Molds and other fungi in indoor environments:
Summary of biology, known health effects and references

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Absidia

Absidia is one of the pin molds (zygomycetes) that is frequently found in soil and plant debris (Ellis 1994, Zycha et al. 1969). They produce structures (sporangia) filled with sticky spores under relatively moist conditions. It is also known in indoor environments from air and surface samples. No species are known to produce mycotoxins. *A. corymbifera* is a well-known agent of zygomycosis, an opportunistic human infection (Ellis 1994, Rippon 1988).

Acremonium

The genus *Acremonium* is a large and diverse group of molds (hyphomycetes) that are widespread in soil and plant debris. They are especially abundant in wet environments and typically have high water requirements. They produce small, hyaline spores in sticky masses or chains from simple phialidic conidiophores (Gams 1971). Common species include *A. strictum, A. terricola, A. bacillisporum*. A few species are known to produce mycotoxins (e.g., citrinin), and several (including *A. kiliense*) are occasional agents of opportunistic human infection (Sigler and Kennedy 1998).

Alternaria

Alternaria is a common mold, and is one of the phylloplane (leaf decay) fungi. It is prevalent in outdoor environments, and may colonize indoor substrata when conditions are suitable. *Alternaria* species produce large, multicelled, brown spores, often in chains. *A. alternata* is the most common indoor species. It is capable of degrading cellulose and is frequently found on drywall paper, ceiling tiles and wood. A number of mycotoxins are produced including alternariol, altertoxin and tenuazonic acid. *Alternaria* is also a well-known agent of allergy and asthma (Fung et al. 2000). Although not normally pathogenic, opportunistic disease has rarely been reported in immunocompromised patients (Cunliffe and Denning 1995).

Antrodia (see Basidiomycetes)

Aphanocladium

Aphanocladium is a white, cottony mold (hyphomycetes) that produces small, solitary hyaline spores from phialides borne at right angles along the hyphae (Gams 1971,

1973). *A. album* has been isolated from soil, plant matter and air samples, and is known to proliferate on indoor substrata (e.g., wood) under suitable conditions. No species are reported to produce mycotoxins.

Ascospores (see Ascomycetes)

Ascotricha (see Ascomycetes)

Ascomycetes

Ascomycetes are one of the major groups of the kingdom fungi, characterized by the production of **ascospores**. Many species occur in nature and ascospores are a frequent component of outside air detected most readily in spore trap samples. Certain species are known to colonize indoor environments and some (including *Ascotricha, Chaetomium, Eurotium*, *Myxotrichum, Petriella, Peziza,* etc.) are common indoors on wet building materials. See specific fungi for more detailed notes.

Aspergillus

The genus *Aspergillus* is a diverse group of common molds and the approximately 175 species are inhabitants of virtually all terrestrial environments. When conditions in indoor situations are favorable for fungal growth, *Aspergillus* species are one of the primary colonizers of man-made substrata. Most species have relatively low moisture requirements and some are extremely xerophilic (dry tolerant)(Klich 2002, Pitt and Hocking 1999), allowing them to colonize areas that cannot support other fungi and where only minimal or intermittent moisture is available. Their rapid growth and production of large numbers of small, dry, easily aerosolized spores makes them a significant contaminant with regards to Indoor Air Quality and potential human exposure-related illnesses. Many species are known to produce mycotoxins, including *A. flavus* (aflatoxin), *A. versicolor* (sterigmatocystin), *A. ochraceus* (ochratoxin), *A. ustus* (austins), *A. terreus* (patulin) and *A. fumigatus* (fumitremorgin)(Frisvad and Thrane 2000). A few species are common opportunistic human pathogens, including *A. fumigatus*, the most common agent of aspergillosis, and *A. niger*, a common agent of otomycosis (ear infection). Aspergillosis is now considered the second most common type of fungal infection requiring hospitalization in the United States (Sigler and Kennedy 1998). *Aspergillus* species are also well-known allergens (type I or atopic allergy), and *A. fumigatus* is one of the most prevalent causes of type III allergy or hypersensitivity pneumonitis, and allergic sinusitis (Hoog et al. 2000).

Basidiospores (see Basidiomycetes)

Basidiomycetes

Basidiomycetes are one of the major groups of the kingdom fungi, characterized by the production of **basidiospores**. The group includes mushrooms and wood decay fungi. Many different species occur in all types of biogeographical zones, and basidiospores are a frequent component of the outside air detected most readily in spore trap samples. Some species of wood decay basidiomycetes are known to colonize building materials and some (including *Antrodia, Gloeophyllum*, *Phellinus, Serpula,* etc.) can cause extensive structural damage. Some species of basidiomycetes produce asexual mold stages, *Geotrichopsis, Hormographiella* or *Spiniger*, in culture. See specific fungi for more detailed notes.

Ceratocystis (see *Ophiostoma*)

Chaetomium (see Ascomycetes)

Cladosporium

Cladosporium is one of the most abundant molds in most environments and is worldwide in distribution. It is a common phylloplane (leaf decay) fungus, frequently found on decomposing plant litter. It is darkly pigmented, producing brown spores in branching chains. Often a dominant spore in outdoor air *Cladosporium* is a common colonizer of indoor substrata (Ho 1999),. It is common on windowsills, painted walls, and a variety of cellulosic materials. Over 500 species have been described, and *C. herbarum, C. cladosporioides*, and *C. sphaerospermum* are common in indoor environments. Because of its ubiquitous nature, it is not regarded as one of the most important indoor species unless present in extremely high levels. A few species produce toxins and it is a common agent of allergic reactions (Pitt and Hocking 1999, Flannigan et al. 1991).

Engyodontium

The genus *Engyodontium* is a type of mold (hyphomycetes) that was formerly included in *Beauveria*, but now recognized as a distinct genus. The most common species, *E. album*, is a cottony, white mold producing numerous, dry, tiny conidia. It is common in soil, plant debris, and on a variety of other substrata (Hoog 1972). It is known from air (indoors and outside) and building materials (e.g., drywall) in indoor environments and extensive growth was seen in samples from a mine (Abbott, unpublished data). Known health effects include, very rarely, opportunistic infection in compromised individuals (Sigler and Kennedy 1998). No species are reported to produce mycotoxins.

Eurotium

Eurotium is a genus of ascomycetes that produces an *Aspergillus* mold stage in its life cycle. It is extremely dry tolerant, or xerophylic, and can be found growing in indoor

conditions with low water availability. (see also notes under Ascomycetes and *Aspergillus*)

Gloeophyllum (see Basidiomycetes)

Gonatobotryum

The most common species, *G. fuscum*, is a mold that grows as a mycoparasite of the ascomycete fungi *Ophiostoma* and *Ceratocystis*. It is, therefore, often seen associated with lumber mold (see additional notes under *Ophiostoma*). It can be recognized by its broad brown hyphae, swollen, nodose conidiophores, and smooth, brown, ellipsoidal conidia (Ellis 1971). No known mycotoxins are produced by this mold.

Hormographiella (see Basidiomycetes)

Memnoniella (see *Stachybotrys*)

Mucor

Mucor is one of the most common genera of pin molds (zygomycetes) and is frequently found in soil, plant debris and dung (Zycha et al. 1969). They produce structures (sporangia) filled with sticky spores under relatively moist conditions. It is also known in indoor environments from air and wet surfaces. *M. plumbeus, M. circinelloides, M. racemosus, M. hiemalis* and *M. mucedo* are common species (Schipper 1973, 1975, 1976, 1978). No species are known to produce mycotoxins. *M. circinelloides* has rarely been invoved in zygomycosis, an opportunistic human infection (Ellis 1994, Rippon 1988).

Myxotrichum

This ascomycete (Myxotrichaceae) is relatively uncommon, but is most frequently encountered in indoor environments on cellulose containing material, especially paper products. It produces black, mesh-like, setose ascocarps with small, fusiform ascospores (Currah 1985). Some species, including *M. deflexum*, produce a pinkish red diffusing pigment and may produce visible stains on the paper surface. No reports of mycotoxins, pathogenicity or allergy are known.

Ophiostoma

Species of the ascomycete genus *Ophiostoma* (and the similar genus *Ceratocystis*) are commonly referred to as ‘lumber molds’, and as the name suggests they are prevalent on freshly cut lumber, including 2x4’s used for building construction. They are also an agent of sap stain and are of economic importance for the damage to building materials.

Some species are important plant parasites, including the agent of Dutch Elm Disease, *O. ulmi*. Ascospores and spores of the *Pesotum, Leptographium,* and *Sporothrix* mold states are produced in sticky masses and are not readily airborne unless disturbed (Wingfield et al. 1993, Upadhyay 1981). Presence of these fungi in indoor environments is common, but often is not associated with particular building moisture problems. Rather, they may be present on the material since the time of construction. The coarse brown hyphae found covering wood surfaces can become airborne through sanding or other remediation work and are occasionally seen in spore trap samples (Abbott unpublished data). No mycotoxins have been reported from this group.

Penicillium

The genus *Penicillium* comprises a diverse group of species of tremendous importance in the human environment. Some species are known agents of food decay, while others are prevalent on various organic substrata. A wide variety of species are known to grow on indoor surfaces including drywall, wood, carpet, painted surfaces, wallpaper, and various types of household contents. Many species are known to produce mycotoxins, including *P. aurantiogriseum* (penicillic acid), *P. viridicatum* (viridicatin), *P. verrucosum* (ochratoxin), *P. islandicum* (luteoskyrin), *P. variabile* (rugulosin), *P. crustosum* (penitrem A), *P. griseofulvum* (patulin, griseofulvin), *P. citrinum* (citrinin), and *P. crateriforme* (rubratoxin), as well as many others (Abbott 2002, Pitt 2000, Pitt and Hocking 1999). Potential mycotoxicoses from ingestion of moldy food and feed are significant hazards. Inhalation of *Penicillium* spores containing mycotoxins is implicated as a contributing factor for Organic Dust Toxic Syndrome (ODTS) and Non-infectious Fungal Indoor Environmental Syndrome (NIFIES). *Penicillium* is also a proven causal agent of allergy (atopic allergy and hypersensitivity pneumonitis) and one species (*P. marneffei*) is a well-known opportunistic pathogen (Rippon 1988; Sigler and Kennedy 1998).

Petriella

Petriella is an ascomycete (Microascaceae) that produces a sticky cirrus of reddish brown ascospores at maturity from small, black ascocarps. It produces a *Graphium* or *Scedosporium* mold state in culture. It is known primarily from plant material and dung in nature (Barron et al. 1961). It is a common fungus in indoor environments, growing relatively slowly on persistently wet wood, and is particularly common under kitchen sinks and in bathrooms where these conditions are prevalent (Abbott, unpublished data). It is readily identified in tape samples and may be observed in spore-trap samples where remediation work has disturbed the surface growth. It can also be recognized in the mold state from surface swabs or carpet dust samples. *P. sordida and P. setifera* are the most commonly encountered species, and none are known to produce mycotoxins.

Peziza (see Ascomycetes)

Phellinus (see Basidiomycetes)

Scopulariopsis

Scopulariopsis is a common genus of mold (hyphomycetes) frequently occurring in indoor environments. Several species are common recovered from the air (indoors and outside) and are known to colonize cellulosic building materials such as drywall and wood. *Scopulariopsis* molds are related to the ascomycete genus *Microascus* (Abbott et al. 1998, Abbott and Sigler 2000). No species of *Scopulariopsis* are known to produce mycotoxins, but the most common species, *S. brevicaulis,* is able to degrade arsenic-containing materials, releasing free arsenic into the environment (Gravesan et al. 1994). Several species are known to cause opportunistic infections, and *S. brevicaulis* is a well-known agent of onychomycosis (nail infection)(Sigler and Kennedy 1998, Rippon 1988). Species often reported from indoor environments include *S. brevicaulis, S. brumptii, S. candida,* and *S. asperula*.

Serpula (see Basidiomycetes)

Spiniger (see Basidiomycetes)

Stachybotrys

Stachybotrys is perhaps the most well known of all molds frequenting indoor environments. Referred to simply as 'stachy' in the trade, *Stachybotrys chartarum* has served as the flagship for mycotoxin-producing molds in indoor environments. The sinister reputation as the 'toxic black mold' may be well founded in the potency of the suite of trichothecene toxins produced. Trichothecenes, including the potent satratoxin, are cytotoxic compounds, capable of killing cells. Carcinogenic effects are occasionally reported, but there is no evidence of carcinogenicity of these toxins or any other compounds produced by species of *Stachybotrys*. Other immune suppressive compounds have also been isolated from *Stachybotrys*. Although *S. chartarum* is by far the most frequently encountered species, others such as *S. cylindrospora* and *S. echinata* (formerly called *Memnoniella echinata*) are also found occasionally indoors and are both known to produce similar toxins. Stachybotryotoxicosis was one of the first mold mycotoxicoses to draw scientific study and paved the way for a broader understanding of the hazards posed by mycotoxins. It was first recorded in the Ukraine in early 1930's, primarily affecting horses fed hay infected with *Stachybotrys chartarum* containing trichothecene mycotoxins. Symptoms included irritation of oral/ nasal passages and necrotic lesions of respiratory and digestive tracts, often proving fatal within 24 hr. The first cases of human stachybotrytoxicoses were a result of inhalation exposure of the spores by handlers of contaminated hay and straw. Without adequate PPE, remediators of mold-contaminated buildings are at similar risk of high mycotoxin doses (Abbott 2002).

S. chartarum has strong cellulolytic capabilities and is a primary colonizer of some building materials including dry wall paper, cardboard and wood. In nature, Stachybotrys species inhabit plant remains in moist environments. It requires wet conditions to grow and is most common on nearly saturated substrata. The black spores are produced in sticky masses and are disseminated in nature by insects. Airborne spores become a more significant potential problem when the old growth dries or when it is disturbed by occupant activities.

Ulocladium

Ulocladium is a common mold, and is one of the phylloplane (leaf decay) fungi. It frequently colonizes indoor substrata when conditions are suitable, and is thus a good potential indicator of building moisture problems. *Ulocladium* species produce large, multicelled, brown spores and *U. atrum, U. botrytis* and *U. chartarum* are common species in the indoor environment. They are capable of degrading cellulose and are frequently found on drywall paper, ceiling tiles and other cellulose containing materials. No mycotoxins are known in species of *Ulocladium.*

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