C4	July 3/02	*Cladosporium sphaerospermum*			
474	C4	July 30/03	*Beauveria bassiana*	*Penicillium steckii*		
473	C4	July 30/03	*Penicillium steckii*			

398	C4	July 9/03	*Cladosporium cladosporioides*		
399	C4	July 9/03	B/y		
397	C4	July 9/03	*Beauveria bassiana*		
400	C4	July 9/03	*Cladosporium cladosporioides*	*Mucor hiemalis*	
289	C4	June 11/03	*Beauveria bassiana*		
47	C4	June 19/02	No growth		
339	C4	June 25/03	*Hormiactus candida*		
340	C4	June 25/03	No growth		
332	C4	June 25/03	*Cladosporium cladosporioides*	*Alternaria alternata*	
334	C4	June 25/03	*Cladosporium cladosporioides*		
335	C4	June 25/03	*Cladosporium cladosporioides*		
337	C4	June 25/03	No growth		
333	C4	June 25/03	*Cladosporium cladosporioides*		
338	C4	June 25/03	No growth		
336	C4	June 25/03	*Cladosporium cladosporioides*		
66	C4	June 26/02	B/y		
273	C4	June 4/03	No growth		
274	C4	June 4/03	*Cladosporium cladosporioides*		
17	C4	June 5/02	B/y		
4	C4	May 22/02	*Beauvaria bassiana*		
1	C4	May 22/02	B/Y		
2	C4	May 22/02	B/Y		
3	C4	May 22/02	B/Y		
255	C4	May 28/03	*Cladosporium sphaerospermum*	*Chrysosporium merdarium*	
256	C4	May 28/03	*Beauveria bassiana*	*Chrysosporium merdarium*	
254	C4	May 28/03	*Beauveria bassiana*	*Chrysosporium merdarum*	
253	C4	May 28/03	No growth		
11	C4	May 29/02	B/y		
12	C4	May 29/02	No growth		
251	C4	Sept 4/02	*Beauvaria bassiana*	*Paecilomyces farinosus*	
250	C4	Sept 4/02	*Beauvaria bassiana*		
248	C4	Sept 4/02	*Cladosporium cladosporioides*		
247	C4	Sept 4/02	*Beauvaria bassiana*		
249	C4	Sept 4/02	*Cladosporium cladosporioides*		
197	C5	Aug 21/02	*Leptographium piriforme*		
195	C5	Aug 21/02	*Leptographium piriforme*		
196	C5	Aug 21/02	*Leptographium piriforme*		
537	C5	Aug 27/03	*Cladosporium cladosporioides*	*Verticicladiella*	
536	C5	Aug 27/03	*Leptographium piriforme*	*Geomyces pannorus*	*Penicillium inflatum*
538	C5	Aug 27/03	No growth		

220	C5	Aug 28/02	No growth		
482	C5	Aug 6/03	*Verticillium sp*	*Beauveria bassiana*	*Penicillium* spp.
483	C5	Aug 6/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Penicillium* sp. 1
484	C5	Aug 6/03	No growth		
485	C5	Aug 6/03	*Sagenomella diversispora*		
173	C5	Aug 7/02	No growth		
107	C5	July 10/02	No growth		
108	C5	July 10/02	No growth		
109	C5	July 10/02	B/y		
406	C5	July 16/03	*Leptographium piriforme*		
405	C5	July 16/03	*Leptographium piriforme*	*Cladosporium cladosporioides*	*Beauveria bassiana*
347	C5	July 2/03	*Verticillium lecanii*		
348	C5	July 2/03	B/y		
349	C5	July 2/03	*Cladosporium sphaerospermum*		
435	C5	July 23/03	B/y		
436	C5	July 23/03	*Beauveria bassiana*		
434	C5	July 23/03	*Beauveria bassiana*		
147	C5	July 24/02	*Cladosporium herbarum*		
148	C5	July 24/02	*Cladosporium cladosporioides*	*Mucor hiemalis*	*Penicillium brevicompactum*
86	C5	July 3/02	*Cladosporium cladosporioides*	*Penicillium griseofulvum*	
466	C5	July 30/03	*Cladosporium cladosporioides*		
465	C5	July 30/03	No growth		
375	C5	July 9/03	*Leptographium piriforme*		
287	C5	June 11/03	No growth		
27	C5	June 12/02	B/Y		
307	C5	June 25/03	B/y		
58	C5	June 26/02	*Beauvaria bassiana*	*Geomyces pannorus*	*Penicillium steckii*
18	C5	June 5/02	No growth		
264	C5	May 28/03	B/y		
263	C5	May 28/03	No growth		
8	C5	May 29/02	B/y		
243	C5	Sept 4/02	No growth		
244	C5	Sept 4/02	No growth		
516	C6	Aug 20/03	*Penicillium steckii*		
187	C6	Aug 21/02	No growth		
533	C6	Aug 27/03	*Beauveria bassiana*	*Penicillium steckii*	
224	C6	Aug 28/02	No growth		
102	C6	July 10/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	*Penicillium* sp. 1
101	C6	July 10/02	*Beauvaria bassiana*		
402	C6	July 16/03	*Mucor hiemalis*	*Penicillium inflatum*	

118	C6	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
119	C6	July 18/02	*Beauvaria bassiana*			
371	C6	July 2/03	No growth			
373	C6	July 2/03	*Beauveria bassiana*			
374	C6	July 2/03	B/y			
372	C6	July 2/03	*Mucor hiemalis*			
370	C6	July 2/03	No growth			
460	C6	July 23/03	*Beauveria bassiana*			
455	C6	July 23/03	*Verticillium psalliotae*			
459	C6	July 23/03	*Verticillium psalliotae*			
458	C6	July 23/03	B/y			
457	C6	July 23/03	*Penicillium brevicompactum*	*Cladosporium sphaerospermum*	*Verticillium psalliotae*	*Beauveria bassiana*
454	C6	July 23/03	No growth			
456	C6	July 23/03	*Penicillium brevicompactum*			
155	C6	July 24/02	No growth			
156	C6	July 24/02	*Cladosporium cladosporioides*			
154	C6	July 24/02	*Paecilomyces farinosus*	*Cladosporium cladosporioides*		
153	C6	July 24/02	B/y			
88	C6	July 3/02	*Beauvaria bassiana*			
87	C6	July 3/02	*Beauvaria bassiana*			
463	C6	July 30/03	*Verticillium psalliotae*			
165	C6	July 31/02	No growth			
164	C6	July 31/02	No growth			
166	C6	July 31/02	No growth			
385	C6	July 9/03	*Cladosporium cladosporioides*	*Beauveria bassiana*		
386	C6	July 9/03	*Penicillium steckii*			
387	C6	July 9/03	*Verticillium psalliotae*			
290	C6	June 11/03	No growth			
291	C6	June 11/03	*Beauveria bassiana*			
40	C6	June 19/02	*Beauvaria bassiana*			
37	C6	June 19/02	*Beauvaria bassiana*			
39	C6	June 19/02	*Beauvaria bassiana*	*Penicillium steckii*		
38	C6	June 19/02	*Beauvaria bassiana*	*Absidia glauca*	*Penicillium steckii*	
331	C6	June 25/03	B/y			
329	C6	June 25/03	B/y			
328	C6	June 25/03	B/y			
330	C6	June 25/03	*Beauveria bassiana*			
327	C6	June 25/03	B/y			
55	C6	June 26/02	*Beauvaria bassiana*			
53	C6	June 26/02	*Beauvaria bassiana*	*Acremonium fusioides*	*Cladosporium cladosporioides*	

54	C6	June 26/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*
257	C6	May 28/03	*Beauveria bassiana*	*Penicillium* spp.
10	C6	May 29/02	*Beauvaria bassiana*	
239	C6	Sept 4/02	*Cladosporium cladosporioides*	*Cladosporium sphaerospermum*
504	C7	Aug 13/03	B/y	
503	C7	Aug 13/03	*No growth*	
206	C7	Aug 21/02	B/y	
207	C7	Aug 21/02	B/y	
208	C7	Aug 21/02	B/y	
205	C7	Aug 21/02	B/y	
204	C7	Aug 21/02	B/y	
233	C7	Aug 28/02	B/y	
232	C7	Aug 28/02	B/y	
180	C7	Aug 7/02	B/y	
181	C7	Aug 7/02	B/y	
182	C7	Aug 7/02	*Cladosporium cladosporioides*	
103	C7	July 10/02	No growth	
104	C7	July 10/02	*Beauvaria bassiana*	*Mucor hiemalis*
401	C7	July 16/03	No growth	
127	C7	July 18/02	B/y	
125	C7	July 18/02	*Beauvaria bassiana*	
126	C7	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*
357	C7	July 2/03	No growth	
354	C7	July 2/03	*Beauveria bassiana*	
355	C7	July 2/03	*Paecilomyces farinosus*	*Scopulariopsis brevicaulis*
356	C7	July 2/03	No growth	
431	C7	July 23/03	No growth	
149	C7	July 24/02	No growth	
84	C7	July 3/02	*Penicillium steckii*	
85	C7	July 3/02	*Penicillium brevicompactum*	
461	C7	July 30/03	*Cladosporium cladosporioides*	
462	C7	July 30/03	*Verticillium psalliotae*	
168	C7	July 31/02	B/y	
170	C7	July 31/02	B/y	
167	C7	July 31/02	B/y	
169	C7	July 31/02	B/y	
377	C7	July 9/03	*Beauveria bassiana*	
376	C7	July 9/03	*Cladosporium cladosporioides*	
44	C7	June 19/02	*Beauvaria bassiana*	
43	C7	June 19/02	*Cladosporium sphaerospermum*	

317	C7	June 25/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
315	C7	June 25/03	No growth			
316	C7	June 25/03	No growth			
68	C7	June 26/02	*Beauvaria bassiana*			
276	C7	June 4/03	*Oidiodendron griseum*			
275	C7	June 4/03	No growth			
277	C7	June 4/03	B/y			
14	C7	June 5/02	*Geomyces pannorus*	*Alternaria alternata*		
259	C7	May 28/03	No growth			
260	C7	May 28/03	*Scopulariopsis brevicaulis*			
258	C7	May 28/03	No growth			
242	C7	Sept 4/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Acremonium fusidioides*	
241	C7	Sept 4/02	*Acremonium longisporum*			
502	C8	Aug 13/03	*Cladosporium sphaerospermum*			
518	C8	Aug 20/03	*Penicillium brevicompactum*	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Verticillium lecanii*
520	C8	Aug 20/03	*Cladosporium cladosporioides*			
519	C8	Aug 20/03	*Cladosporium herbarum*			
209	C8	Aug 21/02	B/y			
210	C8	Aug 21/02	*Beauvaria bassiana*			
213	C8	Aug 21/02	*Mucor hiemalis*			
211	C8	Aug 21/02	*Beauvaria bassiana*			
212	C8	Aug 21/02	B/y			
221	C8	Aug 28/02	No growth			
481	C8	Aug 6/03	*Cladosporium cladosporioides*			
178	C8	Aug 7/02	*Beauvaria bassiana*	*Verticillium lecanii*	*Penicillium steckii*	
179	C8	Aug 7/02	No growth			
100	C8	July 10/02	No growth			
99	C8	July 10/02	*Cladosporium cladosporioides*	*Penicillium steckii*		
418	C8	July 16/03	B/y			
417	C8	July 16/03	B/y			
416	C8	July 16/03	No growth			
117	C8	July 18/02	*Beauvaria bassiana*	*Paecilomyces farinosus*	*Paecilomyces fumosoroseus*	
342	C8	July 2/03	No growth			
160	C8	July 24/02	B/y			
159	C8	July 24/02	*Penicillium* spp.			
158	C8	July 24/02	*Cladosporium cladosporioides*			
157	C8	July 24/02	*Beauvaria bassiana*	*Verticillium lecanii*		
82	C8	July 3/02	*Cladosporium sphaerospermum*			
83	C8	July 3/02	*Beauvaria bassiana*			
383	C8	July 9/03	No growth			

384	C8	July 9/03	No growth				
382	C8	July 9/03	*Verticillium lamellicola*	*Beauveria bassiana*			
297	C8	June 11/03	*Verticillium lecanii*	*Cladosporium sphaerospermum*	*Cladosporium cladosporioides*		
299	C8	June 11/03	*Ramichloridium schulzeri*				
298	C8	June 11/03	*Beauveria bassiana*	*Penicillium* spp.			
36	C8	June 19/02	No growth				
311	C8	June 25/03	No growth				
310	C8	June 25/03	No growth				
60	C8	June 26/02	*Beauvaria bassiana*				
59	C8	June 26/02	No growth				
285	C8	June 4/03	*Alternaria alternata*				
286	C8	June 4/03	*Cladosporium cladosporioides*				
284	C8	June 4/03	*Cladosporium cladosporioides*				
283	C8	June 4/03	B/y				
282	C8	June 4/03	B/y				
16	C8	June 5/02	*Beauvaria bassiana*	*Geomyces pannorus*			
267	C8	May 28/03	B/y				
266	C8	May 28/03	No growth				
508	C9	Aug 13/03	B/y				
507	C9	Aug 13/03	*Cladosporium cladosporioides*				
191	C9	Aug 21/02	*Cladosporium sphaerospermum*				
190	C9	Aug 21/02	*Cladosporium cladosporioides*				
534	C9	Aug 27/03	*Conidiobolus coronotus*				
229	C9	Aug 28/02	*Cladosporium cladosporioides*	*Paecilomyces farinosus*	*Cladosporium sphaerospermum*	*Beauvaria bassiana*	*Geomyces pannorus*
231	C9	Aug 28/02	*Verticillium lecanii*				
230	C9	Aug 28/02	*Beauvaria bassiana*				
479	C9	Aug 6/03	*Penicillium steckii*				
171	C9	Aug 7/02	*Cladosporium cladosporioides*				
98	C9	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
403	C9	July 16/03	*Cladosporium cladosporioides*				
404	C9	July 16/03	*Cladosporium sphaerospermum*				
123	C9	July 18/02	*Cladosporium cladosporioides*				
122	C9	July 18/02	*Cladosporium sphaerospermum*				
124	C9	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
345	C9	July 2/03	B/y				
344	C9	July 2/03	B/y				
343	C9	July 2/03	*Beauveria bassiana*				
346	C9	July 2/03	B/y				
451	C9	July 23/03	B/y				
450	C9	July 23/03	*Beauveria bassiana*	*Cladosporium sphaerospermum*			

453	C9	July 23/03	*Verticillium lamellicola*	*Beauveria bassiana*	
452	C9	July 23/03	B/y		
77	C9	July 3/02	No growth		
75	C9	July 3/02	No growth		
76	C9	July 3/02	*Penicillium raistrickii*		
74	C9	July 3/02	*Beauvaria bassiana*	*Penicillium* spp.	
464	C9	July 30/03	*Verticillium psalliotae*		
161	C9	July 31/02	*Cladosporium sphaerospermum*	*Acremonium strictum*	
396	C9	July 9/03	*Cladosporium cladosporioides*		
393	C9	July 9/03	*Cladosporium cladosporioides*		
392	C9	July 9/03	*Cladosporium sphaerospermum*		
395	C9	July 9/03	B/y		
394	C9	July 9/03	*Cladosporium sphaerospermum*		
303	C9	June 11/03	No growth		
301	C9	June 11/03	*Cladosporium cladosporioides*		
300	C9	June 11/03	*Cladosporium cladosporioides*	*Verticillium lecanii*	
302	C9	June 11/03	No growth		
31	C9	June 12/02	*Beauvaria bassiana*		
48	C9	June 19/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
49	C9	June 19/02	*Cladosporium sphaeospermum*		
323	C9	June 25/03	No growth		
325	C9	June 25/03	*Penicillium rubrum*		
322	C9	June 25/03	No growth		
324	C9	June 25/03	No growth		
326	C9	June 25/03	No growth		
56	C9	June 26/02	B/y		
57	C9	June 26/02	*Cladosporium cladosporioides*		
279	C9	June 4/03	B/y		
280	C9	June 4/03	B/y		
281	C9	June 4/03	*Beauveria bassiana*		
278	C9	June 4/03	No growth		
21	C9	June 5/02	B/y		
20	C9	June 5/02	No growth		
262	C9	May 28/03	*Leptographium piriforme*	*Beauveria bassiana*	*Penicillium steckii*
261	C9	May 28/03	*Beauveria bassiana*		
102	Ct1	Aug 13/03	No growth		
103	Ct1	Aug 13/03	No growth		
109	Ct1	Aug 20/03	*Verticillium lecanii*	*Verticillium psalliotae*	*Penicillium steckii*
115	Ct1	Aug 27/03	No growth		
114	Ct1	Aug 27/03	No growth		

100	Ct1	Aug 6/03	*Cladosporium cladosporioides*	*Acremonium strictum*	
101	Ct1	Aug 6/03	No growth		
99	Ct1	Aug 6/03	*Cladosporium cladosporioides*	*Acremonium strictum*	*Penicillium marquandii*
75	Ct1	July 2/03	*Cladosporium cladosporioides*		
76	Ct1	July 2/03	*Beauveria bassiana*		
88	Ct1	July 30/03	*Mucor hiemalis*		
89	Ct1	July 30/03	No growth		
82	Ct1	July 9/03	*Cladosporium cladosporioides*		
83	Ct1	July 9/03	No growth		
64	Ct1	June 11/03	No growth		
63	Ct1	June 11/03	B/y		
71	Ct1	June 25/03	No growth		
1	Ct1	May 22/02	No growth		
53	Ct1	Aug 21/02	B/y		
54	Ct1	Aug 21/02	B/y		
55	Ct1	Aug 21/02	B/y		
58	Ct1	Aug 28/02	B/y		
57	Ct1	Aug 28/02	B/y		
44	Ct1	Aug 7/02	*Verticillium lecanii*	*Mucor hiemalis*	
45	Ct1	Aug 7/02	*Beauvaria bassiana*	*Penicillium* spp.	
37	Ct1	July 10/02	No growth		
38	Ct1	July 10/02	B/y		
40	Ct1	July 10/02	B/y		
39	Ct1	July 10/02	No growth		
42	Ct1	July 24/02	No growth		
41	Ct1	July 24/02	No growth		
30	Ct1	July 3/02	B/y		
28	Ct1	July 3/02	*Beauvaria bassiana*	*Penicillium rubrum*	
31	Ct1	July 3/02	*Cladosporium sphaerospermum*		
29	Ct1	July 3/02	B/y		
26	Ct1	July 3/02	B/y		
27	Ct1	July 3/02	B/y		
25	Ct1	July 3/02	*Myxotrichum deflexum*		
9	Ct1	June 12/02	No growth		
15	Ct1	June 19/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
19	Ct1	June 26/02	No growth		
6	Ct1	June 5/02	No growth		
3	Ct1	May 29/02	B/y		
4	Ct1	May 29/02	No growth		
59	Ct1	Sept 4/02	B/y		

60	Ct1	Sept 4/02	No growth				
108	Ct2	Aug 13/03	*Penicillium marquandii*				
107	Ct2	Aug 13/03	*Penicillium marquandii*				
106	Ct2	Aug 13/03	*Cladosporium cladosporioides*	*Penicillium marquandii*			
113	Ct2	Aug 27/03	*Penicillium brevicompactum*				
96	Ct2	Aug 6/03	*Penicillium* spp.				
98	Ct2	Aug 6/03	No growth				
97	Ct2	Aug 6/03	*Verticillium lamellicola*				
78	Ct2	July 2/03	No growth				
77	Ct2	July 2/03	No growth				
86	Ct2	July 23/03	No growth				
87	Ct2	July 30/03	*Beauveria bassiana*	*Penicillium* spp.			
68	Ct2	June 11/03	B/y				
69	Ct2	June 11/03	No growth				
67	Ct2	June 11/03	B/y				
72	Ct2	June 25/03	*Beauveria bassiana*				
74	Ct2	June 25/03	*Arthroderma* sp.				
73	Ct2	June 25/03	*Geomyces pannorus*	*Cladosporium cladosporioides*	*Cladosporium sphaerospermum*	*Beauveria bassiana*	
62	Ct2	May 28/03	No growth				
50	Ct2	Aug 21/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
46	Ct2	Aug 7/02	*Cladosporium sphaerospermum*				
47	Ct2	Aug 7/02	No growth				
49	Ct2	Aug 7/02	*Cladosporium cladosporioides*				
48	Ct2	Aug 7/02	B/y				
36	Ct2	July 10/02	*Paecilomyces* cf. *fumosoroseus*	*Beauvaria bassiana*			
35	Ct2	July 10/02	No growth				
43	Ct2	July 24/02	*Beauvaria bassiana*	*Ramichloridium* cf. *schulzeri*	*Cladosporium cladosporioides*	*Veronaea carlinae*	
12	Ct2	June 12/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
13	Ct2	June 12/02	*Verticillium lecanii*				
14	Ct2	June 19/02	*Cladosporium cladosporioides*	*Alternaria alternata*			
20	Ct2	June 26/02	B/y				
21	Ct2	June 26/02	*Penicillium* spp.				
22	Ct2	June 26/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	*Penicillium griseofulvum*		
2	Ct2	May 29/02	B/y				
5	Ct2	May 29/02	*Beauvaria bassiana*				
104	Ct3	Aug 13/03	*Cladosporium cladosporioides*	*Verticillium* sp.			
105	Ct3	Aug 13/03	*Cladosporium cladosporioides*	*Verticillium lamellicola*	*Beauveria bassiana*		
111	Ct3	Aug 20/03	*Cladosporium cladosporioides*	*Leptographium piriforme*	*Penicillium brevicompactum*	*Paecilomyces farinosus*	*Verticillium lamellicola*
110	Ct3	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium restrictum*			
112	Ct3	Aug 20/03	*Paecilomyces farinosus*				

93	Ct3	Aug 6/03	*Verticillium lecanii*	*Beauveria bassiana*	*Penicillium marquandii*	
95	Ct3	Aug 6/03	B/y			
94	Ct3	Aug 6/03	No growth			
84	Ct3	July 16/03	*Penicillium steckii*			
80	Ct3	July 2/03	No growth			
79	Ct3	July 2/03	*Leptographium piriforme*	*Cladosporium cladosporioides*		
81	Ct3	July 2/03	B/y			
85	Ct3	July 23/03	*Cladosporium sphaerosporium*			
90	Ct3	July 30/03	*Verticillium psalliotae*			
92	Ct3	July 30/03	*Beauveria bassiana*	*Verticillium lecanii*	*Acremonium butyri*	
91	Ct3	July 30/03	No growth			
66	Ct3	June 11/03	*No growth*			
65	Ct3	June 11/03	No growth			
70	Ct3	June 25/03	No growth			
52	Ct3	Aug 21/02	*Beauvaria bassiana*			
51	Ct3	Aug 21/02	*Paecilomyces* cf. *fumosoroseus*	*Cladosporium cladosporioides*		
56	Ct3	Aug 28/02	*Beauvaria bassiana*			
33	Ct3	July 10/02	*Cladosporium cladosporioides*			
34	Ct3	July 10/02	*Cladosporium cladosporioides*			
32	Ct3	July 10/02	*Cladosporium cladosporioides*			
24	Ct3	July 3/02	*Cladosporium cladosporioides*	*Penicillium*		
23	Ct3	July 3/02	*Beauvaria bassiana*	*Cladosporium cladosporiodies*		
11	Ct3	June 12/02	*Beauvaria bassiana*	*Geomyces pannorus*		
10	Ct3	June 12/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
17	Ct3	June 19/02	*Beauvaria bassiana*	*Geomyces pannorus*		
18	Ct3	June 19/02	*Cladosporium cladosporioides*	*Cladosporium sphaerospermum*	*Geomyces pannorus*	*Beauveria bassiana*
16	Ct3	June 19/02	*Cladosporium cladosporiodies*	*Geomyces pannorus*	*Beauveria bassiana*	
8	Ct3	June 5/02	*Beauvaria bassiana*			
7	Ct3	June 5/02	*Cladosporium cladosporiodies*	*Beauvaria bassiana*		
61	Ct3	Sept 4/02	No growth			
323	M1	Aug 13/03	*Cladosporium sphaerospermum*	*Acremonium strictum*	*Eupenicillium brefeldianum*	
335	M1	Aug 20/03	No growth			
336	M1	Aug 20/03	*Cladosporium sphaerospermum*	*Verticillium lamellicola*		
337	M1	Aug 20/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*		
166	M1	Aug 21/02	*Cladosporium cladosporioides*			
346	M1	Aug 27/03	*Verticillium psalliotae*	*Beauveria bassiana*	*Penicillium* spp.	
348	M1	Aug 27/03	*Aphanocladium aranearum*			
347	M1	Aug 27/03	*Beauveria bassiana*			
178	M1	Aug 28/02	*Cladosporium cladosporioides*	*Absidia glauca*	*Mucor hiemalis*	
179	M1	Aug 28/02	*Beauvaria bassiana*			

180	M1	Aug 28/02	No growth		
310	M1	Aug 6/03	*Cladosporium cladosporioides*		
106	M1	July 10/02	No growth		
107	M1	July 10/02	No growth		
105	M1	July 10/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Verticillium lecanii*
271	M1	July 16/03	*Cladosporium cladosporioides*		
270	M1	July 16/03	*Cladosporium cladosporioides*		
239	M1	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	
240	M1	July 2/03	*Cladosporium cladosporioides*	*Verticillium lecanii*	
133	M1	July 24/02	*Cladosporium cladosporioides*		
132	M1	July 24/02	*Cladosporium cladosporioides*		
78	M1	July 3/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
79	M1	July 3/02	*Beauvaria bassiana*		
81	M1	July 3/02	*Beauvaria bassiana*		
80	M1	July 3/02	*Beauvaria bassiana*		
309	M1	July 30/03	*Cladosporium cladosporioides*	*Acremonium butyri*	*Penicillium restrictum*
308	M1	July 30/03	*Verticillium lamellicola*	*Beauveria bassiana*	
307	M1	July 30/03	*Verticillium lamellicola*		
260	M1	July 9/03	*Beauveria bassiana*		
263	M1	July 9/03	No growth		
261	M1	July 9/03	B/y		
262	M1	July 9/03	B/y		
259	M1	July 9/03	*Cladosporium cladosporioides*		
214	M1	June 11/03	*Cladosporium cladosporioides*		
38a	M1	June 12/02	*Beauvaria bassiana*		
54	M1	June 19/02	*Beauvaria bassiana*		
55	M1	June 19/02	*Cladosporium cladosporioides*		
53	M1	June 19/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
52	M1	June 19/02	*Chalara* sp.		
51	M1	June 19/02	*Beauvaria bassiana*	*Alternaria alternata*	*Cladosporium cladosporioides*
223	M1	June 25/03	*Cladosporium cladosporioides*		
212	M1	June 4/03	*Beauveria bassiana*	*Scopulariopsis brevicaulis*	
213	M1	June 4/03	*Geomyces pannorus*	*Verticillium lecanii*	
33	M1	June 5/02	*Beauvaria bassiana*		
31	M1	June 5/02	*Beauvaria bassiana*		
30	M1	June 5/02	*Beauvaria bassiana*		
32	M1	June 5/02	*Beauvaria bassiana*		
5	M1	May 15/02	No growth		
4	M1	May 15/02	*Beauvaria bassiana*		
9	M1	May 22/02	*Scopulariopsis brevicaulis*	*Beauvaria bassiana*	

206	M1	May 28/03	*Beauveria bassiana*	*Penicillium* spp.	
22	M1	May 29/02	No growth		
21	M1	May 29/02	*Cladosporium cladosporiodies*	*Beauvaria bassiana*	
20	M1	May 29/02	B/Y		
173	M10	Aug 21/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
172	M10	Aug 21/02	*Verticillium lecanii*		
342	M10	Aug 27/03	*Cladosporium cladosporioides*		
175	M10	Aug 28/02	*Beauvaria bassiana*		
314	M10	Aug 6/03	*Cladosporium cladosporioides*		
160	M10	Aug 7/02	*Cladosporium cladosporioides*		
264	M10	July 16/03	*Beauveria bassiana*		
113	M10	July 18/02	No growth		
112	M10	July 18/02	*Alternaria alternata*	*Beauvaria bassiana*	
294	M10	July 23/03	*Beauveria bassiana*		
295	M10	July 23/03	*Cladosporium cladosporioides*		
296	M10	July 23/03	No growth		
129	M10	July 24/02	No growth		
128	M10	July 24/02	No growth		
68	M10	July 3/02	B/Y		
67	M10	July 3/02	*Cladosporium cladosporioides*		
147	M10	July 31/02	B/y		
244	M10	July 9/03	*Beauveria bassiana*	*Ramichloridium schulzeri*	
45	M10	June 19/02	No growth		
44	M10	June 19/02	*Paecilomyces farinosus*		
46	M10	June 19/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
232	M10	June 25/03	*Beauveria bassiana*		
233	M10	June 25/03	No growth		
234	M10	June 25/03	No growth		
231	M10	June 25/03	No growth		
230	M10	June 25/03	No growth		
58	M10	June 26/02	No growth		
29	M10	June 5/02	*Beauvaria bassiana*		
27	M10	June 5/02	*Beauvaria bassiana*	*Cladosporium cladosporiodies*	
28	M10	June 5/02	*Beauvaria bassiana*		
8	M10	May 22/02	No growth		
192	M10	Sept 4/02	*Beauvaria bassiana*	*Penicillium* spp.	
321	M2	Aug 13/03	*Paecilomyces farinosus*		
339	M2	Aug 20/03	*Cladosporium cladosporioides*	*Eupenicillium brefeldianum*	
340	M2	Aug 20/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Penicillium* spp.
338	M2	Aug 20/03	*Verticillium lamellicola*		

170	M2	Aug 21/02	No growth			
171	M2	Aug 21/02	B/y			
341	M2	Aug 27/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
174	M2	Aug 28/02	No growth			
319	M2	Aug 6/03	*Verticillium lecanii*	*Mucor hiemalis*		
318	M2	Aug 6/03	*Beauveria bassiana*	*Penicillium steckii*		
159	M2	Aug 7/02	*Beauvaria bassiana*			
158	M2	Aug 7/02	*Penicillium steckii*			
95	M2	July 10/02	*Cladosporium cladosporioides*	*Penicillium steckii*		
96	M2	July 10/02	*Beauvaria bassiana*	*Acremonium fusidioides*		
242	M2	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	*Oidiodendron* state of *Myxotrichum arcticum*	
243	M2	July 2/03	*Cladosporium cladosporioides*			
241	M2	July 2/03	*Cladosporium cladosporioides*	*Penicillium* spp.		
288	M2	July 23/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	*Penicillium steckii*	
135	M2	July 24/02	*Alternaria alternata*	*Penicillium* spp.		
136	M2	July 24/02	*Beauvaria bassiana*	*Paecilomyces farinosus*	*Penicillium steckii*	
134	M2	July 24/02	B/y			
69	M2	July 3/02	*Cladosporium cladosporioides*			
305	M2	July 30/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	*Eupenicillium brefeldianum*	*Beauveria bassiana*
306	M2	July 30/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
145	M2	July 31/02	B/y			
154	M2	July 31/02	No growth			
152	M2	July 31/02	B/y			
153	M2	July 31/02	*Beauvaria bassiana*	*Penicillium steckii*		
155	M2	July 31/02	B/y			
253	M2	July 9/03	*Cladosporium cladosporioides*			
254	M2	July 9/03	No growth			
38	M2	June 19/02	*Beauvaria bassiana*			
227	M2	June 25/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
228	M2	June 25/03	*Cladosporium cladosporioides*			
229	M2	June 25/03	No growth			
59	M2	June 26/02	*Beauvaria bassiana*			
3	M2	May 15/02	B/Y			
13	M2	May 22/02	*Beauvaria bassiana*			
202	M2	Sept 4/02	No growth			
203	M2	Sept 4/02	*Verticillium lecanii*			
201	M2	Sept 4/02	*Cladosporium cladosporioides*			
320	M3	Aug 13/03	*Cladosporium cladosporioides*			
334	M3	Aug 20/03	*Verticillium lamellicola*	*Beauveria bassiana*		

333	M3	Aug 20/03	*Verticillium lecanii*		
332	M3	Aug 20/03	*Verticillium lecanii*		
343	M3	Aug 27/03	*Verticillium lamellicola*		
181	M3	Aug 28/02	B/y		
182	M3	Aug 28/02	B/y		
183	M3	Aug 28/02	B/y		
316	M3	Aug 6/03	*Penicillium brevicompactum*		
317	M3	Aug 6/03	*Penicillium steckii*		
313	M3	Aug 6/03	*Ramichloridium schulzeri*	*Verticillium lecanii*	*Penicillium* sp. 1
156	M3	Aug 7/02	*Cladosporium cladosporioides*	*Mucor hiemalis*	
97	M3	July 10/02	*Phialophora americana*		
98	M3	July 10/02	B/Y		
268	M3	July 16/03	*Cladosporium cladosporioides*	*Penicillium janthinellum*	
269	M3	July 16/03	*Cladosporium sphaerospermum*	*Penicillium janthinellum*	
115	M3	July 18/02	B/y		
116	M3	July 18/02	B/Y		
114	M3	July 18/02	No growth		
238	M3	July 2/03	*Beauveria bassiana*	*Cladosporium sphaerosporium*	
285	M3	July 23/03	*Verticillium lecanii*		
122	M3	July 24/02	B/y		
123	M3	July 24/02	*Acremonium fusioides*		
121	M3	July 24/02	*Beauvaria bassiana*		
89	M3	July 3/02	B/y		
84	M3	July 3/02	B/Y		
88	M3	July 3/02	No growth		
83	M3	July 3/02	B/y		
86	M3	July 3/02	B/y		
87	M3	July 3/02	B/Y		
85	M3	July 3/02	*Beauvaria bassiana*		
82	M3	July 3/02	B/y		
144	M3	July 31/02	B/y		
219	M3	June 11/03	B/y		
220	M3	June 11/03	B/y		
218	M3	June 11/03	No growth		
217	M3	June 11/03	B/y		
42a	M3	June 12/02	*Penicillium brevicompactum*		
225	M3	June 25/03	*Beauveria bassiana*		
226	M3	June 25/03	B/y		
224	M3	June 25/03	B/y		
208	M3	June 4/03	B/y		

23	M3	June 5/02	No growth				
2	M3	May 15/02	B/Y				
1	M3	May 15/02	B/Y				
12	M3	May 22/02	No growth				
199	M3	Sept 4/02	B/y				
200	M3	Sept 4/02	B/y				
198	M3	Sept 4/02	B/y				
14	M-3	May 29/02	No growth				
327	M4	Aug 20/03	*Verticillium lamellicola*				
168	M4	Aug 21/02	No growth				
169	M4	Aug 21/02	No growth				
176	M4	Aug 28/02	*Beauvaria bassiana*				
177	M4	Aug 28/02	No growth				
311	M4	Aug 6/03	No growth				
100	M4	July 10/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*			
99	M4	July 10/02	No growth				
284	M4	July 16/03	*Cladosporium cladosporioides*				
281	M4	July 16/03	*Cladosporium cladosporioides*				
283	M4	July 16/03	*Cladosporium sphaerospermum*				
282	M4	July 16/03	No growth				
280	M4	July 16/03	*Cladosporium sphaerospermum*				
277	M4	July 16/03	*Cladosporium cladosporioides*	*Beauveria bassiana*			
278	M4	July 16/03	*Cladosporium cladosporioides*	*Penicillium* sp. 1			
279	M4	July 16/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*			
110	M4	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
111	M4	July 18/02	*Beauvaria bassiana*				
237	M4	July 2/03	*Penicillium steckii*				
125	M4	July 24/02	*Cladosporium sphaerospermum*	*Verticillium lecanii*	*Acremonium fusioides*	*Chalara* sp.	*Acremonium strictum*
70	M4	July 3/02	B/y				
151	M4	July 31/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Acremonium strictum*		
150	M4	July 31/02	*Verticillium lecanii*				
255	M4	July 9/03	*Cladosporium cladosporioides*				
256	M4	July 9/03	No growth				
257	M4	July 9/03	*Cladosporium cladosporioides*				
258	M4	July 9/03	*Cladosporium cladosporioides*	*Penicillium* spp.			
37a	M4	June 12/02	*Auxarthron conjugatum*				
39a	M4	June 12/02	No growth				
40	M4	June 19/02	*Beauvaria bassiana*				
39	M4	June 19/02	*Beauvaria bassiana*	*Penicillium steckii*			
57	M4	June 26/02	B/y				

26	M4	June 5/02	*Beauvaria bassiana*				
6	M4	May 15/02	*Phialophora americana*				
7	M4	May 15/02	No growth				
16	M4	May 29/02	No growth				
15	M4	May 29/02	No growth				
90	M5	July 10/02	*Cladosporium sphaerospermum*				
267	M5	July 16/03	*Cladosporium sphaerospermum*				
266	M5	July 16/03	*Beauveria bassiana*				
290	M5	July 23/03	B/y				
289	M5	July 23/03	*Cladosporium cladosporioides*				
124	M5	July 24/02	*Beauvaria bassiana*	*Paecilomyces farinosus*			
301	M5	July 30/03	*Beauveria bassiana*	*Eupenicillium brefeldianum*	*Penicillium brevicompactum*		
245	M5	July 9/03	*Cladosporium cladosporioides*	*Beauveria bassiana*			
43a	M5	June 12/02	B/y				
37	M5	June 19/02	*Cladosporium cladosporiodies*	*Geomyces pannorus*			
25	M5	June 5/02	*Beauvaria bassiana*	*Aspergillus candidus*	*Eupenicillium brefeldianum*		
195	M5	Sept 4/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*			
197	M5	Sept 4/02	B/y				
196	M5	Sept 4/02	*Beauvaria bassiana*				
17	M-5	May 29/02	No growth				
265	M6	July 16/03	*Penicillium steckii*				
287	M6	July 23/03	*Beauveria bassiana*	*Penicillium implicatum*			
246	M6	July 9/03	No growth				
11	M6	May 22/02	*Beauvaria bassiana*				
207	M6	May 28/03	*Paecilomyces farinosus*	*Cladosporium sphaerosporium*	*Beauveria bassiana*	*Veronaea indica*	*Penicillium griseofulvum*
322	M7	Aug 13/03	*Verticillium lecanii*	*Penicillium* sp. 1			
344	M7	Aug 27/03	*Beauveria bassiana*				
345	M7	Aug 27/03	*Veronaea parvispora*				
315	M7	Aug 6/03	No growth				
157	M7	Aug 7/02	*Verticillium lecanii*				
91	M7	July 10/02	No growth				
92	M7	July 10/02	*Cladosporium cladosporioides*				
235	M7	July 2/03	No growth				
130	M7	July 24/02	*Cladosporium cladosporioides*				
131	M7	July 24/02	No growth				
74	M7	July 3/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	*Penicillium* spp.		
73	M7	July 3/02	*Cladosporium cladosporioides*	*Penicillium steckii*			
303	M7	July 30/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Geomyces pannorus*		
304	M7	July 30/03	*Cladosporium cladosporioides*				
148	M7	July 31/02	*Acremonium strictum*				

149	M7	July 31/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Cladosporium sphaerospermum*	
252	M7	July 9/03	No growth			
251	M7	July 9/03	No growth			
40a	m7	June 12/02	No growth			
42	M7	June 19/02	No growth			
43	M7	June 19/02	No growth			
41	M7	June 19/02	B/y			
221	M7	June 25/03	No growth			
63	M7	June 26/02	No growth			
60	M7	June 26/02	*Alternaria alternata*	*Sagenomella* cf. *diversispora*		
62	M7	June 26/02	*Cladosporium cladosporioides*			
61	M7	June 26/02	*Verticillium lecanii*			
211	M7	June 4/03	*Cladosporium cladosporioides*			
210	M7	June 4/03	No growth			
194	M7	Sept 4/02	*Cladosporium cladosporioides*			
193	M7	Sept 4/02	*Beauvaria bassiana*			
324	M8	Aug 13/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*		
326	M8	Aug 13/03	*Cladosporium sphaerospermum*			
325	M8	Aug 13/03	No growth			
330	M8	Aug 20/03	*Cladosporium sphaerospermum*			
331	M8	Aug 20/03	*Cladosporium cladosporioides*			
167	M8	Aug 21/02	No growth			
191	M8	Aug 28/02	No growth			
190	M8	Aug 28/02	*Acremonium strictum*			
189	M8	Aug 28/02	B/y			
163	M8	Aug 7/02	No growth			
164	M8	Aug 7/02	*Cladosporium cladosporiodies*	*Acremonium strictum*	*Penicillium steckii*	
165	M8	Aug 7/02	*Verticillium lecanii*	*Absidia glauca*	*Penicillium* spp.	
101	M8	July 10/02	*Cladosporium cladosporioides*			
103	M8	July 10/02	*Cladosporium cladosporioides*			
102	M8	July 10/02	*Cladosporium sphaerospermum*			
104	M8	July 10/02	*Cladosporium cladosporioides*			
273	M8	July 16/03	*Penicillium brevicompactum*	*Leptographium piriforme*	*Cladosporium cladosporioides*	*Beauveria bassiana*
275	M8	July 16/03	*Geomyces pannorus*	*Beauveria bassiana*	*Cladosporium cladosporioides*	
274	M8	July 16/03	No growth			
276	M8	July 16/03	*Beauveria bassiana*	*Penicillium marquandii*		
108	M8	July 18/02	*Beauvaria bassiana*	*Penicillium marquandii*		
109	M8	July 18/02	*Beauvaria bassiana*	*Penicillium steckii*		
299	M8	July 23/03	*Cladosporium sphaerospermum*	*Eupenicillium brefeldianum*	*Penicillium* spp.	
298	M8	July 23/03	*Cladosporium cladosporioides*			

297	M8	July 23/03	*Cladosporium sphaerospermum*		
126	M8	July 24/02	*Cladosporium cladosporioides*		
127	M8	July 24/02	*Cladosporium sphaerospermum*	*Penicillium brevicompactum*	
72	M8	July 3/02	No growth		
71	M8	July 3/02	B/y		
302	M8	July 30/03	*Cladosporium cladosporioides*	*Penicillium raistrickii*	
249	M8	July 9/03	B/y		
250	M8	July 9/03	*Cladosporium cladosporioides*		
41a	M8	June 12/02	No growth		
56	M8	June 26/02	No growth		
18	M8	May 29/02	No growth		
19	M8	May 29/02	*Acremonium strictum*		
328	M9	Aug 20/03	*Beauveria bassiana*		
329	M9	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
350	M9	Aug 27/03	B/y		
349	M9	Aug 27/03	*Cladosporium cladosporioides*		
187	M9	Aug 28/02	B/y		
188	M9	Aug 28/02	No growth		
184	M9	Aug 28/02	*Geomyces pannorus*		
185	M9	Aug 28/02	*Verticillium lecanii*	*Penicillium brevicompactum*	
186	M9	Aug 28/02	*Verticillium lecanii*	*Penicillium brevicompactum*	
312	M9	Aug 6/03	*Cladosporium cladosporioides*	*Verticillium lecanii*	
161	M9	Aug 7/02	*Cladosporium cladosporioides*		
162	M9	Aug 7/02	B/y		
94	M9	July 10/02	B/y		
93	M9	July 10/02	*Cladosporium cladosporioides*		
272	M9	July 16/03	*Cladosporium sphaerospermum*	*Cladosporium orchidis*	
120	M9	July 18/02	*Geomyces pannorus*		
119	M9	July 18/02	*Cladosporium cladosporiodes*		
118	M9	July 18/02	*Geomyces pannorus*		
117	M9	July 18/02	*Beauvaria bassiana*	*Penicillium* spp.	
236	M9	July 2/03	*Cladosporium cladosporioides*		
292	M9	July 23/03	*Aphanocladium aranearum*	*Alternaria alternata*	
286	M9	July 23/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	
291	M9	July 23/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Beauveria bassiana*
293	M9	July 23/03	*Beauveria bassiana*		
142	M9	July 24/02	No growth		
141	M9	July 24/02	*Cladosporium cladosporioides*		
143	M9	July 24/02	*Cladosporium cladosporioides*		
137	M9	July 24/02	*Cladosporium cladosporioides*		

138	M9	July 24/02	*Paecilomyces farinosus*	*Verticillium lecanii*	
139	M9	July 24/02	*Beauvaria bassiana*	*Conidiobolous coronatus*	
140	M9	July 24/02	No growth		
75	M9	July 3/02	No growth		
77	M9	July 3/02	No growth		
76	M9	July 3/02	No growth		
300	M9	July 30/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	
146	M9	July 31/02	No growth		
247	M9	July 9/03	*Beauveria bassiana*		
248	M9	July 9/03	No growth		
216	M9	June 11/03	No growth		
215	M9	June 11/03	B/y		
36	M9	June 12/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
35	M9	June 12/02	*Beauvaria bassiana*		
34	M9	June 12/02	*Beauvaria bassiana*		
48	M9	June 19/02	No growth		
50	M9	June 19/02	No growth		
47	M9	June 19/02	No growth		
49	M9	June 19/02	No growth		
222	M9	June 25/03	B/y		
66	M9	June 26/02	No growth		
65	M9	June 26/02	*Beauvaria bassiana*		
64	M9	June 26/02	*B/y*		
209	M9	June 4/03	No growth		
24	M9	June 5/02	*Beauvaria bassiana*		
10	M9	May 22/02	No growth		
204	M9	Sept 4/02	*Cladosporium cladosporioides*	*Geomyces pannorus*	
205	M9	Sept 4/02	B/y		
113	W1	Aug 07/02	*Cladosporium sphaerospermum*	*Penicillium raistrickii*	
114	W1	Aug 07/02	*Cladosporium cladosporioides*		
297	W1	Aug 20/03	*Cladosporium cladosporioides*		
296	W1	Aug 20/03	*Penicillium* sp. 1		
140	W1	Aug 28/02	No growth		
66	W1	July 10/02	*Beauvaria bassiana*		
65	W1	July 10/02	No growth		
72	W1	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	
71	W1	July 18/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Penicillium* sp. 1
197	W1	July 2/03	*Beauveria bassiana*		
192	W1	July 2/03	*Cladosporium cladosporioides*	*Penicillium janthinellum*	
195	W1	July 2/03	B/y		

191	W1	July 2/03	No growth			
196	W1	July 2/03	*Verticillium lecanii*	*Beauveria bassiana*	*Cladosporium cladosporioides*	
244	W1	July 23/03	*Verticillium lamellicola*	*Penicillium steckii*		
86	W1	July 24/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	*Cladosporium cladosporiodies*	*Penicillium* sp. 1
49	W1	July 3/02	No growth			
50	W1	July 3/02	*Cladosporium cladosporioides*			
48	W1	July 3/02	*Cladosporium sphaerospermum*			
209	W1	July 9/03	No growth			
208	W1	July 9/03	*Cladosporium sphaerospermum*			
22	W1	June 12/02	No growth			
21	W1	June 12/02	*Beauvaria bassiana*			
23	W1	June 12/02	*Beauvaria bassiana*			
33	W1	June 19/02	*Beauvaria bassiana*	*Penicillium* spp.		
32	W1	June 19/02	*Beauvaria bassiana*			
31	W1	June 19/02	No growth			
173	W1	June 25/03	B/y			
37	W1	June 26/02	No growth			
13	W1	June 5/02	No growth			
151	W1	May 28/03	*Hormicactus candida*			
152	W1	May 28/03	*Cladosporium cladosporioides*			
10	W1	May 29/02	No growth			
287	W10	Aug 13/03	*Penicillium steckii*			
128	W10	Aug 21/02	*Alternaria alternata*	*Verticillium lecanii*	*Penicillium brevicompactum*	
127	W10	Aug 21/02	No growth			
129	W10	Aug 21/02	No growth			
308	W10	Aug 27/03	No growth			
142	W10	Aug 28/02	*Paecilomyces fumosoreus*	*Cladosporium cladosporioides*	*Penicillium steckii*	
143	W10	Aug 28/02	*Cladosporium cladosporioides*	*Verticillium lecanii*		
279	W10	Aug 6/03	*Penicillium marquandii*			
58	W10	July 10/02	*Cladosporium cladosporiodies*			
57	W10	July 10/02	*Penicillium* sp. 1			
236	W10	July 16/03	B/y			
237	W10	July 16/03	B/y			
235	W10	July 16/03	*Beauveria bassiana*			
77	W10	July 18/02	*Cladosporium cladosporioides*			
253	W10	July 23/03	B/y			
251	W10	July 23/03	*Beauveria bassiana*	*Penicillium* spp.		
252	W10	July 23/03	*Verticillium psalliotae*	*Penicillium steckii*		
266	W10	July 30/03	*Verticillium psalliotae*			
265	W10	July 30/03	*Penicillium steckii*			

101	W10	July 31/02	*Verticillium lecanii*	*Cladosporium sphaerospermum*	
223	W10	July 9/03	*Cryptendoxyla hypophloia*		
220	W10	July 9/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Geomyces pannorus*
219	W10	July 9/03	No growth		
221	W10	July 9/03	No growth		
222	W10	July 9/03	No growth		
168	W10	June 11/03	B/y		
16	W10	June 12/02	*Beauvaria bassiana*		
178	W10	June 25/03	*Verticillium lecanii*		
177	W10	June 25/03	*Beauveria bassiana*		
179	W10	June 25/03	No growth		
42	W10	June 26/02	*Beauvaria bassiana*		
43	W10	June 26/02	*Beauvaria bassiana*		
41	W10	June 26/02	*Beauvaria bassiana*		
156	W10	June 4/03	*Gliocladium* cf. *penicillioides*		
110	W2	Aug 07/02	*Cladosporium cladosporioides*	*Penicillium steckii*	
136	W2	Aug 21/02	*Cladosporium sphaerospermum*	*Cladosporium cladosporioides*	*Penicillium brevicompactum*
130	W2	Aug 21/02	*Cladosporium cladosporioides*	*Penicillium* spp.	
131	W2	Aug 21/02	B/y		
133	W2	Aug 21/02	*Cladosporium cladosporioides*	*Penicillium brevicompactum*	
134	W2	Aug 21/02	*Cladosporium sphaerospermum*	*Penicillium* spp.	
135	W2	Aug 21/02	*Cladosporium cladosporioides*		
132	W2	Aug 21/02	No growth		
139	W2	Aug 28/02	No growth		
280	W2	Aug 6/03	*Cladosporium cladosporioides*	*Beauveria bassiana*	*Verticillium lamellicola*
62	W2	July 10/02	No growth		
61	W2	July 10/02	*Cladosporium cladosporioides*		
84	W2	July 18/02	*Acremonium strictum*	*Cladosporium cladosporioides*	
81	W2	July 18/02	No growth		
82	W2	July 18/02	No growth		
83	W2	July 18/02	*Cladosporium sphaerospermum*	*Penicillium steckii*	
186	W2	July 2/03	*Leptographium piriforme*	*Cladosporium cladosporioides*	
98	W2	July 24/02	*Cladosporium cladosporioides*		
99	W2	July 24/02	*Cladosporium cladosporioides*		
100	W2	July 24/02	*Acremonium strictum*	*Cladosporium cladosporioides*	
97	W2	July 24/02	*Penicillium steckii*		
44	W2	July 3/02	No growth		
45	W2	July 3/02	*Penicillium steckii*		
36	W2	June 26/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*	
164	W2	June 4/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	

166	W2	June 4/03	*Cladosporium sphaerospermum*		
165	W2	June 4/03	*Cladosporium sphaerospermum*		
167	W2	June 4/03	B/y		
11	W2	June 5/02	*Beauvaria bassiana*		
1	W2	May 15/02	B/Y		
3	W2	May 22/02	*Penicillium* spp.	*Cladosporium cladosporioides*	
7	W2	May 29/02	No growth		
146	W2	Sept 4/02	*Beauvaria bassiana*	*Verticillium lecanii*	*Penicillium steckii*
148	W2	Sept 4/02	B/y		
147	W2	Sept 4/02	*Cladosporium cladosporioides*		
288	W3	Aug 13/03	*Penicillium steckii*		
306	W3	Aug 27/03	*Penicillium steckii*		
137	W3	Aug 28/02	No growth		
277	W3	Aug 6/03	*Penicillium steckii*		
55	W3	July 10/02	No growth		
56	W3	July 10/02	*Cladosporium sphaerospermum*	*Penicillium* sp. 1	
233	W3	July 16/03	No growth		
234	W3	July 16/03	No growth		
232	W3	July 16/03	No growth		
74	W3	July 18/02	No growth		
73	W3	July 18/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*	
246	W3	July 23/03	*Penicillium steckii*		
247	W3	July 23/03	*Oideodendron maius*	*Beauveria bassiana*	*Penicillium steckii*
245	W3	July 23/03	*Eupenicillium brefeldianum*		
248	W3	July 23/03	*Verticillium psalliotae*	*Rhizopus stolinifer*	*Absidia glauca*
85	W3	July 24/02	*Leptographium piriforme*	*Acremonium strictum*	
51	W3	July 3/02	*Penicillium brevicompactum*		
52	W3	July 3/02	No growth		
102	W3	July 31/02	No growth		
206	W3	July 9/03	B/y		
207	W3	July 9/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	
29	W3	June 19/02	No growth		
28	W3	June 19/02	*Beauvaria bassiana*		
39	W3	June 26/02	*Absidia glauca*	*Penicillium steckii*	
38	W3	June 26/02	No growth		
159	W3	June 4/03	No growth		
160	W3	June 4/03	No growth		
149	W3	May 28/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	
109	W4	Aug 07/02	No growth		
299	W4	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium implicatum*	

298	W4	Aug 20/03	*Penicillium steckii*				
124	W4	Aug 21/02	*Cladosporium cladosporioides*				
123	W4	Aug 21/02	*Cladosporium sphaerospermum*				
282	W4	Aug 6/03	*Verticillium lamellicola*	*Penicillium marquandii*			
283	W4	Aug 6/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*			
281	W4	Aug 6/03	*Cladosporium cladosporioides*	*Penicillium marquandii*			
187	W4	July 2/03	*Beauveria bassiana*				
188	W4	July 2/03	*Cladosporium sphaerospermum*				
243	W4	July 23/03	*Verticillium lamellicola*	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
263	W4	July 30/03	*Beauveria bassiana*	*Penicillium brevicompactum*			
17	W4	June 12/02	No growth				
181	W4	June 25/03	*Cladosporium cladosporioides*				
180	W4	June 25/03	B/y				
182	W4	June 25/03	*Cladosporium cladosporioides*				
12	W4	June 5/02	*Beauvaria bassiana*	*Cladosporium cladosporiodies*			
5	W4	May 22/02	*Beauvaria bassiana*				
150	W4	May 28/03	No growth				
145	W4	Sept 4/02	*Beauvaria bassiana*				
116	W5	Aug 07/02	No growth				
120	W5	Aug 07/02	*Cladosporium cladosporioides*				
117	W5	Aug 07/02	*Beauvaria bassiana*				
115	W5	Aug 07/02	*Cladosporium cladosporioides*				
118	W5	Aug 07/02	No growth				
119	W5	Aug 07/02	*Penicillium brevicompactum*	*Cladosporium cladosporioides*	*Geomyces pannorus*	*Beauvaria bassiana*	
291	W5	Aug 13/03	*Cladosporium cladosporioides*				
290	W5	Aug 13/03	*Acremonium butyri*	*Cladosporium cladosporioides*	*Beauveria bassiana*		
302	W5	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium steckii*			
301	W5	Aug 20/03	No growth				
300	W5	Aug 20/03	*Cladosporium cladosporioides*	*Penicillium steckii*			
121	W5	Aug 21/02	*Cladosporium cladosporioides*				
312	W5	Aug 27/03	*Beauveria bassiana*				
311	W5	Aug 27/03	B/y				
138	W5	Aug 28/02	*Penicillium steckii*				
276	W5	Aug 6/03	*Cladosporium cladosporioides*				
226	W5	July 16/03	*Cladosporium cladosporioides*				
225	W5	July 16/03	*Cladosporium cladosporioides*				
227	W5	July 16/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*			
78	W5	July 18/02	*Paecilomyces farinosus*	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Beauveria bassiana*	*Geomyces pannorus*
189	W5	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*			
190	W5	July 2/03	*Mucor hiemalis*				

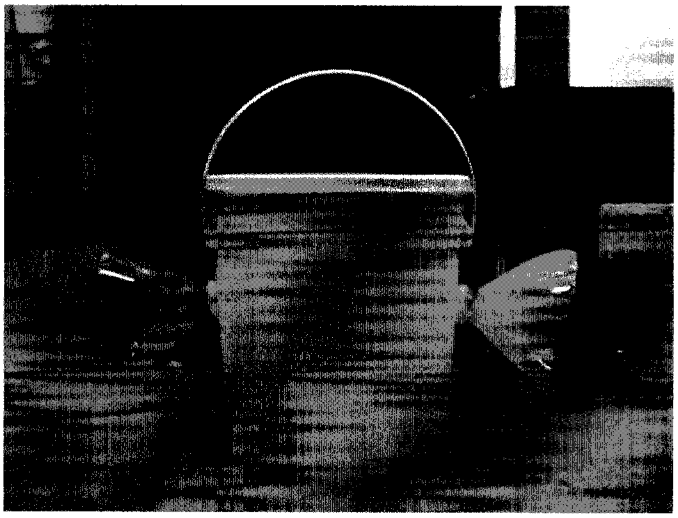
87	W5	July 24/02	*Cladosporium sphaerospermum*	*Penicillium steckii*	
46	W5	July 3/02	*Cladosporium cladosporioides*		
264	W5	July 30/03	*Beauveria bassiana*		
213	W5	July 9/03	*Verticillium lamellicola*		
212	W5	July 9/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	
169	W5	June 11/03	*Verticillium psalliotae*		
155	W5	June 4/03	*Beauveria bassiana*		
6	W5	May 22/02	*Cladosporium cladosporiodies*		
107	W6	Aug 07/02	*Beauvaria bassiana*		
289	W6	Aug 13/03	*Cladosporium cladosporioides*	*Penicillium steckii*	
307	W6	Aug 27/03	B/y		
286	W6	Aug 6/03	*Cladosporium sphaerospermum*	*Penicillium marquandii*	
284	W6	Aug 6/03	*Penicillium steckii*		
285	W6	Aug 6/03	*Verticillium lamellicola*	*Alternaria alternata*	*Penicillium* spp.
59	W6	July 10/02	*Beauvaria bassiana*		
60	W6	July 10/02	*Beauvaria bassiana*		
229	W6	July 16/03	No growth		
228	W6	July 16/03	*Hormicactus candida*		
76	W6	July 18/02	*Penicillium* spp.		
185	W6	July 2/03	*Cladosporium cladosporioides*		
259	W6	July 23/03	*Cladosporium sphaerospermum*	*Beauveria bassiana*	*Penicillium steckii*
254	W6	July 23/03	*Beauveria bassiana*	*Mucor hiemalis*	*Penicillium steckii*
255	W6	July 23/03	*Cladosporium cladosporioides*	*Verticillium lamellicola*	*Penicillium implicatum*
256	W6	July 23/03	*Cladosporium cladosporioides*	*Penicillium steckii*	
258	W6	July 23/03	*Cladosporium sphaerospermum*	*Penicillium steckii*	
257	W6	July 23/03	*Penicillium steckii*		
260	W6	July 23/03	*Penicillium steckii*		
261	W6	July 23/03	*Penicillium griseofulvum*		
96	W6	July 24/02	*Hormiactuis candida*		
93	W6	July 24/02	*Beauvaria bassiana*		
94	W6	July 24/02	No growth		
95	W6	July 24/02	*Verticillium lamellicola*		
272	W6	July 30/03	*Penicillium steckii*		
270	W6	July 30/03	*Verticillium lamellicola*		
271	W6	July 30/03	*Verticillium lamellicola*		
275	W6	July 30/03	*Beauveria bassiana*		
274	W6	July 30/03	*Beauveria bassiana*		
273	W6	July 30/03	*Penicillium steckii*		
205	W6	July 9/03	*Cladosporium sphaerospermum*	*Penicillium steckii*	
20	W6	June 12/02	*Beauvaria bassiana*		

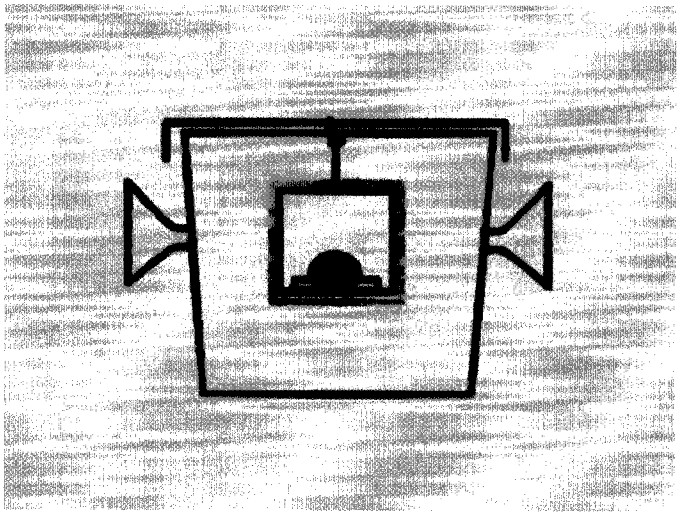
24	W6	June 19/02	*Beauvaria bassiana*			
25	W6	June 19/02	*Beauvaria bassiana*			
175	W6	June 25/03	No growth			
40	W6	June 26/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*		
157	W6	June 4/03	*Beauveria bassiana*			
158	W6	June 4/03	No growth			
8	W6	May 29/02	No growth			
111	W7	Aug 07/02	*Beauvaria bassiana*			
112	W7	Aug 07/02	No growth			
126	W7	Aug 21/02	No growth			
125	W7	Aug 21/02	*Alternaria alternata*	*Verticillium lecanii*	*Cladosporium sphaerospermum*	*Penicillium* spp.
309	W7	Aug 27/03	*Verticillium lamellicola*	*Penicillium* spp.		
310	W7	Aug 27/03	*Verticillium lecanii*			
69	W7	July 10/02	*Cladosporium cladosporioides*			
70	W7	July 10/02	*Absidia glauca*			
67	W7	July 10/02	No growth			
68	W7	July 10/02	*Penicillium* sp. 1			
231	W7	July 16/03	By			
230	W7	July 16/03	B/y			
183	W7	July 2/03	*Beauveria bassiana*	*Cladosporium sphaerospermum*	*Cladosporium cladosporioides*	
184	W7	July 2/03	*Beauveria bassiana*			
250	W7	July 23/03	B/y			
249	W7	July 23/03	B/y			
88	W7	July 24/02	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
214	W7	July 9/03	*Cladosporium cladosporioides*			
215	W7	July 9/03	*Cladosporium cladosporioides*			
19	W7	June 12/02	No growth			
30	W7	June 19/02	No growth			
172	W7	June 25/03	*Cladosporium cladosporioides*			
163	W7	June 4/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		
162	W7	June 4/03	*Cladosporium sphaerospermum*			
161	W7	June 4/03	No growth			
2	W7	May 15/02	*Beauvaria bassiana*	*Geomyces panorus*	*Aspergillus fumigatus*	
153	W7	May 28/03	No growth			
154	W7	May 28/03	No growth			
108	W8	Aug 07/02	*Verticillium lecanii*			
141	W8	Aug 28/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*		
278	W8	Aug 6/03	*Beauveria bassiana*	*Penicillium marquandii*		
64	W8	July 10/02	No growth			
63	W8	July 10/02	*Beauvaria bassiana*	*Cladosporium sphaerospermum*		

224	W8	July 16/03	*Cladosporium sphaerospermum*	*Penicillium steckii*		
80	W8	July 18/02	No growth			
79	W8	July 18/02	*Cladosporium cladosporioides*	*Beauvaria bassiana*		
194	W8	July 2/03	*Cladosporium sphaerospermum*			
193	W8	July 2/03	*Beauveria bassiana*			
242	W8	July 23/03	*Cladosporium cladosporioides*	*Penicillium* spp.		
92	W8	July 24/02	*Cladosporium cladosporioides*			
90	W8	July 24/02	*Cladosporium cladosporioides*			
91	W8	July 24/02	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Penicillium* sp. 1	
47	W8	July 3/02	*Acremonium strictum*			
269	W8	July 30/03	*Penicillium marquandii*			
268	W8	July 30/03	*Beauveria bassiana*	*Alternaria alternata*	*Cladosporium sphaerospermum*	*Penicillium steckii*
267	W8	July 30/03	*Cladosporium cladosporioides*	*Acremonium strictum*		
210	W8	July 9/03	No growth			
211	W8	July 9/03	*Cladosporium sphaerosporium*	*Phialophora americana*		
18	W8	June 12/02	*Beauvaria bassiana*			
27	W8	June 19/02	*Beauvaria bassiana*			
174	W8	June 25/03	No growth			
15	W8	June 5/02	*Beauvaria bassiana*			
106	W9	Aug 07/02	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
292	W9	Aug 13/03	*Cladosporium cladosporioides*	*Penicillium brevicompactum*		
294	W9	Aug 13/03	No growth			
293	W9	Aug 13/03	*Penicillium brevicompactum*			
305	W9	Aug 20/03	*Penicillium brevicompactum*			
304	W9	Aug 20/03	*Alternaria alternata*	*Penicillium brevicompactum*		
295	W9	Aug 20/03	*Penicillium raistrickii*			
303	W9	Aug 20/03	*Penicillium marquandii*			
122	W9	Aug 21/02	*Verticillium lecanii*	*Absidia glauca*		
241	W9	July 16/03	*Beauveria bassiana*			
240	W9	July 16/03	No growth			
238	W9	July 16/03	*Beauveria bassiana*			
239	W9	July 16/03	*Beauveria bassiana*	*Penicillium brevicompactum*		
75	W9	July 18/02	*Paecilomyces fumosoroseus*	*Beauvaria bassiana*		
203	W9	July 2/03	*Absidia glauca*			
202	W9	July 2/03	*Beauveria bassiana*			
199	W9	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*	*Eupenicillium brefeldianum*	
204	W9	July 2/03	*Beauveria bassiana*	*Verticillium lecanii*	*Penicillium brevicompactum*	
200	W9	July 2/03	*Cladosporium cladosporioides*	*Eupenicillium brefeldianum*		
198	W9	July 2/03	*Gliocladium penicillioides*	*Beauveria bassiana*	*Cladosporium cladosporioides*	
201	W9	July 2/03	*Beauveria bassiana*	*Cladosporium cladosporioides*		

89	W9	July 24/02	*Beauvaria bassiana*	*Cladosporium cladosporioides*	*Verticillium lecanii*	*Paecilomyces farinosus*
54	W9	July 3/02	B/y			
53	W9	July 3/02	B/y			
262	W9	July 30/03	*Cladosporium sphaerospermum*	*Penicillium steckii*		
105	W9	July 31/02	*Beauvaria bassiana*			
104	W9	July 31/02	*Cladosporium cladosporioides*			
103	W9	July 31/02	*Cladosporium sphaerospermum*			
217	W9	July 9/03	*Cladosporium cladosporioides*			
216	W9	July 9/03	*Cladosporium cladosporioides*			
218	W9	July 9/03	*Verticillium psalliotae*	*Cladosporium sphaerospermum*		
171	W9	June 11/03	*Beauveria bassiana*	*Acremonium kiliense*		
170	W9	June 11/03	*Verticillium lecanii*			
26	W9	June 19/02	*Cladosporium cladosporioides*	*Penicillium frequetans*		
176	W9	June 25/03	No growth			
35	W9	June 26/02	*Beauvaria bassiana*			
34	W9	June 26/02	No growth			
14	W9	June 5/02	*Beauvaria bassiana*			
4	W9	May 22/02	*Penicillium* spp.	*Cladosporium cladosporiodies*	*Geomyces panorus*	*Phialophora americana*
9	W9	May 29/02	*Beauvaria bassiana*			
144	W9	Sept 4/02	*Cladosporium cladosporioides*			

Appendix 3: Bucket trap described in chapter 2.





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Education:

University of Alberta: Ph.D. Ecology and Evolution. Degree conferred in 2006.

University of Toronto: Bachelor of Science (Honours), Botany specialist.
Degree conferred in 2000.

Academic Employment:

The Field Museum
Post-doc, 2006-08

University of Alberta:
Teaching assistant in the following courses, 2000 – 2005
Biol 108 Organisms in their environment
Bot 201 Biology of algae, fungi, and lichens
Bot 205 Fundamentals of plant biology
Bot 306 Biology of the fungi

Duties include teaching students in a laboratory setting, preparing and marking assignments and tests, and assisting with the development of future course material with the lab coordinator.

Workshop assistant in the following course, 2005
Biol 108 Organisms in their environment

Duties include holding weekly workshops where topics discussed in lecture are covered in more detail, introducing thought questions designed to lead discussion with students, and marking final exam material.

University of Toronto, Victoria College: Assistant to the Registrar, 2000.

Duties include composition of letters, assisting in convocation mailings, data entry, and creating student mailing lists using on-line student data base.

University of Toronto: Mycology lab assistant under supervision of Professor David Malloch, 1998 and 1999.

Duties included fieldwork, preparation of fungal samples for study, observation and collection of data, and data entry.

Professional Organizations:

Mycological Society of America (MSA)

Publications and Other Contributions:

Publications, including submitted and in press

Greif M, Gibas CFC, Tsuneda A, Currah RS 2006 Ascoma development and phylogeny of an apothecioid dothideomycete, *Catinella olivacea*. American Journal of Botany (Submitted June 12 2006; ref # No. 2006-235)

Grief M, Gibas CFC, Tsuneda A, Currah RS 2006 Leptographium piriforme sp. nov., from a taxonomically diverse collection of arthropods collected in an aspen-dominated forest in Western Canada. Mycologia (Submitted April 24 2006, ref # 06-088).

Greif M, Currah RS 2006 Development and dehiscence of the cephalothecoid peridium in *Aporothielavia leptoderma* and a proposal to transfer the species to *Chaetomidium*. Mycological Research (Submitted March 2 2006; ref # Mycres-D-0600050).

Greif M, Currah RS 2006 Patterns in the occurrence of saprophytic fungi carried by arthropods caught in traps baited with rotted wood and dung. Mycologia (Submitted March 15 2006; ref # 06-056).

Greif M, Tsuneda A, Currah RS 2004 The development and dehiscence mechanism of Cryptendoxyla hypophloia, a cleistothecial ascomycete isolated from the bodies of arthropods. International Journal of Plant Science 165: 957-964.

Greif M, Currah RS 2003 A functional interpretation of the role of the reticuloperidium in whole-ascoma dispersal by arthropods. Mycological Research 107: 77-81.

Non-refereed Publications:

Greif M, Gibas CFC, Currah RS 2006 A new species of *Leptographium* from arthropods collected in an aspen-dominated woodland in western Canada. Abtracts. APS, CPS, MSA Joint meeting. Pg 197 (Abstract).

Greif M, Gibas CFC, Tsuneda A, Currah RS 2006 *Catinealla olivacea* – an ascostromatic fungus masquerading as an inoperculate discomycete. Abtracts. APS, CPS, MSA Joint meeting. Pg 197 (Abstract).

Greif M, Currah RS 2005 Arthropod dispersal of cycloheximide resistant fungi in central Alberta. Schedule and abstracts. Plant Canada 2005. Pg 167 (Abstract).

Greif M, Currah RS 2005 A structural analysis of peridial development in *Aporothielavia leptoderma* has ecological and taxonomic significance. Schedule and abstracts. Plant Canada 2005. Pg 77 (Abstract)

Greif M, Currah RS 2004 A survey of arthroconidial fungi isolated from insects. Program and abstracts. Mycological Society of America. Pg 54 (Abstract).

Greif M, Currah, RS 2004 The development and function of the cephalothecoid peridium in *Cryptendoxyla hypophloia*. Program and Abstracts. Mycological Society of America. Pg 54 (Abstract).

Greif M, Currah RS 2002 Ascocarp impalement: A novel mechanism of dispersal in cleistothecial ascomycetes. Book of Abstracts. International Mycological Congress 7. Pg 203 (Abstract).

Greif M, Currah RS 2001 Is the gastroid inoperculate discomycete genus *Myxotrichum* dispersed by arthropods" Program and Abstracts. Canadian Botanical Association. Pg 54 (Abstract).

Other Contributions:

Greif M, Gibas CFC, Currah RS 2006 A new species of *Leptographium* from arthropods collected in an aspen-dominated woodland in western Canada. APS, CPS, MSA Joint meeting. (Presentation).

Greif M, Gibas CFC, Tsuneda A, Currah RS 2006 *Catinealla olivacea* – an ascostromatic fungus masquerading as an inoperculate discomycete. APS, CPS, MSA Joint meeting. (Poster).

Greif M, Currah RS 2005 Arthropod dispersal of cycloheximide resistant fungi in central Alberta. Plant Canada 2005, Edmonton, Alberta. (Presentation).

Greif M, Currah RS 2005 A structural analysis of peridial development in *Aporothielavia leptoderma* has ecological and taxonomic significance. Plant Canada 2005, Edmonton, Alberta. (Presentation).

Greif M 2004 Don't Panic! A fungal hitchhikers guide to the galaxy (the role of the peridium in spore dispersal) Bot 600 University of Alberta (Invited speaker).

Greif M, Currah RS 2004 A survey of arthroconidial fungi isolated from insects. Mycological Society of America annual meeting, Asheville, North Carolina. (Presentation).

Greif M, Currah, RS 2004 The development and function of the cephalothecoid peridium in *Cryptendoxyla hypophloia*. Mycological Society of America annual meeting, Asheville, North Carolina. (Presentation).

Greif M 2003 Hitchhikers and stowaways; A review of insect mediated dispersal of fungi. Ent 620 University of Alberta (Invited speaker).

Greif M, Currah, R.S. (2002) Ascocarp impalement: A novel mechanism of dispersal in cleistothecial ascomycetes. International Mycological Congress 7, Oslo, Norway. (Poster).

Greif M, Currah RS 2001 Is the gastroid inoperculate discomycete genus *Myxotrichum* dispersed by arthropods? Canadian Botanical Association annual meeting, Kelowna, BC. (Presentation).

Awards and Commendations:

Letters of Commendation for TA duties (2001-2, 2003-4, 2005-6)
Department of Biological Sciences, Excellence in Teaching award (2004-5)
Mycological Society of America, Best Student Oral Presentation (2004)
Faculty of Science, Graduate Teaching Assistantship Scholarship (2000 - 2004)
J Gordin Kaplan Graduate Student Award (2002)
Department of Biological Sciences, Travel Support (2002)
Challenge Grant in Biodiversity (2001 - 2002)
The Bloor Lands Admissions Scholarship (1995)
The Ivan Prock Scholarship (1995)

Relevant Activities:

Database coordinator for Vargo digital atlas of fungi. 2005-6.
The Vargo digital atlas is to be an online database of images, text, and keys concerning fungi commonly encountered from dung and other substrates in Alberta. Duties include constructing a file system; setting up standards for species accession and formatting of digital images; scanning submitted data; compiling images; and entering taxonomic information.

Volunteer organizer Plant Canada Meeting 2005
Duties included preparing information packages for delegates and providing technical assistance and set up for scheduled powerpoint presentations.

Biology Graduate Student Association Executive: Secretary 2003 – 2005

Museum committee: Student representative 2003 – 2005

Mycology journal club. 2004. Organized weekly meetings discussing a broad range of mycological research, including mycorrhizal associations, arthropod dispersal, plant diseases, and fungal taxonomy. This club was intended for graduate students whose projects had a mycological component and who were interested in increasing their knowledge of the fungal kingdom.

Ecology journal club. 2003 – 2004. Organized weekly meetings where graduate students discussed topics in ecology. The aim of this club was to generate new ideas in ecology by bringing together students from different research backgrounds.

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