

# **Investigations of Indoor Allergens and Fungal Growth (“mold”)**



**Allergen Science & Consulting**

## **Fungal Spore Glossary With Applications in Determining the Cause and Origin of Moisture Problems in Buildings**

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# **Investigations of Indoor Allergens and Fungal Growth (“mold”)**

## **Overview:**

This document describes the spores produced by the most common fungal genera and species that grow in buildings and that are detected in air and/or surface samples collected during the completion of building investigations for moisture problems and the resultant fungal growth (“mold”). The ecological relevance of these fungi associated with moisture problems is explained.

## **Scope:**

The scope of this document is to assist mold remediation companies and building structural engineers in determining the cause and origin of moisture problems in buildings that caused fungal growth (“mold”). By understanding the ecological relevance of the different fungi detected in a building, scientifically based recommendations regarding the remediation activities to perform can be provided. This approximation could save cost to building insurance companies.

This glossary is also a valuable tool for laboratories that analyze air and surface samples collected during the completion of building assessments for moisture problems and fungal growth (“mold”).

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## Introduction to Fungi:

### Fungal classification

There are currently approximately 100,000 named species of fungi. Estimates of the total number of fungal species that exist range from one to ten million.

Modern fungal systematics began with Carl Von Linnaeus (1707-1778) who introduced the binomial system of nomenclature. Fungi are not plants, and they belong to their own kingdom, the Kingdom Fungi. The classification of the Kingdom Fungi is complex. Currently, relationships in the fungi are based on details of the fungal life cycle. Specifically, the morphology of the sexual reproductive structures is used because they are considered the most evolutionary stable characters.

The Kingdom Fungi is currently divided in the following Divisions:

- 1.- **Chytridiomycota** (“lower fungi”): they are the simplest of the true fungi. They have both sexual and asexual reproduction. They include the Class Oomycetes (water molds and downy mildews), of which *Peronospora*, that parasites strawberries, is commonly seen in outdoor air samples in Florida. Some taxonomists include Myxomycetes (slime molds) in this group, which is wrong.
  - 2.- **Zygomycota** (“lower fungi”): they have both sexual and asexual reproduction. One of the most important characteristics of this group is that the hyphae lack septations. Some examples include *Mucor* and *Rhizopus*.
  - 3.- **Ascomycota** (“higher fungi”): this is the largest group of fungi, also known as the “cup fungi”. They produce sexual spores called Ascospores by means of meiosis, formed inside of a structure called ascus, often in groups of eight. They also have asexual reproduction by formation of conidia or by budding.
  - 4.- **Basidiomycota** (“higher fungi”): these are the “true” fungi, including puffballs, rusts, smuts, jelly fungi, and bracket fungi. They produce sexual spores called Basidiospores by means of meiosis, formed inside of an external structure called basidium. They also produce asexual spores by formation of conidia and rarely by budding.
- Mitosporic Fungi:** this is an artificial group for fungi apparently lacking sexual stage, known as the “fungi imperfect” or “imperfect fungi”. Most are probably the anamorph or asexual stage of Ascomycetes and Basidiomycetes. Fungal types classified in this group include the majority of fungi that grow indoors on building materials and fungi with medical importance.

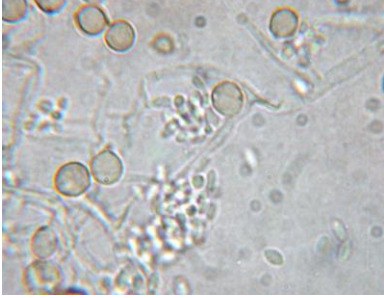
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## Glossary

### *Acremonium*

Numerous species of this fungus have been identified. *Acremonium* is mostly present in soil and dead plant material. It can also grow indoors on a variety of wet building materials.

*Acremonium* spores are small, hyaline, and round. *Acremonium* spores are difficult to identify in air samples. A surface sample is essential to identify this spore type.



### *Alternaria*

This genus is present in large numbers in the outdoor environment. It can also grow indoors on damp cellulose-containing building materials. It requires moderate water activity levels to grow. Therefore, it is not normally the primary colonizer of building materials after a moisture intrusion event. Its presence normally indicates that a drying out process has occurred after a moisture intrusion event or that low levels of water have been intermittently intruding over an extended period of time.

*Alternaria* spores are large, dark pigmented, septated, and with a characteristic shape resembling a bowling pin. They can be easily identified in air samples.



### Ascospores

They are sexual spores formed by means of meiosis within a structure named ascus, often in groups of eight. The majority of Ascomycetes are plant parasites or saprophytes and are abundant in the outdoor environment. They play an important role in the decay of dead plant materials. Many parasite Ascomycetes are host-specific. Certain Ascomycetes, i.e., *Chaetomium* can also grow on building materials.

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Ascospores are hydrophilic. Once exposed to atmospheric moisture, the asci swell and the spores are ejected forcefully. Thus, Ascomycetes tend to release spores during periods of high humidity or rainfall. Ascospores are particularly abundant during and after rainfall episodes. The presence of Ascospores in indoor air samples normally indicates infiltration of outdoor air.

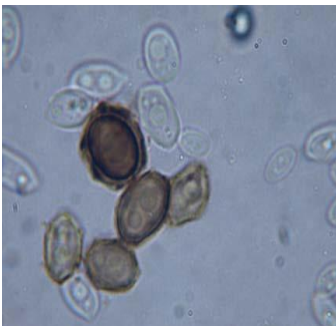
Ascospores are extremely variously shaped and sized. They can be small or large, pigmented or hyaline, round or elongated, septated or not septated. The common characteristic of all Ascospores is that they never have attachment points. Some Ascospores can be identified at the genus level.



### *Aureobasidium*

This is a yeast-like fungus, which is commonly found on the silicon caulk used in bathrooms and kitchens, on damp window frames, and in shower tracks. It starts out as a pale pink growth but turns black staining the material on which it is growing.

*Aureobasidium* produces two types of spores. While one type of spores are small and hyaline, the other type of spores are pigmented and larger. If several spores are present as a clump, they can be identified in air samples. Otherwise, a surface sample is necessary to identify these spores.



### Basidiospores

They are sexual spores formed by means of meiosis in a structure named basidium. The majority of Basidiomycetes are plant saprophytes or symbionts and are abundant in the outdoor environment. Basidiomycetes can degrade lignin (the component of the cell walls of wood) and play an important role in the decay of dead plant materials, especially wood. Many symbiont Basidiomycetes live associated with tree roots forming structures

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called mycorrhizas. These Basidiomycetes are often host-specific. Certain Basidiomycetes, i.e., *Serpula* can grow indoors on wooden materials and cause wood rot. The presence of Basidiomycete growth indoors normally reflects important moisture problems that have occurred over an extended period.

The conditions required for Basidiospore release vary between species. Many species require moisture for spore release and Basidiospores are particularly abundant during and after rainfall. Some Basidiospores reach a peak in concentration during the early morning and late evening, when ambient moisture is high. The presence of Basidiospores in indoor air samples normally indicates infiltration of outdoor air.

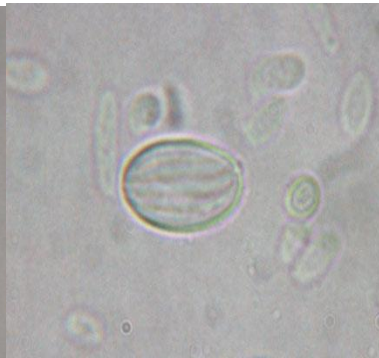
Basidiospores are extremely variously shaped and sized. They are normally small, but can be dark pigmented or hyaline, round or ovate, smooth or highly ornamented. The common characteristic of all Basidiospores is that they are asymmetric, and the majority contain an apical pore and an appendix. Some Basidiospores can be identified at the genus level.



*Lacaria*



*Peniulus*



*Clitopilus*



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### *Bipolaris/Drechlera/Helminthosporium* group

This group includes genera that produce spores with a similar morphology. These spores are abundant in the outdoor environment. They can also grow indoors on a variety of materials, and require moderate water activity levels to grow. Therefore, they are not normally the primary colonizers of building materials after a moisture intrusion event. Their presence normally indicates that a drying out process has occurred after a moisture intrusion event or that low levels of water have been intermittently intruding over an extended period.

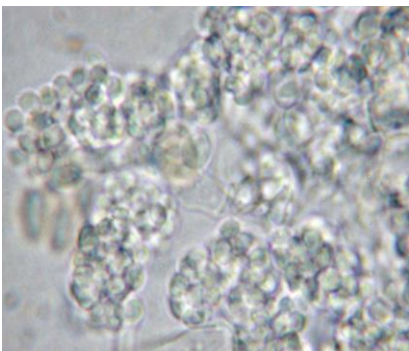
*Bipolaris/Drechlera* spores are large, brown, ellipsoidal, and falsely septated. They can be easily identified in air samples.



### *Botrytis*

*Botrytis* is a common plant parasite. High levels of *Botrytis* spores are likely to be found in greenhouses or other indoor areas where there are large number of plants and high humidity levels. It commonly contaminates strawberry fields in Florida.

*Botrytis* spores are small, round, and hyaline. These spores are difficult to identify in air samples. A surface sample is essential to identify this spore type.



### *Cercospora*

*Cercospora* spores are common in the outdoor environment, especially during harvest, and do not normally grow indoors. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.



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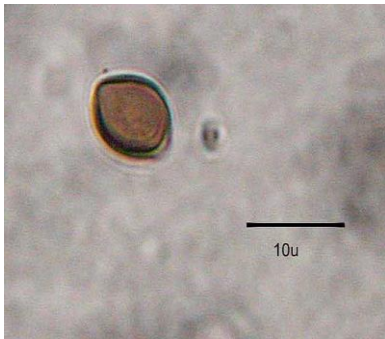
*Cercospora* spores are very long (sometimes can exceed 200 microns in length), and are from hyaline to pale brown. They have a refractile attachment point at one end. They can be easily identified in air samples.



### *Chaetomium*

*Chaetomium* is one of the few Ascomycetes that grow indoors on damp building materials, especially on deteriorated wood and paper. *Chaetomium* requires high water activity levels to grow. Therefore, this fungal genus is considered a moisture indicator, and it is normally associated with materials that have been damp for an extended period. Some species of *Chaetomium* may contribute a musty odor to the indoor environment.

*Chaetomium* spores are medium sized, brown, and have a fusoidal shape that resembles a lemon with a pore at one end. These spores are easily identified in air samples.



### *Cladosporium*

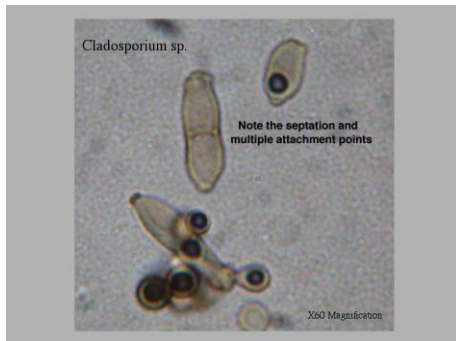
*Cladosporium* is the most common fungus in the outdoor environment. Indoors, it can be found in refrigerator drip pans and the bottom of refrigerators, on moist window frames, on moist painted surfaces, and within HVAC systems.

*Cladosporium* spores are typically found in single or branched chains, often with a refractile scar at each end, the spores are from round to oval, they may be septated or not septated, the walls are smooth to warty, and the color is from pale yellow to olivaceous. There are three major groups of *Cladosporium* with different ecological relevance, which can be differentiated accordingly to microscopic characteristics:



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- ◆ *Cladosporium cladosporoides* type: the spores are ellipsoidal, with smooth walls, and form long branched chains. This type can grow both outdoors and indoors.
- ◆ *Cladosporium herbarum* type: the spores are similar to the *C. cladosporoides* spores but have a thick warty wall. This type is common outdoors and does not normally grow indoors.
- ◆ *Cladosporium sphaerospermum*: the spores are round and smaller than the two types described above. This type normally grows indoors and is rare outdoors. It is considered a moisture indicator.



### Curvularia

*Curvularia* species are tropical and sub tropical plant pathogens. They are common in the outdoor environment but can also grow indoors when appropriate moisture is present.

*Curvularia* requires moderate water activity levels to grow. Therefore, it is not normally the primary colonizer of building materials after a moisture intrusion event. Its presence normally indicates that a drying out process has occurred after a moisture intrusion event or that low levels of water have been intermittently intruding over an extended period.

The spores are large, brown, with three septa and four cells, almost always curved. These spores are easily identified in air samples.



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## Geotrichum

It is a widespread fungus in the indoor and outdoor environments. Some species of *Geotrichum* are a normal part of the microflora of humans.

It produces two types of small hyaline spores, round and squared. The squared spores are formed by segmentation of the hyphae and are called arthrospores. These spores are difficult to identify in air samples. A surface sample is essential to identify this spore type.



## Epicoccum

*Epicoccum* is a plant parasite common in the outdoor environment but can also grow indoors on building materials. It requires moderate water activity levels to grow. Therefore, it is not normally the primary colonizer of building materials after a moisture intrusion event. Its presence normally indicates that a drying out process has occurred after a moisture intrusion event or that low levels of water have been intermittently intruding over an extended period.

*Epicoccum* produces large, globose, dark pigmented spores with both oblique and transverse septations and with a coarse ornamentation. The spores have a funnel-shaped base attachment scar. These spores are easily identified in air samples.

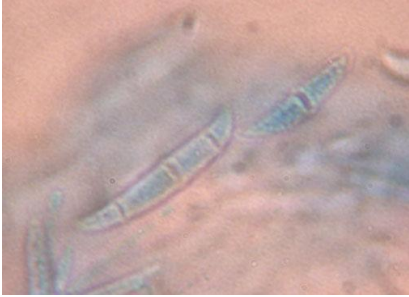


## Fusarium

*Fusarium* is distributed worldwide in soil and plants. It can grow on stored vegetables, especially strawberries and onions. It has been reported to affect water-damaged carpets and other interior building materials with high water activity level. It is often found in dehumidifiers.

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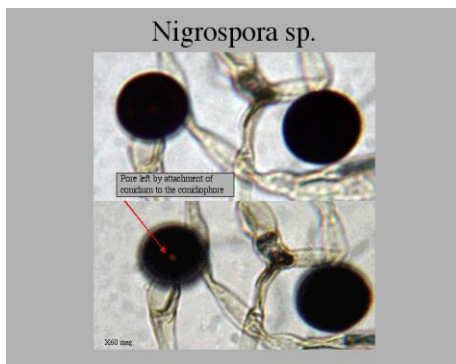
*Fusarium* spores are elongated and curved, hyaline and with three or five septa and with a “foot cell”. *Fusarium* spores can be easily identified in air samples if contrast is utilized.



### *Nigrospora*

It is common in the outdoor environment and does not normally grow indoors. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.

The spores are dark brown, large, and spherical. Sometimes an attachment point and an equatorial germinal slit can be observed. They can be easily identified in air samples.



### *Paecilomyces*

This fungus is heat tolerant and is often found in warm and arid regions. It grows indoors on many different materials. It can attack PVC, photographic paper, wood, optical lenses, and leather. It causes spoilage of foods, and some species are resistant to preservatives. It can attack juices undergoing pasteurization. It can also grow in water towers.

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*Paecilomyces* spores are small, round or slightly elongated, and hyaline. These spores are difficult to identify in air samples. A surface sample is essential to identify this spore type.



### *Penicillium/Aspergillus* types

This group includes spores belonging to two widespread genera (*Penicillium* and *Aspergillus*). Each of these two genera includes hundreds of species. The *Penicillium/Aspergillus* type spores also include spores belonging to other genera. These types of spores look alike (small, round, variously ornamented, and from dark pigmented to hyaline), and cannot be identified in air samples. A surface sample is essential to properly identify these two genera of fungi as well as other genera that produce spores with a similar morphology. Speciation of these fungal types by means of viable culture may be necessary in cases of building occupants experiencing health-related complaints or when looking for indicator organisms belonging to these genera of fungi. *Aspergillus versicolor* is frequently isolated from water-damaged building materials, and it is considered a moisture indicator.

Both *Penicillium* and *Aspergillus* are common in the indoor environment. They are normally present indoors at levels greater than those present outdoors. Low levels of these fungal genera are normally present in homes without obvious moisture problems.

*Penicillium* and *Aspergillus* often cause spoilage of food. They can grow on a variety of materials, including drywall, paints, wallpaper, and house dust. *Penicillium* also grows well on articles of leather.



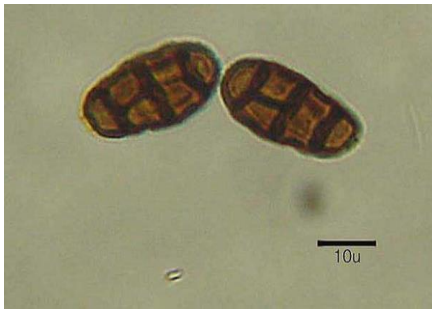
*Penicillium/Aspergillus*

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## *Pithomyces*

*Pithomyces* grow on decaying wood, soil, and plant materials. It rarely grows indoors. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.

It produces large, dark-pigmented, oblong or barrel-shape, and septated spores. They are easily identified in air samples.



## Rusts

Rusts are a group of obligated host-specific plant parasite fungi common in the outdoor environment. They do not grow on building materials. They can grow indoors only if the specific host is present. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.

The spores are spiny or warty, spherical or irregular spherical, golden brown to gray or reddish-brown, with or without a reticulate surface.



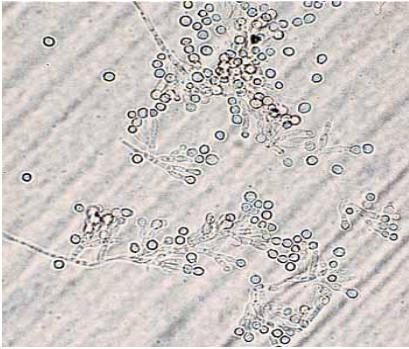
## *Scopulariopsis*

*Scopulariopsis* is frequently isolated from fruits and nuts. It can also be isolated from house dust and old carpeting and wallpaper. This fungus is able to decompose arsenic compounds, so is able to grow on wallpaper containing certain kinds of green paint. Anti-static compounds containing arsenic are often used on some wall-to-wall carpet, which can result in a high number of this fungus.



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The spores are small, round or slightly elongated, and difficult to identify in air samples. A surface sample is essential to identify this spore type.



### Smuts, *Periconia*, Myxomycetes

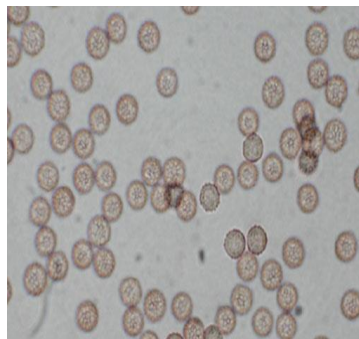
This group includes three unrelated organisms, which produce spores that cannot be easily identified by optical microscopy according to their morphological characteristics. These spores are normally round, light or dark pigmented, and spiny or warty.

Smuts are obligated plant parasites common in the outdoor environment around harvest in fall. *Periconia* is a saprophyte mitosporic fungus common in the outdoor environment and does not normally grow indoors. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.

Myxomycetes are protozoans also common in the outdoor environment, which feed on bacteria. Myxomycetes can also grow indoors especially in locations where wet dust and dirt accumulate.



*Periconia*



Myxomycetes



Smuts

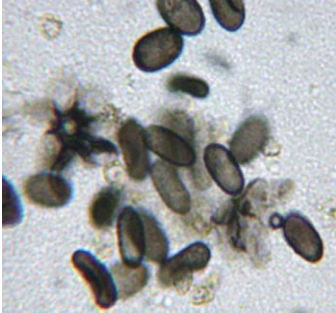
### *Stachybotrys*

*Stachybotrys* requires high water activity levels to grow, and it is considered a moisture indicator. *Stachybotrys* is a slow spore producer. It grows on wet cellulose-containing materials (including drywall, paper, and wicker), which have been damp for an extended period.

*Stachybotrys* spores are coated with a mucilaginous layer, and do not become easily airborne. The presence of high levels of these spores in air samples indicates that a drying

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out process of the contaminated material most likely occurred. The spores are round to oblong, black, gray to black, and with a warty ornamentation. These spores can be easily identified in air samples.



### *Stemphylium*

*Stemphylium* is a plant saprophyte and does not normally grows indoors. *Stemphylium* spores are common in the outdoor environment. The presence of these spores in indoor samples normally indicates infiltration of outdoor air.

*Stemphylium* spores are pleomorphic (can vary in morphology), and sometimes resemble *Alternaria* spores. The spores are large, dark pigmented, septated, with a major septation across the equatorial plane.



### *Torula*

*Torula* is a plant saprophyte abundant in the outdoor environment. It can rarely grow indoors on cellulose-containing materials. It requires moderate water activity levels to grow. Therefore, it is not normally the primary colonizer of building materials after a moisture intrusion event. Its presence normally indicates that a drying out process has occurred after a moisture intrusion event or that low levels of water have been intermittently intruding over an extended period.



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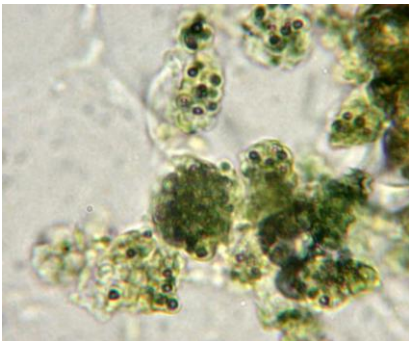
Torula spores are cylindrical with rounded ends, dark pigmented, strongly constricted at the septa. These spores can be easily identified in air samples.



### Trichoderma

*Trichoderma* is a widespread soil fungus. It is a strong cellulolytic fungus that requires high water activity levels to grow. *Trichoderma* is considered a moisture indicator. It can grow indoors on a variety of materials, typically on wallpaper, wood, carpet, and unglazed ceramics.

*Trichoderma* spores are small, round, and contain a characteristic green pigment. If present in clumps, they can be identified in air samples.



### Ulocladium

*Ulocladium* is a plant saprophyte common in the outdoor environment. It can also grow indoors on damp drywall and particleboard. Although it is not one of the most important fungi that grow on building materials, it requires high water activity levels to grow. Therefore, it is considered a moisture indicator.

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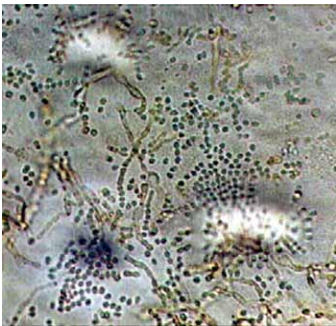
*Ulocladium* spores are pleomorphic (can vary in morphology), and sometimes resemble *Alternaria* spores. The spores are large, dark pigmented, and septated.



### Wallemia

*Wallemia* is a widespread fungus found worldwide in house dust, soil, dry foodstuffs, and salted meat. This fungus can grow indoors on materials with low water activity. Its presence does not indicate a moisture problem.

*Wallemia* spores are small, round, and with few differential characteristics. These spores are difficult to identify in air samples. A surface sample is essential to identify this spore type.



### Zygomycetes

The most important genera of Zygomycetes include *Mucor* and *Rhizopus*. *Mucor* and *Rhizopus* are commonly found in house dust worldwide. They are also frequently found in leftover food and fruit and vegetable garbage.

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They produce small round-shaped spores, which cannot be identified in air samples. A surface sample is essential to identify these spore types.

