

MOLD MONSTERS

HOW THINGS YOU CAN'T SEE CAN REALLY GET IN

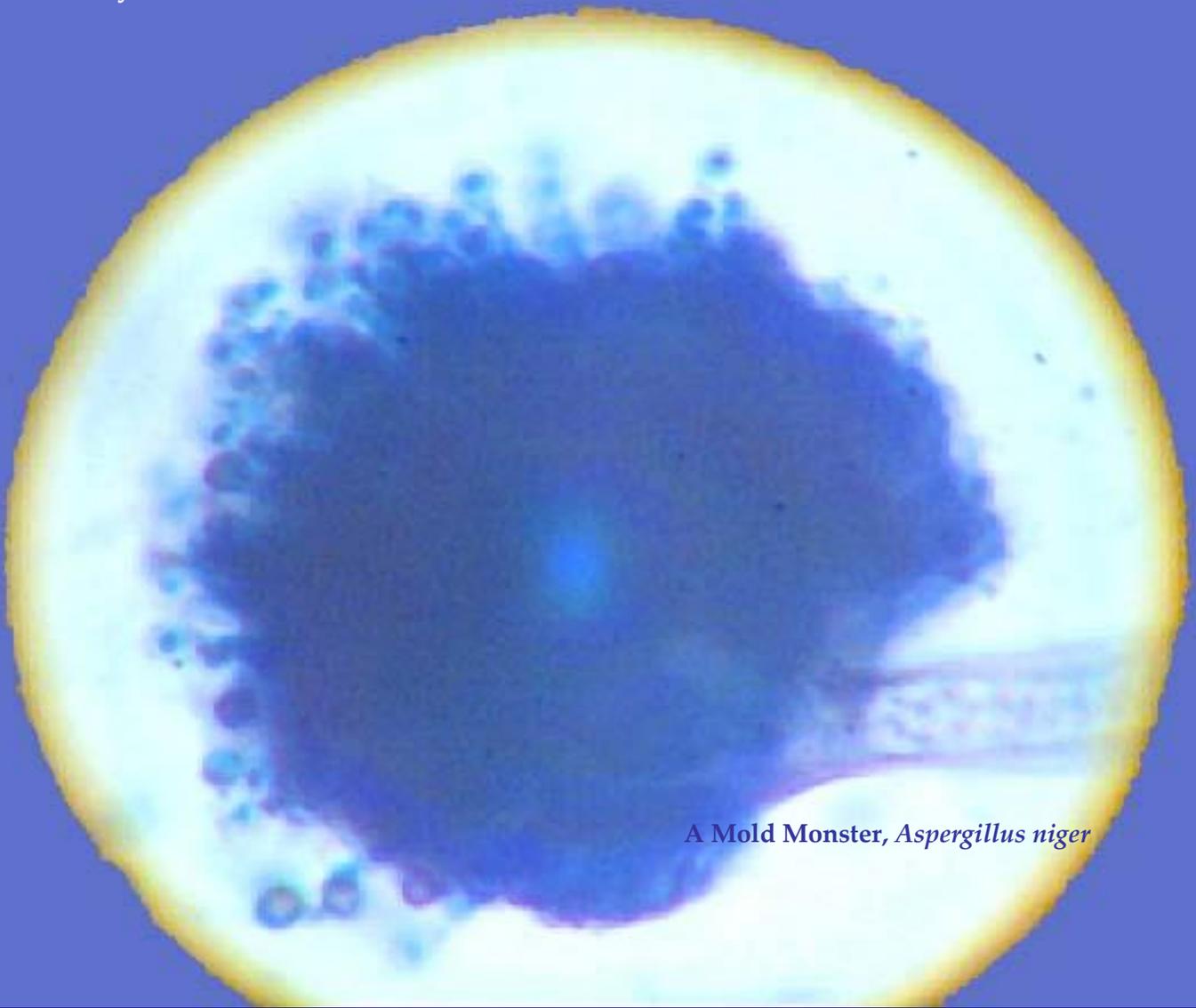
By:

Phillip S. Fry
International Mold Expert

Ma. Adee Light E. Hilado
Mold Microbiologist

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A Mold Monster, Aspergillus niger

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PREFACE

Mold – related concerns are one of the hottest issues of today’s time. People are continuously discussing about its potential risk to health and its economic impact as well. It is inevitable, but molds and their killer airborne spores are everywhere, invisibly fleeting in the air that every individual breathe on everyday.

It is known that prolonged exposures to unhealthy molds have been linked to a variety of illnesses - from mere nuisance allergies to severe chronic respiratory disorders, especially to those who are highly sensitive to these airborne minute – sized spores.

This e - book is intended as an enlightening and practical reading tool for readers on how to make themselves more acquainted with the unhealthy mold species found both from their indoor and outdoor environments that are highly considered as health risks. It provides a brief and concise overview of each mold species’ pathogenicity, the common sources of where these mold monsters can be found, their interesting microscopic and macroscopic appearances, plus easy and practical ways on how to deal and avoid exposures to these aggravating mold monsters. This e - book is a complete package of valuable and educational information that ought to be learned about these unwanted mold monsters.

'Monster' Mold Forces Family From Home

POSTED: 9:45 pm EST November 7, 2006

UPDATED: 6:59 pm EST November 8, 2006

A mold described as a "monster" became so bad inside a Central Florida apartment that it began to grow on a couple's clothes and threatened their health, according to a Problem Solvers investigation.

Miguel Sanchez and his wife have lived in the Logan Heights Apartments in Sanford for four years, and recently the mold has become a serious problem.

"The oppressive weight of mold in the air would nearly knock the breath out of you," Local 6's Steven Cooper said.

Recently, Sanchez's wife was diagnosed with lung cancer.

"When I told the doctor we had a lot of mold here, he said, 'Miguel, you got to get out of that place. Your wife has lung cancer, you cannot be living in a place like that,'" Miguel Sanchez said.

Sanchez said he hoped the apartment management would do something about the mold.

He said maintenance has been in twice to clean with bleach, but it was not able to kill the mold.

Local 6 News showed video of mold growing on shoes in a closet and on pants. Sanchez said he sent the pants to the dry cleaners but the mold returned after two days.

"We've been complaining to these people that we don't want to be here, but we can't afford to move to an expensive place because I am not a rich man, I'm not rich anymore," Sanchez said.

"He is not rich because his wife's illness has all but depleted their savings," Local 6's Steven Cooper said.

Cooper said that at the time of the story, management offered to move the Sanchez's to another unit but the wait would be a few months.

However, other apartments Local 6 News inspected in the complex appeared to have mold issues as well, Cooper said.

Local 6 tried to contact Logan Heights corporate offices several times but did not receive a response.

"You will have to leave the property and you will have to contact corporate," a worker said. "Thank you. Have a good day."

"What do I do if corporate does not respond? That's my problem," Cooper said.

"The problem doesn't go away because corporate is not responding."

"I don't know," the worker said. "You'll have to talk to corporate."

A landlord and tenant attorney said she gets mold complaints from apartment dwellers all over Central Florida.

"What I personally tell people to do is I advise them to get a mold inspection service to come out, spend a little money and get a mold report to say there is a problem and it's a health hazard --- fix it or give us a new apartment if they like that apartment complex," attorney Roshani Gunewardene said. "Or terminate the lease and move."

"Other than that, there really is no legal remedy and little hope for people who can't afford a mold inspection service," Cooper said. "What's worse, we checked with authorities at every-level, city, county, and state -- and there are no mold standards or codes that residential rentals must comply with."

Renters should also be aware of mold addendums, now common in leases, which put much of the burden on the renter to keep the apartment mold-free, according to the report.

Cooper said the man who owns the complex has paid almost \$4,000 to move the Sanchezes out of the complex and replace some of their items damaged by the mold.

Note:

This e – book has been written through collected valuable information from reliable sources.

Chapter 1

INTRODUCTION TO FUNGI

When someone mentions the word “fungi” you may think right away of the fungus growing on human toes or maybe the moldy food stored in the refrigerator. In fact, fungi are present everywhere and play a role in our everyday lives, from edible mushrooms to industrially important products to plant pathogens and human diseases.

Fungi are any member of a diverse group of organisms, Kingdom Fungi, which obtain food by absorbing nutrients from an external source, unlike plants and animals. Based on the fossil record, fungi were present on Earth five - hundred fifty million years ago and may even have evolved earlier. Today, there are thousands of different fungal species present that grow on and absorb food from organic substances such as soil, wood, decaying organic matter, or living plants and other organisms.

Fungi serve as the vital links in the food web as they play the role of being the valuable decomposers and pathogens of the ecosystem. Furthermore, many are marvelous scavengers in nature which breakdown dead animal and vegetable debris into simpler compounds that will, in turn, become available to other members of the ecosystem.

But fungi, like people, have a darker side and are detrimental. Several fungal species are known as causative agents of large number of plant diseases, of increasing number of animal diseases, and many human maladies. Fungi – induced plant diseases result in the loss of tremendous amount of money worth of economic crops each year and the same holds true for animal breeding industry. Additionally, fungi are known to cause diseases in humans, either directly or through their toxins.

A Study of Fungi

Based on the five – kingdom system established by Whittaker, fungi are placed in the Kingdom Fungi. The study of fungi, **Mycology**, evolved as a branch of botany. Scientists who study fungi are known as **mycologists**. The study of

fungi has exponentially increased in the past hundred years; however, they are still being disregarded or neglected in many fields of study. There are still more than ninety percent of fungal species that have not yet been screened for antibiotics or for other useful compounds. Hundreds of fungal species are described each year. In effect, finding and identifying fungi acquires most of the time and intellectual energy of field mycologists.

Microbiologists use the term “fungus” to include eukaryotic, spore – bearing organisms with absorptive mode of nutrition, does not possess chlorophyll pigments, and reproduce sexually or asexually. The fungi are considered eukaryotic organisms as they possess one or more cells each of which has a true nucleus and other well – developed membrane – bound compartments which has its own special functions.

Fungi are considered as important experimental organisms since they are eukaryotes and more closely related to animals thus, their study is more relevant to human problems compared to the study of bacteria. Many fungal species can be grown in pure cultures easily, with high growth rates and even in large amounts, if required. For scientists, these fungal features have made them attractive research materials for fundamental biological processes such as generation of energy, the control of metabolism, and the mechanisms of maintenance. Many fundamental biological discoveries have been made through the utilization of fungi as scientific material. One of the discoveries made during the 1940s is the establishment of the concept that an enzyme is specified by a gene based on the studies on the nutritional mutants of the mold *Neurospora crassa* done by Beadle and Tatum which have then, paved the way for the evolution of biochemical genetics. Thus, the fungi have been of great importance to biochemists and geneticists, who have in turn, provided important contributions to the study of fungi. Currently, fungi are used as model organisms to study the structure and functions of genes.

Mycologists study the many attributes of the biology of fungi, usually starting with their **systematics** which refers to the study of the diversity of their characteristics; **taxonomy** which refers to the theory and practice of describing, naming and classifying fungal organisms; and **classification** which is a systematic arrangement of fungal organisms into groups or categories according to a set of established criteria. It is important to be able to identify first the exact fungal species so as to be able to work effectively with it. After which, the mycologists would continue on to their **physiology**, the biological study of their functions, activities, and performed vital processes; **ecology** which refers to the

study of the relationships between the fungal organisms and their environment; **pathology**, the study of diseases; **evolution** which is defined as change in heritable characteristics in a fungal population over time; **genetics** refers to the science of genes, heredity, and the variation of fungal organisms; and **molecular biology** which refers to the study of biology at a molecular level which chiefly concerns itself with understanding the interactions between the various systems of a cell, including the inter - relationship of DNA, RNA and protein synthesis and learning how these interactions are regulated. **Plant pathology** and **human pathology**, additionally, are one of the few studied disciplines of applied mycology.

Ecological Distribution

Fungi grow best in dark, moist habitats, but they are found wherever organic material is available. There are mainly terrestrial organisms, though a few are freshwater or marine. Several are pathogenic and infect plants, animals and humans. Fungi also form beneficial relationship with other organisms. About three – fourths of all vascular plants form associations between their roots and fungi, called mycorrhizae. Association between fungi with either an algae or cyanobacteria forms lichens which are thought to be more than four thousand and five hundred years old thus, this living partnerships is considered one of the longest – lived organisms on Earth.

Importance

Fungi are essential to humans in both beneficial and harmful ways. Fungi play a role of enormous significance of being decomposers which degrade complex organic materials in the environment into simple organic compounds and inorganic molecules. Through this manner, carbon, phosphorus, and other essential constituents of decomposed materials are released and made available for other organisms' use.

Fungi are considered the “threads that keep the ecosystems together,” according to Thomas J. Volk, University of Wisconsin – La Crosse.

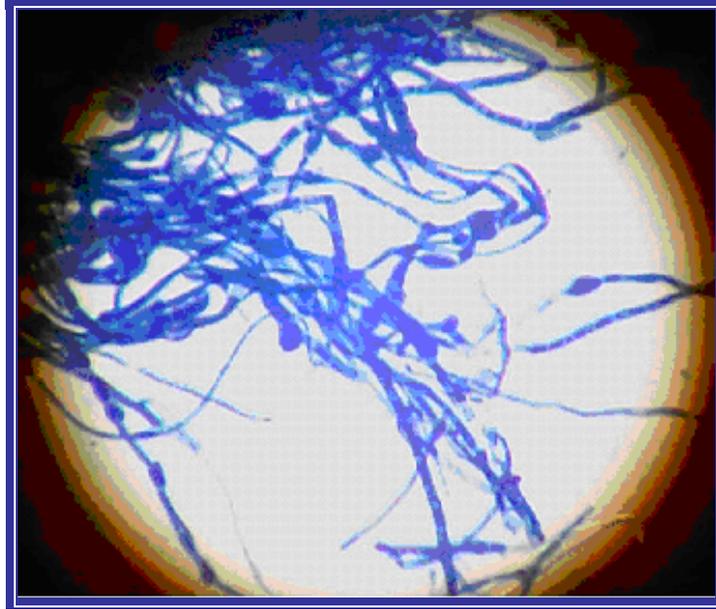
Fungi affect human lives in countless and diverse ways thus, it is vital to learn something about fungal biology so as to be able to control or exploit them for human purposes. It is known that there have been a lot of ways wherein fungi have been advantageously utilized by people. The most popular example is the manufacture of antibiotics such as penicillin and cephalosporin which are obtained from fungi. Another classic example is the worldwide use for many millennia of yeasts for baking, brewing, and in wine - making. Fungi also play a major role in the preparation of some cheeses such as the famous Roquefort cheese, soy sauce, and sufu.

In most natural ecosystems, fungi also form beneficial relationships with other organisms such as with the roots of plants called mycorrhizae wherein fungi help to take up nutrients from soil. Lichens are associations of fungi and either algae or cyanobacteria, presence of which in the environment indicates a good air quality.

Fungi receive much attention from various fields of biological science. Plant pathologists focus their attention on plant diseases – producing fungi. On the other hand, specialists in medical and veterinary mycology deal with several fungal species known to be causative agents of important human and animal diseases. Additionally, many are responsible for spoilage of food which is being dealt with by food microbiologists; fungal organisms which cause decay of timber attract timber technologists; while several are known to cause damage to manufactured products which draw the interest of biodeterioration experts.

Fungi Structure

Central to their mechanism of growth, fungi have a unique structure and organization. Characteristically, there are two broad groups of fungi, the **yeasts** and **molds**. The body of a fungus is termed as a thallus. The thallus varies in complexity and size, ranging from the unicellular and solitary microscopic yeasts to multicellular molds, macroscopic puffballs, and mushrooms.



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of a multicellular mold, *Microsporium audouinii*, which is known to cause tinea infections among humans.



(Image courtesy of [University of California - Museum of Paleontology](#))

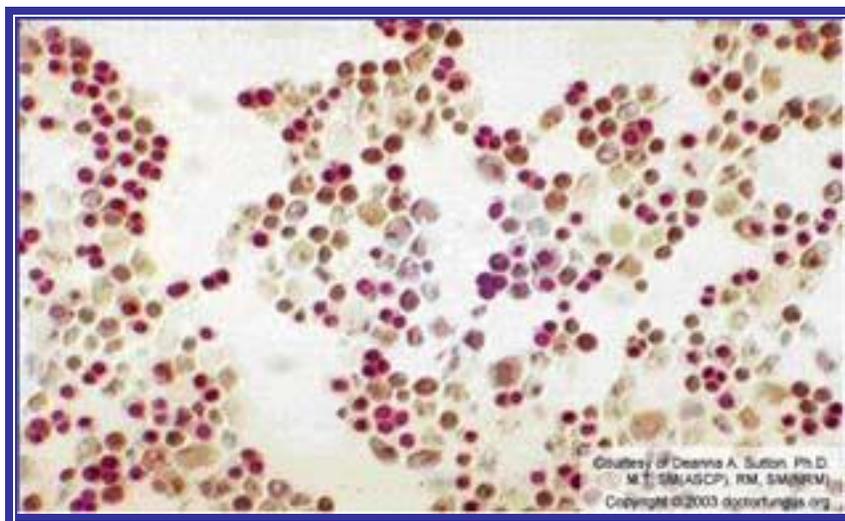
A very interesting picture of a macroscopic saphrophytic fungus



(Image Courtesy of [Wayne's Word @ 2005](#))

A striking starfish fungus, *Aseroe rubra*, photographed by Pete Adams on the Island of Maui. The dark, slimy spore mass has a fetid odor and attracts flies.

Yeast is a unicellular fungus that has a single nucleus. In general, yeast cells are larger than bacteria, and size vary significantly ranging from spherical to egg – shaped. Yeast cells are non – motile as they do not possess flagella – a whip-like organelle use by organisms to move about; but they do obtain most of the other eukaryotic organelles.



(Image Courtesy of www.doctorfungus.org @ 2005)

A microscopic morphology of *Saccharomyces cerevisiae* which is popularly known as the Brewer's Yeast.

Molds, on the other hand, are composed of long, branched, thread – like filaments called hyphae. A fairly rigid wall of chitin – the same material that forms the exoskeleton of insects, surrounds each individual hypha. Septate hyphae refer to a type of hyphae that are separated by dividing cross walls while non – septate hyphae refer to hyphae with cross walls.

Moreover, fungal cells contain a mixture of internal fluids and nutrients which is collectively called the cytoplasm. The cytoplasm flows freely within the hyphae which functions in providing nutrients wherever they are needed.

Mycelium is made up of an interwoven mat of branching hyphae. Large fruiting bodies or other structures that contain spores may be produced as the mycelium develops. The fruiting bodies are usually found growing above the soil or other surfaces thus, are often considered the most visible structure of a fungus; such structure allows the spores, the microscopic single - celled reproductive bodies of a fungus which is capable of growing into a new organism, to be easily dispersed by air currents or other mechanisms. The mycelium, on the other hand, is typically buried underneath the surface of the plant, animal, or other material it is decomposing. A classic example is the growing mushroom in the garden, as seen in the picture, below wherein its familiar umbrella – shaped fruiting structure sprouts from the ground while its mycelium is hidden beneath the soil surface.



(Image Courtesy of [Wayne's Word @ 2005](#))

A close – up picture of yellow parasol mushrooms, *Lepiota lutea*.

Nutrition and Metabolism

Dark, moist habitats are the best place for fungi to grow and most especially in the presence of organic material such as decomposing plant matter and dung of animals. Fungi do not possess chlorophyll, a green pigment that allows plants to make their own food, as a result fungi cannot synthesize their own food the way plants do. Fungi are described as saprophytes due to their nutritional feature of obtaining food from dead organic material.

The fungus release digestive enzymes to break down the food outside their bodies in order to feed. The dissolved food is then absorbed by the fungus through its cell walls.

Fungi have developed diverse living arrangements that can boost their opportunities for food absorption. Some fungi survive as parasites, obtaining their nutrient requirements from the living tissues of plants, animals, and even on other fungi. Moreover, out of the hundreds of thousands of fungal species, about an estimate of a hundred species are known to produce human diseases ranging from mere irritating allergies to skin infections, to severe asthma attacks and to downright fatal anaphylactic shock.

Some fungi have the ability to form highly specialized symbiotic relationships with other organisms [a close ecological relationship between the individuals of two (or more) different species]. One classic example is the beneficial association between a fungus and the roots of the plant to form mycorrhizae which increases the nutrient – absorbing capacity of the plant root and at the same time, the fungus absorbs minerals from the soil and exchanges them for organic nutrients synthesized by the plant. Molds are usually aerobic [microorganisms that can only grow in the presence of oxygen]; however, some yeast is facultatively anaerobic [microorganisms that do not require oxygen for growth, but do not grow better in its presence]. Additionally, the fungi that are found in the rumen of cattle are considered obligately anaerobic [microorganisms that cannot tolerate the presence of oxygen and die when exposed to it].

Fungi are the major decomposers of organic matter in natural environments, and almost every naturally occurring organic compound can be degraded by one fungus or another.

Reproduction

The wide variety of fungi exhibits many reproductive methods which is usually complex as it involves both asexual and sexual processes. Several fungi produce both asexually and sexually through microscopic, resistant spores that are easily dispersed to produce new fungi. Spores are formed and projected above the mycelium, allowing the spores to be dispersed by wind and water. Yeasts, unicellular fungi, reproduce by budding wherein a bump forms on the yeast cell which eventually separates from the “mother” yeast cell and grows into a “daughter” yeast cell. Other fungi undergoes asexual reproduction in which the mycelium breaks down into pieces and each grows into its own individual piece

Characteristics of the Fungal Divisions

There are nearly a hundred thousand species of modern fungi and around thousand of species are discovered each year, however, biologists have only begun to comprehend the diversity of fungi. The fungi are classified into divisions which are based primarily on variations in their sexual reproduction.

The four major divisions of fungi are Zygomycota, Ascomycota, Basidiomycota, and Deuteromycota.

The Four Major Divisions of Fungi:

- **Division Zygomycota** contains about six hundred fungal species called zygomycetes. Most live on decaying plant and animal matter in the soil; a few are parasites of plants, insects, animals, and humans.

Rhizopus stolonifer, the bread mold, is a very common member of this division which grows on the surface of moist, carbohydrate – rich foods such as breads, fruits, and vegetables with the help of its special hyphae called rhizoids which extend into the bread to absorb the nutrients. Other zygomycetes, on the other hand, cause soft fruit rot. Their reproductive spores called zygospores are disseminated through the air and may remain dormant until conditions will become favorable for them to grow.

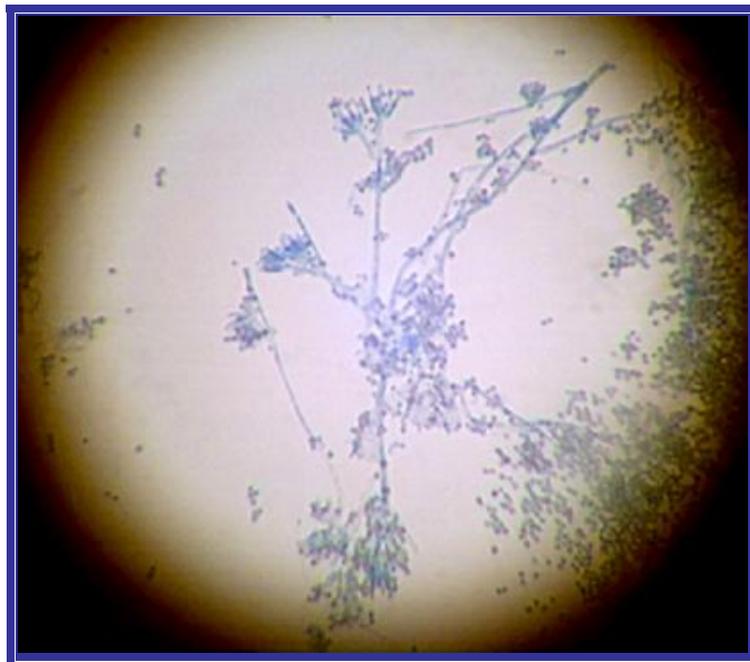


Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Rhizomucor* species, a zygomycete

- **Division Ascomycota** contains the fungi called ascomycetes which are also known as the sac fungi. There are about thirty – five thousand species in this division which are quite familiar and economically important.

Most of the red, brown, and blue – green molds that cause spoilage are ascomycetes. Some species belonging to this group causes Dutch elm disease and chestnut blight. Unicellular yeasts also belong to this group as well as the edible morels and truffles. *Neurospora crassa*, the pink bread mold, which is one of the important research tools in genetics and biochemistry is also an ascomycete.



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A microscopic photograph of *Penicillium* species, an ascomycete, taken under 40X objective

- **Division Basidiomycota** contains the basidiomycetes commonly known as the club fungi. There are about thirty thousand species under this division which includes the smuts, jelly fungi, rusts, stinkhorns, toadstools, bird’s nest fungi, and mushrooms wherein some of them being edible.

Basidiomycetes are named for their characteristic structure, the club – shaped basidium, which is involved in sexual reproduction. The reproductive spores called the basidiospores are produced by the basidium.

The basidiomycetes affect humans in variety of ways. Some species are considered as dangerous pests to plants such as smuts and rusts that cause billions of dollars worth annually of damage to grain crops.



(Image Courtesy of [Wayne's Word @ 2005](#))

A close – up photograph of a basidiomycete, *Amanita muscaria*, the infamous poisonous fly agaric mushroom.

- **Division Deuteromycota** is commonly called the **Fungi Imperfecti**. This division contains about thirty thousand fungal species which lack the sexual phase (perfect stage), or may be this phase has not been observed. Once a perfect stage is observed, the specific fungus would be transferred to its proper division.

Deuteromycetes are mostly terrestrial, only a few are isolated from freshwater and marine habitats. Almost deuteromycetes are either saprophytes or parasites of plants while some are parasitic on humans

and on other fungi. Some may set deadly traps for unsuspecting roundworms acting as though they are predators.

Many deuteromycetes directly affect human welfare. Several are human pathogens causing diseases such as ringworm and athlete's foot, and histoplasmosis. There are some deuteromycetes that are industrially useful such as the *Penicillium* species which synthesize the well – known antibiotics penicillin and griseofulvin. Other species provide characteristic aromas to cheeses such as Camembert and Roquefort. Certain species of *Aspergillus* are used in manufacturing of soy sauce, however, *Aspergillus flavus* and *Aspergillus parasiticus* produce aflatoxins that are highly toxic to animals and humans which are frequently encountered in infected nuts.



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of a deuteromycete, *Aspergillus niger*.

Chapter 2

WHAT ARE MOLD MONSTERS?

A Brief Description

Molds belong to the Kingdom Fungi and are characterized as multi – cellular saprobes, feeding on dead, decaying matter and they reproduce by sending out millions of microscopic seeds, called spores, into the air. These spores, when inhaled, can cause allergic reactions in sensitive individuals.

All of us are exposed to killer airborne mold spores daily in the air we breathe. Mold spores are very small and may enter the air passages and can also reach the lungs without getting caught by the protective mechanisms of the air passages.

Mold monsters have the capacity to thrive all year round both indoors and outdoors. Moreover, mold spores are present in all kinds of weather and many release their spores during dry weather, on the other hand, there are also some molds such as *Fusarium*, *Phoma* and *Cephalosporium* that only release their spores during a rainy weather or if there is moisture due to high humidity, fog or dew.

Killer mold spores are similar to plant seeds. They can remain dormant for months or even for years and can withstand harsh conditions. Mold spores continually drift through the indoor and outdoor air and upon landing on a damp spot indoors, mold spores may begin growing and digesting whatever they are growing on in order to survive. Whenever nutrients and moisture are present in sufficient amounts, mold growth would always likely to occur. Rapid fungal growth continues as long as moisture is present.

Common Indoor Mold Monsters

Molds are widespread in nature. Problem arises when killer airborne mold spores are found in excessive amounts in the indoor environment. Due to its minute – sized characteristic, mold spores can easily be carried indoors through clothing, pets, shoes, etc. Airborne molds spores may also enter a building through open doors, windows or ventilation systems. It must be noted,

however, that it is impossible and impractical to attempt to annihilate all indoor killer mold spores but it is essential to prevent significant accumulation.

According to the U.S. Environmental Protection Agency, "There is no practical way to eliminate all molds and mold spores in the indoor environment; the way to control indoor mold growth is to control moisture."

An estimate of around one hundred common indoor mold types has the potential to be harmful to one's health in a wide variety of ways. Hazardous molds that are commonly encountered are *Alternaria*, *Aspergillus*, *Cladosporium*, *Mucor*, *Penicillium*, and *Stachybotrys*.

According to *Post – Graduate Medicine*, indoor molds can be classified into two groups depending on their moisture intake. The first group includes molds that only require low to moderate moisture such as *Alternaria*, *Cladosporium*, and *Penicillin* while molds belonging to the second group require high moisture such which include *Aspergillus niger*, *Chaetomium*, *Stachybotrys*, and *Trichoderma*.

Table 1. List of molds commonly found in indoor environments.

<i>Genus</i>	<i>Source</i>
<i>Alternaria</i>	Apples, cabbage, citrus fruits, cheeses, grains, pork, potatoes, tomatoes
<i>Aspergillus</i>	Cloth, cheeses, cured meats, decaying plants or vegetables, leather, textiles, soil
<i>Cladosporium</i>	Cheeses, decaying plants, grains, leather, old window frames, soil, textiles
<i>Fusarium</i>	Bacon, beans, cabbage, carrots, cheeses, corn, potatoes, onions, soil, tomatoes
<i>Penicillium</i>	Compost, decaying vegetation, fabric, fruits, leather, paper, soil, wine
<i>Stachybotrys</i>	Cellulose, decaying plants, hay straw soil,
<i>Trichoderma</i>	Decaying wood, fruits, grains, paper, soil, sweet potatoes, textiles, tomatoes
<i>Trichophyton</i>	Fingernails, skin, soil

Information from PostGraduateMedicineOnline

Mold growths can easily be detected by spotting growths that appear cottony, granular, leathery, or velvety and may differ in color ranging between white, gray, black, brown, green, or yellow. It may initially appear as stains or discolorations. Detection of a musty odor, caused by volatile organic compounds, is another common indicator of a mold problem.

Pathways of Exposure

There are two common pathways of exposure to molds which are through inhalation and dermal contact. Additionally, accidental ingestion is considered as another possible pathway.

When an individual becomes exposed to allergens produced by molds, exposure through inhalation may likely to occur. This type of exposure usually occurs when mold spores, fragments, or mold mycotoxins become airborne, especially when the mold growth is disrupted or disturbed. Exposure through inhalation is the most common type.

On the other hand, dermal exposure may result if an individual comes into contact with the mold accidentally, or if attempting to remediate a mold – infested area without wearing proper safety equipment.

It must be noted that reactions through any pathways may be immediate or delayed which greatly depends on the sensitivity of the affected individual.

Mold Monster Health Impacts

Mold – related concerns are one of the hottest issues of today’s time and people are continuously discussing about its potential impact to one’s health. Over the past decade, there has been an increased awareness among clinicians and the general public that sensitivity to mold is a significant cause of allergic diseases.

Mold monsters produce a wide range of substances from mere allergy – provoking allergens, irritants, and to potentially toxic mycotoxins. Molds can also produce a variety of organic chemicals such as alcohols and sulfur – containing compounds that give off musty and pungent odors. Volatile organic

substances, under unusual circumstances, may reach levels sufficient to produce central nervous system symptoms such as dizziness, headache, or inability to concentrate. Thus, it is known that mold monsters really have the potential to cause health problems which include:

- Allergic asthma
- Allergic rhinitis
- Allergic fungal sinusitis
- Bronchopulmonary mycoses
- Hypersensitivity pneumonitis

Mold exposure may aggravate existing allergic rhinitis or asthma because of its irritant effects. Allergic reaction to mold ranges from mild to severe and from short – lived to chronic. **Allergic asthma** due to fungal allergens is characterized by chest tightness, cough, wheezing, and dyspnea that worsen with allergen – exposure.

In its early stages, **hypersensitivity pneumonitis** is characterized by intermittent symptoms of cough, chest tightness, and fever. Chronic hypersensitivity pneumonitis exhibits progressive dyspnea, fatigue, interstitial pneumonitis, and pulmonary fibrosis. This kind of disease is usually experienced mainly by farmers, cheese makers, pigeon breeders, mushroom growers, and wood processors who are exposed to high levels of airborne fungal allergens and organic dust.

Tinea infection is an example of **superficial mycosis** which, in turn, is the most common fungal disease and is not related to indoor air quality or building – related illness. Conversely, bronchopulmonary aspergillosis or allergic bronchopulmonary aspergillosis has been linked to building – related illness. It is an inflammatory disease caused by an immunologic response to an *Aspergillus* species, frequently *Aspergillus fumigatus*, growing in the bronchi of an asthmatic patient.

Over ninety percent of all chronic sinusitis problems, based on the medical study conducted by the Mayo Clinic, are directly related to living or working while exposed to elevated levels of mold, which is termed as **fungal sinusitis**. Additionally, health care experts estimate that thirty – seven million Americans are affected by sinusitis every year.

Molds produce antibiotics and mycotoxins so as to gain competitive advantage over bacteria and other mold species. Mycotoxins have the capacity to disrupt cell membrane and interfere with protein, RNA, and DNA synthesis. However, not all mold species are mycotoxin – producer. Aflatoxin [any group of toxic compounds produced by certain molds, especially *Aspergillus flavus* that contaminate stored food supplies such as animal feed and peanuts] can cause such diseases as acute fatty liver syndrome, hepatic necrosis, and encephalopathy. Furthermore, development of hepatocellular carcinoma [a tumor in which the cancer starts during adulthood in cells in the liver and is characterized by a hard lump just below the rib cage on the right side due to swelling of the liver, discomfort in the upper abdomen on the right side, pain around the right shoulder blade, or yellowing of the skin also called as jaundice] is a result of chronic exposure to aflatoxins.

It must be noted that the type of individuals who are at greater risk for experiencing hazardous health effects include infants and children, the elderly, and immunocompromised patients, such as caused by chemotherapy or disease.

To learn more on mold – related health concerns, you would be wise to read our in – depth [Mold Health Guide Book](#).

Chapter 3

TYPES OF MOLD MONSTERS

What are Allergenic Mold Monsters?

The so – called allergenic molds are types of molds that do not commonly produce life – threatening health problems, and are most likely to affect those who are already suffering from allergic reactions. The human system responses to the allergy – triggering molds tend to be relatively mild, typically producing only scratchy throats and skin rashes.

Mold monster spores are easily carried by wind currents and are considered as important airborne allergies especially at elevated levels. Similar to pollen allergies, mold allergies can also be seasonal. People with mold allergies may suffer allergic reactions from spring to fall with the season hitting its highest point in the middle of to late summer. An estimate of twenty percent of people suffering from airborne allergies is affected by mold spores - allergens.

This type of allergy can become worse during rainy or humid weather due to the fact that molds love living in a damp, moist environment. Furthermore, in the winter most outdoor molds become dormant but can thrive whole year in the warmest areas while molds growing indoors can endure year – round, even in the coldest climates.

You would be wise to read our in – depth [Seventy-one Health Home Remedies for Airborne Allergies](#), an essential, low-cost health e-book, which contains information needed to comprehend and deal with airborne allergic reactions.

What are Pathogenic Mold Monsters?

Pathogenic molds are types of molds that usually produce some type of infection in both humans and animals. The word “pathogenic” literally means, “capable of causing disease,” thus these monster molds have the capacity to cause serious health effects in individuals especially those with suppressed, underdeveloped, or compromised immune system. An immunocompetent, healthy individual can resist such infections regardless of dose. However, in some acute cases,

otherwise immunocompetent hosts at high exposure or through trauma may also be infected by this type of molds. People who are most likely vulnerable to mold – health problems are the elderly, infants and small children, and patients suffering from AIDS, pneumonia, bronchitis, and other respiratory infections, and also those who are exposed to chemotherapy.

What are Toxigenic Mold Monsters?

Toxigenic molds are types of molds who are capable of producing secondary metabolites that form toxins, known as mycotoxins. Mycotoxins can cause serious health effects in both humans and animals. These agents have toxic effects ranging from short – term irritation to immunosuppression and possibly cancer. There are several mold monster species that are mycotoxin – producers. Aflatoxin, produced by *Aspergillus flavus*, is commonly found in peanuts and several cases of severe allergic reactions have been reported due to the consumption of aflatoxin – contaminated nuts. Therefore, when toxigenic molds are present further evaluation is recommended.

Chapter 4

MOLD MONSTERS' COMPLETE PROFILE

An Introduction

Mold monsters have definitely made their way to become an important issue for these past few years among health workers, homeowners, insurance companies, and the media. The overwhelming issue of monstrous mold infestation has become a significant concern in the home and the workplace and people are consistently talking about its potential health and economic impact.

Molds belong to the Kingdom Fungi and are characterized as multi – cellular saprobes, feeding on dead, decaying matter and they reproduce by sending out millions of microscopic seeds, called spores, into the air.

These spores, when inhaled, can cause allergic reactions in sensitive individuals. Mold spores are very small and may enter the air passages and can also reach the lungs without getting caught by the protective mechanisms of the air passages. An estimate of twenty percent of people suffering from airborne allergies is affected by these mold spore allergens.

It is known that prolonged exposures to molds have been linked to a variety of illnesses - from mere nuisance allergies to severe chronic respiratory disorders.

According to the U.S. Environmental Protection Agency (EPA), "All molds have the potential to cause health effects. Molds can produce allergens that can trigger allergic reactions or even asthma attacks in people allergic to mold. Others are known to produce potent toxins and / or irritants."

In addition, millions of dollars are spent alone for home and office repairs due to big – time mold infestations. Extensive mold growth damages building materials thus; property owners are forced to and must get rid of the creeping mold monster.

Unfortunately, many people still do not fully understand the health hazards of fungal exposure. In this chapter, in – depth focus is given to each different kind of mold monsters that are identified, in both indoors and outdoors

environments, as causative agents of a wide range of health problems in both humans and animals.

Absidia Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Sub – Phylum: Zygomycotina
Class: Zygomycetes
Order: Mucorales
Family: Mucoraceae
Genus: *Absidia*



(Image Courtesy of www.doctorfungus.org @ 2005)

A microscopic morphology of *Absidia* species showing a sporangium filled with sporangiospores.

Ecology

Absidia species is a cosmopolitan filamentous fungus and very widespread in nature as a common environmental contaminant. *Absidia* species is primarily isolated from soil and decaying vegetation, as well as from indoor air

environment, and from foods, as it frequently causes spoilage of food. This fungus frequently causes spoilage of food.

Species

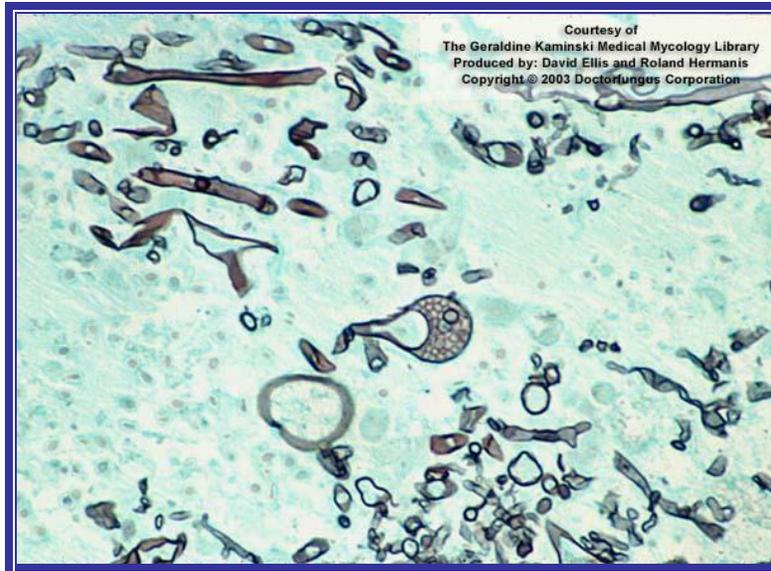
There are twenty – one species under genus *Absidia*. *Absidia corymbifera* is the most commonly isolated species which is considered pathogenic among the other *Absidia* species. Other *Absidia* species are *Absidia coerulea*, *Absidia cylindrospora*, *Absidia glauca*, and *Absidia spinosa*.

Pathogenicity and Health Effects

Absidia corymbifera is among the recognized rare cause of human zygomycosis [refers to the angiotropic, a blood vessel - invading infection produced by the various Zygomycetes fungi disease] which manifests with cutaneous, gastrointestinal, pulmonary, meningeal, renal or rhinocerebral involvement. Zygomycosis is very rarely observed in immunocompetent host. *Absidia corymbifera* is more commonly considered as an animal pathogen as it is an occasional cause of mycotic abortion [a bovine abortion associated with fungi - derived from spores in moldy hay and straw in the cow].

Absidia species are also known as common laboratory contaminants thus; their isolation in culture entails cautious evaluation. The growth of *Absidia*, however, should be viewed as potentially significant, particularly from clinical samples of patients with immunosuppression or diabetes mellitus.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Absidia mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

A cross – section of a stained lung tissue showing by chance a sporangium of *Absidia corymbifera*

Macroscopic Appearance

- Growth rate is rapid and colonies are flat, wooly to cottony in texture;
- Surface colony color is gray while the reverse is uncolored;
- At 37°C, psychrotolerant - thermophilic *Absidia corymbifera* grows rapidly than at 25°C and its maximum growth temperature is as high as 48°C to 52°C; and
- The optimum growth condition for *Absidia corymbifera* is at a temperature range of 35 - 37°C and at a pH value range of 3.0 to 8.0.

Microscopic Appearance

- Hyphae are non – septate, wide with a diameter measuring 6 – 15 µm, however a few septa may occasionally be present;
- Rhizoids [short branching root-like hyphae seen in some Zygomycetes] are observed rarely and may be difficult to find without the aid of a dissecting microscope;

- Sporangiophores [specialized hyphae that bears a sporangium] are hyaline to slightly pigmented, branched with a funnel – shaped swelling, called as apophysis, found beneath the sporangium, arise stolons from points between the rhizoids but not opposite the rhizoids, and carry pyriform shaped - sporangia;
- Sporangia [a sac-like structure producing asexual spores endogenously by cytoplasmic cleavage] are relatively small measuring between 20 – 120 μm in diameter, pyriform – shaped, and with a conical – shaped columella and pronounced apophysis;
- The columella, the tip of the sporangiophore that extends into the sporangium, is semi – circular in shape; and
- Sporangiospores [asexual spores produced within a sporangium] are unicellular, round - to oval – shaped, measuring 3 – 4.5 μm in diameter, hyaline to light black, smooth to rarely echinulate on surface, are found in the sporangium and are released upon the rupture of the sporangium.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

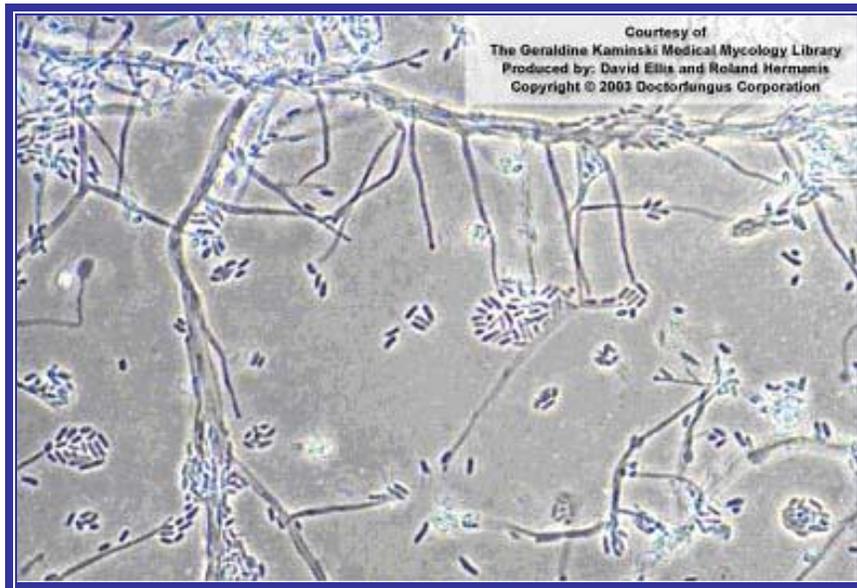
Data on *in vitro* susceptibility are very limited. Amphotericin B serves as the only antifungal drug which shows consistent activity against *Absidia corymbifera*. Generally, *Absidia corymbifera* is resistant to azoles, including voriconazole which is a new derivative. Flucytosine is also ineffective against *Absidia corymbifera*.

On the other hand, *in vivo* response largely depends on the application of full – dose amphotericin B therapy as well as surgical debridement and correction of the underlying predisposing factors such as immunosuppression and diabetic acidosis.

Acremonium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Sub – Phylum: Ascomycotina
Order: Hypocreales
Family: Hypocreaceae
Genus: *Acremonium*



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the long, hyaline, awl - shaped, simple, erect, phialides of an *Acremonium* species arising from hyphae.

Ecology

Acremonium species is a cosmopolitan filamentous fungus and is classified under the deuteromycetes group by some experts due to its undefined sexual state while others prefer to include the said species under the Ascomycota phylum

based on its structural properties which are similar to those belonging to this phylum.

According to **The Environmental Reporter, Vol. 3, No. 9**, "*Acremonium* species is primarily isolated from soil, plant debris, foodstuffs, hay, rotting mushrooms, and indoor building materials, such as the acoustic and thermal fiber glass insulation used in heating ventilation and air conditioning system. *Acremonium* has a high water affinity of A_w 0.90 to 0.98 and is often isolated from cooling coils, drain pans, window seals, and water from humidifiers. Additionally, *Acremonium* is occasionally found growing with *Stachybotrys*. The spores of this fungus are formed in a slimy mass resulting to a limited aerosolization."

Species

The genus *Acremonium* currently contains one hundred species, mostly are saprophytic in nature, leaving on dead organic matter. There are three main species concerned in infections namely, *Acremonium falciforme*, *Acremonium kiliense*, and *Acremonium recifei*.

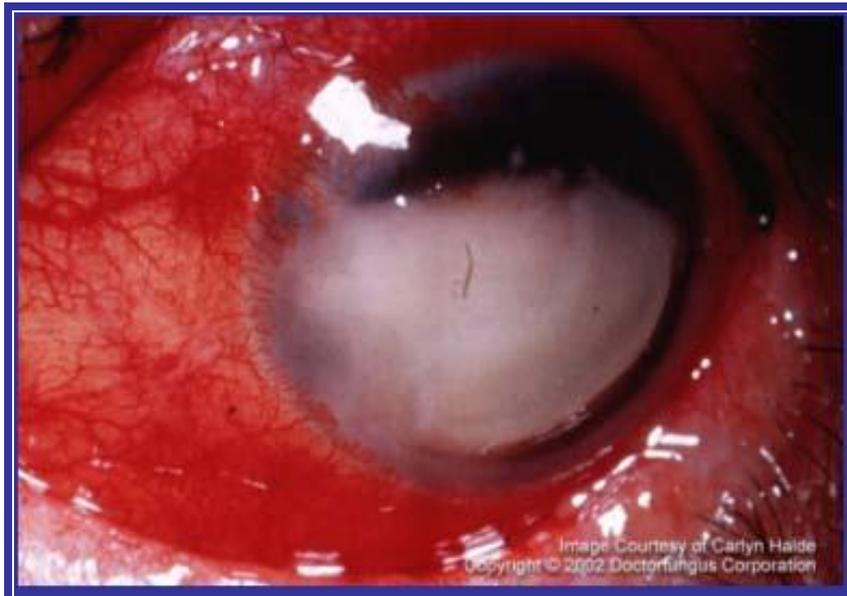
Pathogenicity and Health Effects

Acremonium is considered as one of the causative agents of white grain mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and sclerotia]. In addition to some cases of onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus] due to *Acremonium*, cases of endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], keratitis [wide variety of corneal infections, irritations and inflammations], meningitis [inflammation of the meninges characterized by early flu – like symptoms and are followed by more serious symptoms which include confusion, fever, headache, loss of appetite, rash, stiff neck, vomiting, and coma; the onset is frequently rapid, and the disease can be fatal within a very short period of time, if untreated, as it can cause permanent damage to the brain and nervous system and is sometimes the cause of deafness], and peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers

most of the organs in the abdomen] have also been reported. This fungus is known to cause opportunistic infections mainly among the immunocompromised patients, such as bone marrow transplant recipients.

Acremonium species are encountered as contaminants as well thus, their isolation in culture requires careful evaluation. Additionally, some *Acremonium* species are even parasitic toward other fungal organisms which are generally termed as mycoparasites.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Acremonium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

Endophthalmitis due to *Acremonium* species

Macroscopic Appearance

- Growth rate is moderately rapid and colonies are compact, flat or folded and occasionally raised in the center; initially, texture is glabrous, velvety and membranous and becoming cottony with age due to the overgrowth of loose hyphae;

- Colonies are observed having diameter measuring from 1 to 3 cm after seven days of incubation at 25°C; and
- Surface colony color ranges from white, to pale gray or pale pink while the reverse is uncolored or a pink to rose colored - pigmentation may be observed.

Microscopic Appearance

- Hyphae are hyaline [colorless] and septate which are characteristically fine and narrow;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are erect, unbranched and solitary which arise directly from the hyphal tips; phialides are separated by a septum from the hyphae and taper towards their tips; and
- Conidia are hyaline, may be unicellular or multicellular, fusiform – shaped with a slight curve or may look like a shallow crescent, appear in clusters, in balls or as fragile chains rarely, with size of 2 – 3 x 4 – 8 µm, and are found at the tips of the phialides; the structural properties of the conidia may vary depending on the species.

Table 1. Structural Differences of Conidia of Acremonium species

Acremonium species	Structural Differences of Conidia
<i>Acremonium falciforme</i>	Produces crescent - shaped, non - septate conidia, 2 - or 3 - celled conidia may also be observed sometimes
<i>Acremonium kiliense</i>	Produces short straight conidia
<i>Acremonium recifei</i>	Produces usually crescent – shaped and non – septate conidia

The wet conidial spores are disseminated mechanically by insects or water droplets. Occasionally, spores from old growth are wind - disseminated, according to The Environmental Reporter, Vol. 3, No. 9.

Mold Analysis

On spore traps, *Acremonium* is not easily identified due to their very small, colorless and non – distinctive spores. Furthermore, some spores are so small that they may be obscured by background debris. Air sampling cultures are

better way to recover and identify airborne *Acremonium* spores. *Acremonium* can easily be identified on direct examination as it is possible to view distinctive chains or the slimy heads of conidia.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

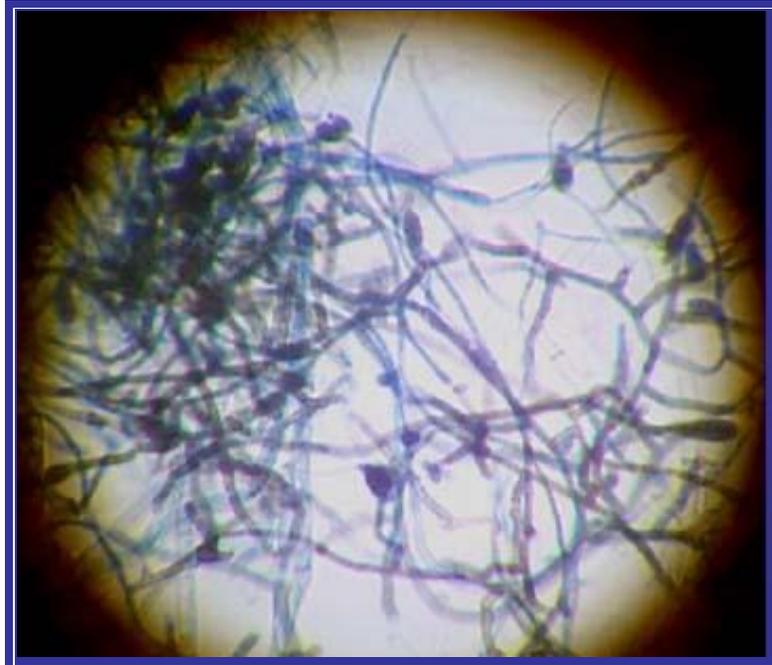
Reported data on *in vitro* susceptibility are very limited. The novel azoles, posaconazole and voriconazole show favorable *in vitro* activity against *Acremonium* strains.

On the other hand, *in vivo* response largely depends on both antifungal therapy and surgical involvement. Amphotericin B remains as the mainstay of therapy among the available antifungal agents.

Alternaria Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Pleosporales
Family: Pleosporaceae
Genus: *Alternaria*



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Alternaria* species taken under 40X objective

Ecology

Alternaria species is a cosmopolitan dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] fungus primarily isolated from food, plants – either as pathogens or as saprobes, soil,

and indoor air environment. One of its major characteristics is the production of a melanin – like pigment and *Clathrospora* and *Leptosphaeria* are its sexual or teleomorphic genera.

Species

There are around fifty species belonging to the genus *Alternaria*. *Alternaria alternata*, among these species, is the most common one isolated from human infections. *Alternaria chartarum*, *Alternaria dianthicola*, *Alternaria geophila*, *Alternaria infectoria*, *Alternaria stemphyloides*, and *Alternaria teunissima* are among the other *Alternaria* species isolated from infections. Some infection – causing *Alternaria* strains, however, remain unspecified.

Pathogenicity and Health Effects

Alternaria species are known as opportunistic pathogens particularly among immunosuppressed patients such as bone marrow transplant recipients. They are occasional causative agents of onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], keratitis [wide variety of corneal infections, irritations and inflammations], sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever], visceral infections, as well as osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood] and ulcerated infections. Additionally, rare cases of deep infection have also been reported in immunocompromised patients. The infecting mechanism of *Alternaria* in immunocompromised patients involves fungal colonization which may end up with development of invasive disease. While in immunocompetent patients, *Alternaria* colonizes the paranasal sinuses resulting to chronic hypertrophic sinusitis. Moreover, *Alternaria* is among the causative agents of otitis media [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo] among agricultural field workers.

Alternaria species are encountered as contaminants as well thus; their isolation in culture requires careful evaluation.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Alternaria mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

*An opportunistic infection, termed as granulomatous lesion, due to **Alternaria alternata***

Macroscopic Appearance

- Growth rate is rapid and colonies are flat, downy to wooly and are covered by grayish, short, aerial hyphae in time, and may reach a diameter size of 3 to 9 cm after seven days of incubation at 25°C; and
- Surface colony color is pale gray initially and becomes greenish black or olive brown with a light border while the reverse is brown to black due pigment production.

Microscopic Appearance

- Hyphae are brown – colored and septate, and conidiophores [specialized hyphae upon which conidia develop] may occasionally produce a zigzag appearance and bear simple or branched large conidia; and
- Conidia [asexual reproductive spores which function as organs of dissemination] arise from conidiophores with both transverse and longitudinal septations, with size of 7 – 10 x 23 – 24 µm their tips, ovoid to obclavate in shape, muriform, darkly pigmented, smooth or roughened, and its end nearest to the conidiophore is round while it tapers towards the apex thus, giving its typical or club – like appearance.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

In vitro susceptibility testing for dematiaceous fungi is not standardized yet. Caspofungin shows activity *in vitro* against *Alternaria* as well as voriconazole which generated lower MICs compared to itraconazole for *Alternaria* strains.

A successful clinical outcome may be achieved by amphotericin B and flucytosine therapy. Fluconazole, itraconazole, or terbinafine treatment may also be effective. However, to clarify their actual range in treatment of *Alternaria* infections further data are still required.

Aspergillus Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Order: Eurotiales
Family: Trichocomaceae
Genus: *Aspergillus*



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Aspergillus* species showing a columnar type of a conidial head

Ecology

Aspergillus species is cosmopolitan, filamentous, saprobic [utilizes dead organic matter for food] fungus. It is widely distributed in nature, especially during the autumn and winter months in the northern hemisphere. It is primarily isolated

from soils, especially cultivated soils, decomposing plant material, and indoor air environment.

Species

There are around one hundred eighty – five species under the genus *Aspergillus*. Around twenty species have been reported so far as causative agents of opportunistic infections in humans. Among these, *Aspergillus fumigatus* is the most frequently isolated species, followed by *Aspergillus flavus* and *Aspergillus niger*. Among the other species not often isolated as opportunistic pathogens are *Aspergillus clavatus*, *Aspergillus glaucus* group, *Aspergillus nidulans*, *Aspergillus oryzae*, *Aspergillus terreus*, *Aspergillus ustus* and *Aspergillus versicolor*.

Pathogenicity and Health Effects

Aspergillus species are recognized to play a significant role in three different clinical settings in man namely, in opportunistic infections, allergic conditions, and in toxicoses. The major factor which led to the emergence of opportunistic infections is immunosuppression. Opportunistic infections are generally called aspergillosis [infection observed especially in people with a deficient immune system which includes invasive lung infection and disseminated disease, commonly with cough, chest pains, fever, and spitting up blood; it may also mimic asthma with cough and noise on breathing in or sinusitis with fever, localized pain]. The most common forms of aspergillosis in humans are pulmonary in nature; on the other hand, other deep infections are also encountered particularly among immunocompromised patients. Among all filamentous fungi, *Aspergillus* is generally the most recovered one in invasive infections and is second to *Candida* as the most frequently isolated fungus in opportunistic mycoses.

Cerebral, cutaneous, hepatosplenic, pulmonary, and disseminated aspergillosis, endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], meningitis [inflammation of the meninges characterized by early flu – like symptoms and are followed by more serious symptoms which include confusion, fever, headache, loss of appetite, rash, stiff neck, vomiting, and coma; the onset is

frequently rapid, and the disease can be fatal within a very short period of time, if untreated, as it can cause permanent damage to the brain and nervous system and is sometimes the cause of deafness], myocarditis [an inflammation of the myocardium, the heart muscle], onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood], otomycosis [a superficial infection of the outer ear canal which may either be sub – acute or acute and is characterized by inflammation, pruritus, scaling, and severe discomfort], sinusitis, and as well as *Aspergillus* fungemia [the presence of fungi in the blood] may develop as almost any organ or system in the human body may be involved once *Aspergillus* - induced infection sets in.

Furthermore, there are numerous outbreaks of disseminated aspergillosis cases that have been recorded in neutropenic patients in concurrence with construction / renovation projects in hospital environments.

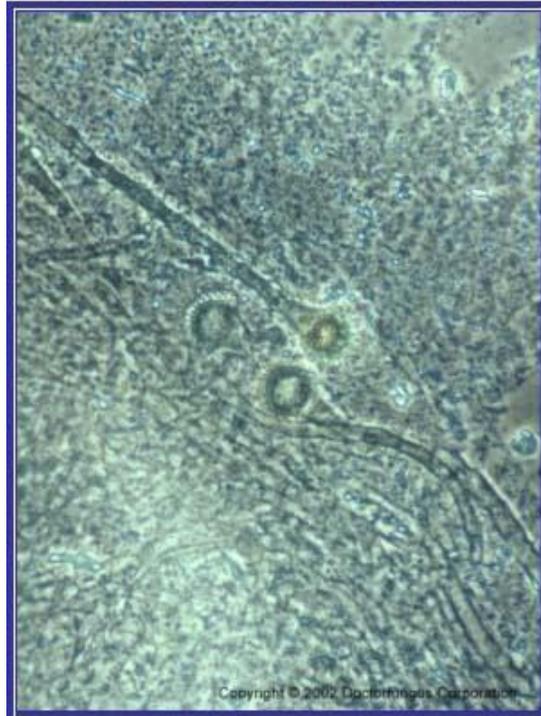
Aspergillus species may colonize lung cavities which may have previously been developed due to tuberculosis, sarcoidosis, bronchiectasis, pneumonia [an inflammation of one or both lungs with symptoms of chest pain, chills, cough with sputum production, fever, and shortness of breath], ankylosing spondylitis [is a form of chronic inflammation of the spine and the sacroiliac joints which are located in the low back where the sacrum meets the iliac bones] or neoplasms. This whole distinct clinical identity is referred to as aspergilloma [the fungus forms a mycelial ball in a lung cavity produced by an earlier attack of tuberculosis]. Kidneys may also be targeted by aspergilloma.

Some *Aspergillus* species produce various mycotoxins which have proven to possess carcinogenic potential particularly in animals and these are acquired through chronic ingestion. *Aspergillus flavus* produces aflatoxin which is a well – known mycotoxin. **Aflatoxin** may induce hepatocellular carcinoma [a tumor in which the cancer starts during adulthood in cells in the liver and is characterized by a hard lump just below the rib cage on the right side due to swelling of the liver, discomfort in the upper abdomen on the right side, pain around the right shoulder blade, or yellowing of the skin also called as jaundice] and it contaminates foodstuffs such as peanuts and grains. Ingestion of high amounts of aflatoxin may induce toxic effects in poultry animals fed with aflatoxin – contaminated grain.

Aspergillus species are known as occasional causative agent of respiratory infection in birds and mycotic abortion [bovine abortion associated with fungi - derived from spores in moldy hay and straw, and is characterized by presence of hyphae in the thickened and necrotic placental cotyledons] in certain animals, particularly cattle and sheep. *Aspergillus* species are also encountered as common laboratory contaminants due to being ubiquitous in nature.

Furthermore, many common household foods are also manufactured by the *Aspergillus* - fermentation process. This can also be unhealthy for already compromised individual who has been exposed to *Aspergillus* in high counts to be in contact with. Thus, it is recommended that these products be avoided at all costs.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Aspergillus mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy from www.doctorfungus.org @ 2005)

Take note of the microscopic growth of *A. fumigatus* in chest drainage fluid.

Macroscopic Appearance

- The major macroscopic characteristics that are essential in *Aspergillus* species identification are the growth rate, colony color and thermo – tolerance;
- Texture of colonies varies from being downy to powdery;
- Growth rate varies from slow to rapid depending on the species with diameter size ranging from 0.5 to 1 cm and 1 to 9 cm after seven days of incubation at 25°C on Czapek – Dox agar;
- Surface colony color may also vary depending on the species while the reverse is mostly uncolored to pale yellow, however, some strains of *Aspergillus nidulans* may be purple or olive while it is orange to purple in *Aspergillus versicolor*; and
- The only thermo – tolerant *Aspergillus* which can grow at temperature range of 20°C to 50°C is *Aspergillus fumigatus*.

Microscopic Appearance

- Hyphae are septate and hyaline; and
- Conidiophores [specialized hyphae upon which conidia develop] arise from the basal foot cell found at the supporting hyphae and terminate in a vesicle at the tip;
- Vesicle [a swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] is the typically formation for the genus *Aspergillus*;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are flask – shaped, may either cover the surface of the vesicle entirely called as “radiate head,” or partially at the upper surface only termed as “columnar head,” and may either be uniseriate – directly attached to the vesicle, or biseriate – attached to the vesicle via a supporting cell, metula;
- Conidia are found over the phialides forming radial chains and with diameter size of 2 to 5 µm.
- Other microscopic structures of the genus *Aspergillus* are:
 - a. Aleuriconidia – observed with a truncated base and carries remnants of the lysed supporting cell; a type of conidium produced by lysis of the cell that supports it;

- b. Cleistothecia – produced during the sexual production of some *Aspergillus* species, are round and closed structures which enclose the ascospore – containing asci wherein the asci are distributed into the surrounding upon the bursting of cleistothecia;
- c. Hülle cells - are large sterile cell bearing a small lumen; and
- d. Sclerotia - are compact or hard masses of mycelium.

Table 1. Morphological Characteristics of Aspergillus species

<i>Aspergillus</i> species	Colony Color		Conidial Head	Conidiophore	Phialides	Other Characteristics
	Surface	Reverse				
<i>Aspergillus flavus</i>	Yellow-green	Yellow, brownish	Mostly radiate, some becoming columnar at maturity	Rough, colorless	Uniseriate and biseriate	Sclerotia occasionally present
<i>A. fumigatus</i>	Gray green, blue green	yellowish	Columnar	Smooth, colorless or greenish	Uniseriate	Good growth at 48°C
<i>A. glaucus</i> group	Green and yellow	Yellowish, brown	Radiate to loosely columnar	Smooth, colorless	Uniseriate	Yellow to orange cleistothecia present
<i>A. nidulans</i>	Green, buff	Purplish red, olive	Short columnar	Smooth, brown	Biseriate	Round hülle cells and red cleistothecia usually present
<i>A. niger</i>	Black	White, yellowish	Radiate, however, becoming loosely columnar at maturity	Smooth, colorless or brown	Biseriate	-
<i>A. terreus</i>	Brown, cinnamon	Yellowish brown	Columnar	Smooth, colorless	Biseriate	Round, solitary, aleurioconidia produced directly on hyphae
<i>A. versicolor</i>	White, buff, yellow, pink, pale green	White, yellow, purplish red	Radiate	Smooth, colorless	Biseriate	Round hülle cells occasionally present

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Most of *Aspergillus* isolates yield acceptably low MICs for amphotericin B, itraconazole and voriconazole, however, a number of isolates show high MICs which indicates potential prediction of resistance. Such as the few isolates of *Aspergillus fumigatus* which are itraconazole – resistant and *Aspergillus terreus* resistant to amphotericin B. Fortunately, voriconazole appears effective *in vitro* against itraconazole – resistant *Aspergillus fumigatus*.

Treatment of invasive aspergillosis is still troublesome with high rate of mortality. The clinical success rate of both amphotericin B and itraconazole are still unsatisfactory due to low efficacy and / or high toxicity of the drugs and existence of adverse immune status of the host.

The novel azoles which include voriconazole, posaconazole or ravuconazole, glucan inhibitors such as caspofungin and V - echinocandins, and liposomal nystatin are active *in vitro* against *Aspergillus* and remain promising for future therapy treatment of aspergillosis.

Aspergillus Mold as a Possible Biological Warfare Agent

The interesting article below is taken from Mold-Help.org.

To further understand the significance of the component aflatoxin as a known carcinogen by the government, review the following expert on Iraq's declaration of biological weapons in 1998 according to this SIPRI fact sheet,

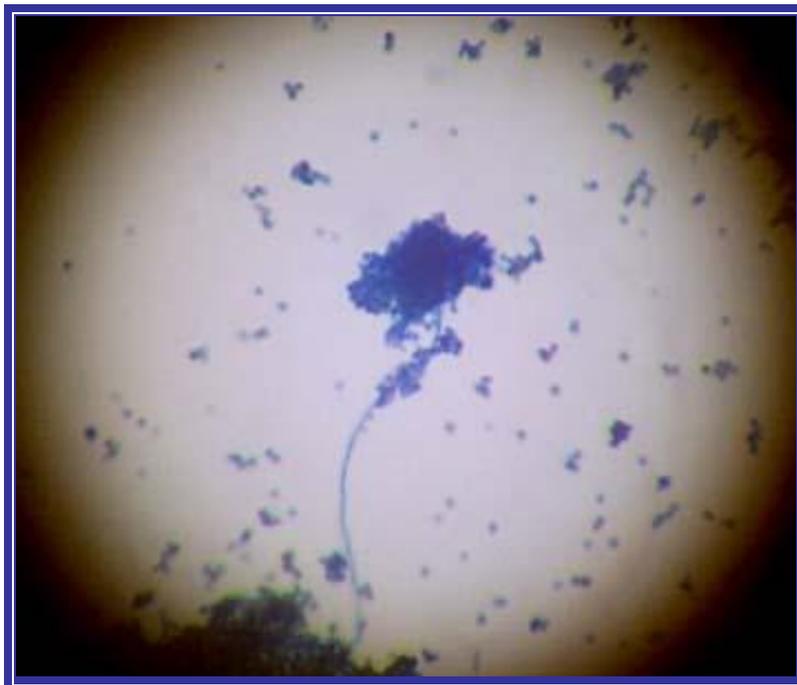
The discovery that Iraq was researching aflatoxin, not a traditional BW candidate, was a cause for some surprise. It is a carcinogen, the effects of which manifest themselves only after many years, and several Western experts have rationalized this Iraqi programme only in terms of genocidal goals. If aflatoxin were used against the Kurds, for instance, it would be impossible definitively to prove the use of BW once the symptoms emerged. Another possible explanation is its potential use as an immune suppressant, making

victims more susceptible to other agents. However, the aflatoxin declaration may also hide other aspects of Iraq's BW programme: according to Iraq's depositions, the production programme never encountered any mishap (as other parts of the BW programme had) and, to judge from the declared time-frame for the total amount produced, production could never have stopped, even for cleaning of the equipment. This raises the suspicion that Iraq declared an excessive amount of aflatoxin in order to disguise the fact that other, more destructive agents had been produced in greater quantities.

Source - <http://editors.sipri.se/pubs/Factsheet/unscom.html>

Specific Profiles of the Different Pathogenic *Aspergillus* Species

Aspergillus flavus



Asian Mold Inspector Laboratory Mold Species Documentation

Take note of the radiate conidial head of *Aspergillus flavus* specimen, however, as the species mature the conidial masses may split into blocky columns.

Ecology

Aspergillus flavus is a cosmopolitan fungus which is isolated primarily from plants and soil. It is known for its aflatoxin [any group of toxic compounds produced by certain molds, especially *Aspergillus flavus* that contaminate stored

food supplies such as animal feed and peanuts] produced in certain food such as peanuts.

Pathogenicity and Health Effects

Aspergillus flavus is an occasional causative agent of pulmonary or disseminated infections among immunocompromised patients. Cases of onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus] and sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever] have also been reported. *Aspergillus flavus* may also be the agent of respiratory infections in animals.

Macroscopic Appearance

- Growth rate is rapid and the texture of colonies varies from wooly to cottony to granular;
- Sclerotia are dark brown in color when present; and
- The surface colony color is olive to lime green and the reverse is cream or pale.

Microscopic Appearance

- Conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] are mostly radiate with conidial masses splitting into blocky columns with age ;
- Conidiophores [specialized hyphae upon which conidia develop] are with roughened walls especially near the vesicle, with size of 800 µm long x 15 – 20 µm wide;
- Hyphae are septate and hyaline; vesicles are globose to sub – globose with size ranging from 20 – 45 µm; metulae cover the entire vesicle in biseriata species and with size ranging from 8 – 10 x 5 – 7 µm;
- Some isolates may be uniseriate [phialides arising directly from a vesicle as in the genus *Aspergillus*] producing only phialides covering the vesicle, and with size ranging from 8 - 12 x 3 – 4 µm; and

- Conidia [asexual reproductive spores which function as organs of dissemination] are round, globose to sub – globose, with smooth to finely roughened walls, appear in chains, and with diameter size of 3 - 6 μm .

Aspergillus fumigatus



Asian Mold Inspector Laboratory Mold Species Documentation

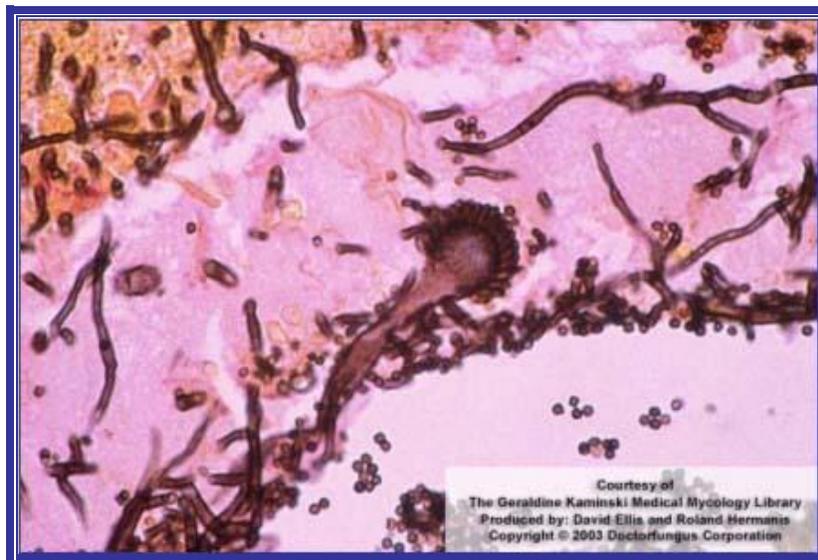
A microscopic view of *Aspergillus fumigatus* showing typical columnar, uniseriate conidial heads.

Ecology

Aspergillus fumigatus is a cosmopolitan and thermotolerant fungus [capable of growing at high temperatures] which is isolated primarily from compost, plant material and from soil. It is considered as one of the most common aspergilli in nature which grows mainly in warm environments.

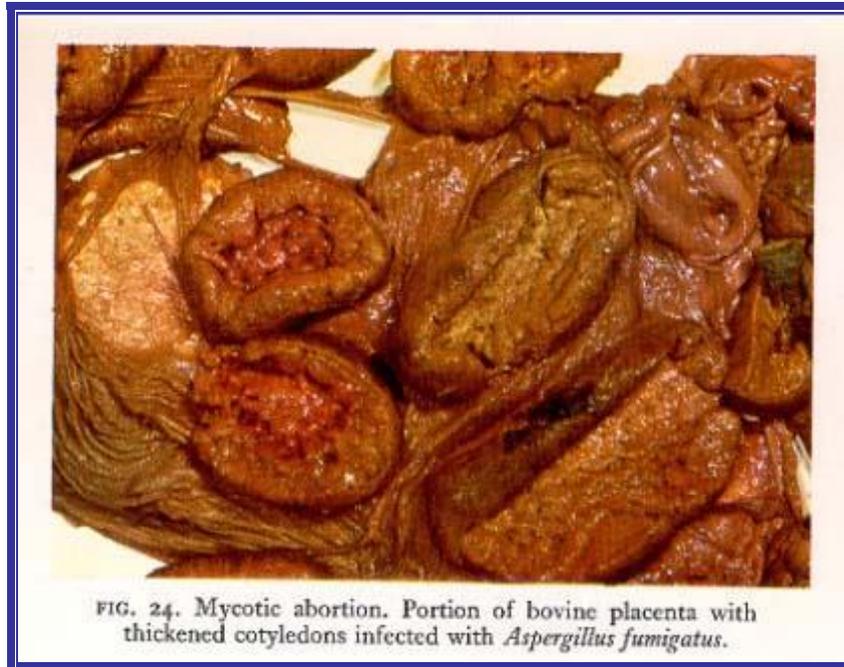
Pathogenicity and Health Effects

Aspergillus fumigatus is an occasional causative agent of aspergillosis [infection observed especially in people with a deficient immune system which includes invasive lung infection and disseminated disease, commonly with cough, chest pains, fever, and spitting up blood; it may also mimic asthma with cough and noise on breathing in or sinusitis with fever, localized pain] in humans. Cases of pulmonary, nasal, cerebral, bone, ocular, cardiovascular, and organ infections have been reported, especially among immunocompromised patient. *Aspergillus fumigatus* is also an agent of mycotic abortion [bovine abortion associated with fungi - derived from spores in moldy hay and straw, and is characterized by presence of hyphae in the thickened and necrotic placental cotyledons] in the cow and of respiratory infections in fowl.



(Image Courtesy of www.doctorfungus.org @ 2005)

Methenamine silver (GMS) stained tissue sections showing *Aspergillus fumigatus* in lung tissue, note conidial heads forming in an alveolus.



(Image Courtesy of aspergillus @ man.ac.uk)

A photograph of thickened cotyledons of bovine placenta infected with *Aspergillus fumigatus*

Macroscopic Appearance

- Growth rate is rapid and the texture of colonies varies from wooly to cottony to granular;
- Surface colony color is smoky gray - green and the reverse is yellow, however, some isolates may show a lavender diffusible pigment; and
- Color of very mature colonies turn to slate gray while atypical colonies may remain white with slight conidiation.

Microscopic Appearance

- Conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] are in the form of compact columns in an undisturbed culture;

- Conidiophores [specialized hyphae upon which conidia develop] are smooth – walled, often tinted greenish, up to 300 µm long, and terminate in a dome – shaped vesicle with a diameter of 20 – 30 µm long;
- Hyphae are septate and hyaline;
- The species is uniseriate [phialides arising directly from a vesicle as in the genus *Aspergillus*] producing a closely compacted phialides with size ranging from 5 - 10 x 2 – 3 µm, and only occurring on the upper portion of the vesicle; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are round to sub – globose, smooth to finely roughened, and with diameter size of 2 – 3.5 µm.

Aspergillus glaucus group



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the smooth, pale brown conidiophores, and sub - globose vesicles, with phialides covering at least two - thirds of the vesicle and bearing finely roughened conidia.

Ecology

Aspergillus glaucus is a cosmopolitan and osmophilic fungus [being able to grow under conditions of high osmotic pressure] which is isolated primarily from house dust, plant material and from soil.

Pathogenicity and Health Effects

Aspergillus glaucus is an occasional causative agent of pulmonary or disseminated infection among immunocompromised patients.

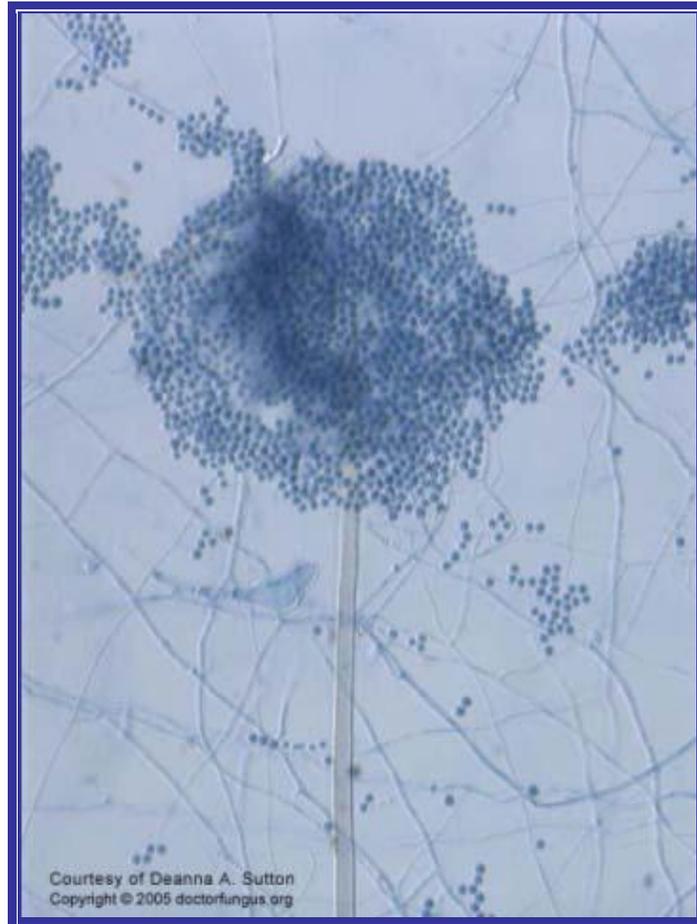
Macroscopic Appearance

- Growth rate is slow to moderately rapid and the texture of colonies varies from downy to powdery; and
- Surface colony color is grayish - turquoise to deep green with yellow central portions due to cleistothecial production while reverse is yellowish to chestnut.

Microscopic Appearance

- Conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] radiate to loosely columnar;
- Conidiophores [specialized hyphae upon which conidia develop] are smooth - walled, uncolored to pale brown, and 200 - 350 μm long;
- Hyphae are septate and hyaline and phialides cover the upper portion of the vesicle;
- Vesicles [swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] are globose to sub - globose, uniseriate, and with diameter of 15 - 30 μm ;
- Conidia are ellipsoidal or round, finely roughened to echinulate, and with diameter of 3.5 - 6.5 μm ;
- Cleistothecia [enclosed ascocarp containing randomly dispersed asci] are globose, thin - walled, typically numerous, yellow - colored, normally covered with red hyphae, more prominent than conidial heads at times, and with diameter of 75 - 125 μm ;
- Asci [sac - like cells containing ascospores] contains eight spores; and
- Ascospores [haploid spores produced within an ascus] are hyaline, pale, and mature within two to three weeks, smooth to slightly roughened, with or without equatorial crests, with size ranging from 6 - 7 x 3.5 - 5 μm .

Aspergillus granulosis



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Aspergillus granulosis*

Pathogenicity and Health Effects

Aspergillus granulosis is a causative agent of disseminated infection among cardiac transplant recipients.

Macroscopic Appearance

- Growth rate is moderate to rapid and texture of colonies varies from plane to irregularly furrowed, frequently floccose, with uneven texture, and have a granular appearance due to formation of small hülle aggregates which may at first resemble sclerotia; and
- Surface colony color is buff to ochraceous to dull brown while reverse is dark yellow to reddish brown; and
- Presence of pale blue – green colored conidial heads may contribute color pigmentation; however, in some strains their production may be minimal that this color pigmentation may not manifest.

Microscopic Appearance

- Conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] are radiate and hyphae are septate and hyaline;
- Conidiophores [specialized hyphae upon which conidia develop] are thin – walled, pale brown, smooth, and are 350 - 500 µm long as described by Raper and Fennell, on the other hand, the Fungus Testing Laboratory has measured an isolate with very long conidiophores of up to over 1 mm;
- Vesicles [a swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] are biseriate [phialides arising from metulae as in the genus *Aspergillus*], elliptical, with diameter of 12 – 18 µm, and with almost the entire surface being covered;
- Conidia are globose, finely roughened, pale green, and with diameter of 3.5 – 5.5 µm; and
- Hülle cells [thick - walled cells developed by budding at the tips of specialized hyphae, with characteristic thin - walled pores, and may envelop the developing cleistothecium thus, may serve as nurse cells] are sub – globose to ovoid to quite elongate, with size ranging from 12 – 30 µm long, appear numerous in freshly isolated chains, and occur in colorless clusters.

Aspergillus nidulans



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Aspergillus nidulans* showing short brown, smooth conidiophores, sub - globose vesicles, metulae, and phialides bearing slightly roughened globose conidia.

Ecology

Aspergillus nidulans is a cosmopolitan fungus which is primarily isolated from soil.

Pathogenicity and Health Effects

Aspergillus nidulans is an occasional causative agent of pulmonary or disseminated infection among immunocompromised patients.

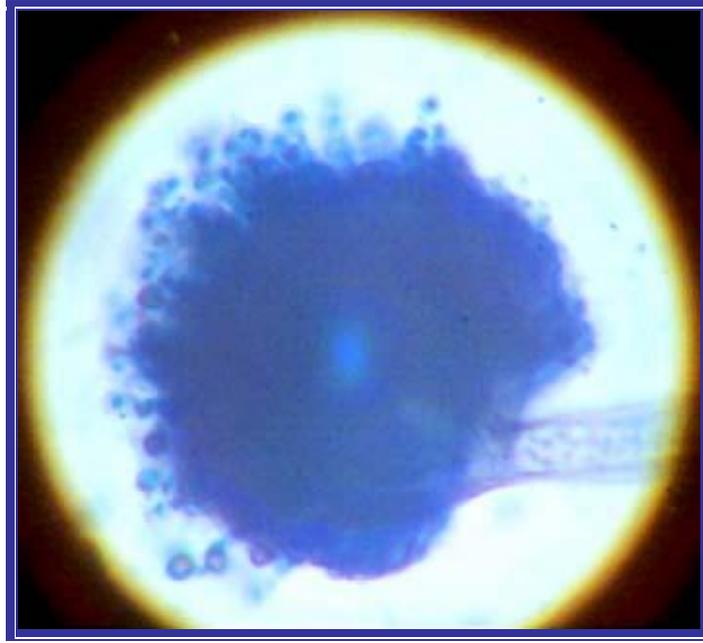
Macroscopic Appearance

- Growth rate is slow to moderately rapid and texture of colonies varies from downy to powdery; and
- Surface colony color is dark green or dark olive buff with orange to yellow in areas with cleistothecial formation while reverse is purplish to olive.

Microscopic Appearance

- Conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] are columnar and hyphae are septate and hyaline;
- Conidiophores [specialized hyphae upon which conidia develop] are smooth – walled, brown, and short with length ranging from 60 - 50 μm long;
- Vesicles [a swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] are hemispherical, small, with size ranging from 8 – 12 μm in diameter, with metulae and biserial phialides occurring on the upper portion;
- Conidia are globose, rough, and with size of 3 - 4 μm in diameter; and
- Ascospores [haploid spores produced within an ascus] are reddish purple, lens – shaped, with two equatorial crests, and with size of 4 x 5 μm .

Aspergillus niger



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of a radiate conidial head *Aspergillus niger* viewed under 100X objective.

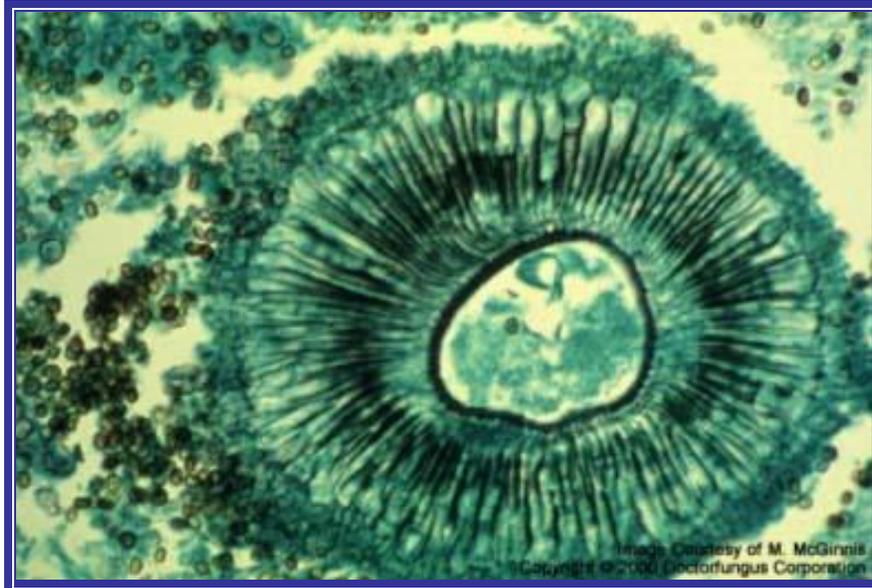
Ecology

Aspergillus niger is a cosmopolitan fungus which is primarily isolated from soil and decomposing plant material.

Pathogenicity and Health Effects

Aspergillus niger is a frequent causative agent of aspergilloma [the fungus forms a mycelial ball in a lung cavity produced by an earlier attack of tuberculosis]. It rarely causes primary cutaneous, pulmonary, and disseminated infection, particularly among immunocompromised patients. *Aspergillus niger* is isolated often in cases of chronic otitis [an inflammation of the ear, which may be marked

by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo] where, generally, from the outer ear canal colonizations.



(Image Courtesy of www.doctorfungus.org @ 2005)

Aspergilloma infection showing a biseriate fruiting body of *Aspergillus niger* in a lung cavity.

Macroscopic Appearance

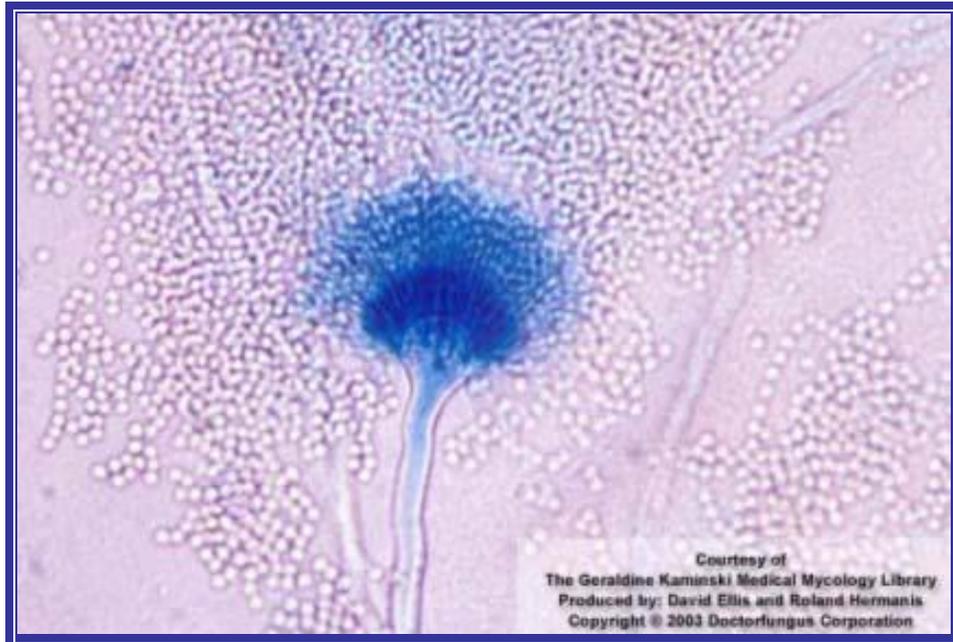
- Growth rate is rapid and texture of colonies varies from downy to powdery, and may produce radial fissures in the agar; and
- Surface colony color is initially white becoming black to deep brown with conidial production while the reverse is pale yellow or uncolored.

Microscopic Appearance

- Hyphae are septate and hyaline and conidial heads are initially radiate, however, splitting into columns in age;
- *Aspergillus niger* is biseriate wherein its vesicles form sterile cells, called as metulae, support the conidiogenous phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length];

- Conidiophores [specialized hyphae upon which conidia develop] are hyaline, smooth – walled, with length ranging from 400 – 3, 000 μm long, and are becoming darker at the apex and terminating in a globose vesicle with size of 30 – 75 μm in diameter; and
- Metulae [sterile cells below the phialides of some *Aspergillus* and *Penicillium* species] and phialides cover the entire surface of the vesicle;
- Conidia [asexual reproductive spores which function as organs of dissemination] are globose, brown - to black – colored, very rough, and with size of 4 – 5 μm in diameter.

Aspergillus terreus



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Aspergillus terreus* showing a compact, columnar and biserial conidial head.

Ecology

Aspergillus terreus is a cosmopolitan fungus which is primarily isolated from compost, plant material, and from soil. *Aspergillus terreus* is more common in tropical or sub – tropical areas.

Pathogenicity and Health Effects

Aspergillus terreus is an occasional causative agent of pulmonary aspergillosis [infection observed especially in people with a deficient immune system which includes invasive lung infection and disseminated disease, commonly with cough, chest pains, fever, and spitting up blood; it may also mimic asthma with

cough and noise on breathing in or sinusitis with fever, localized pain] among immunocompromised patients. A few cases of cerebral infection have been reported. *Aspergillus terreus* is isolated occasionally from outer ear canal colonizations.

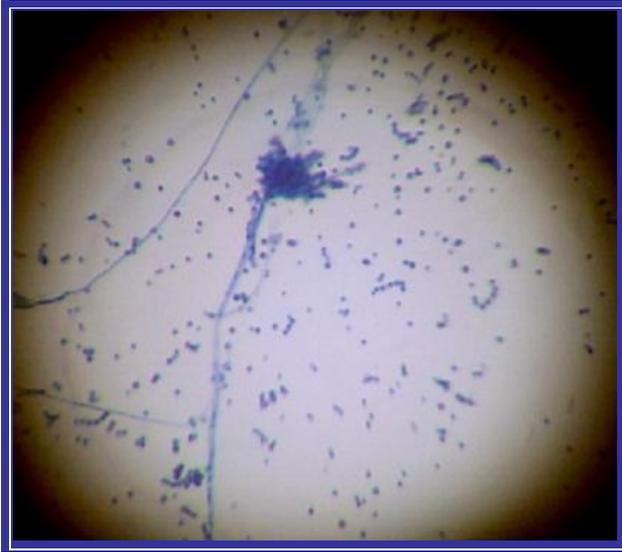
Macroscopic Appearance

- Growth rate is rapid and texture of colonies varies from downy to powdery; and
- Surface colony color is beige to buff to cinnamon while reverse is pale yellow to brown with yellow soluble pigments that are frequently present.

Microscopic Appearance

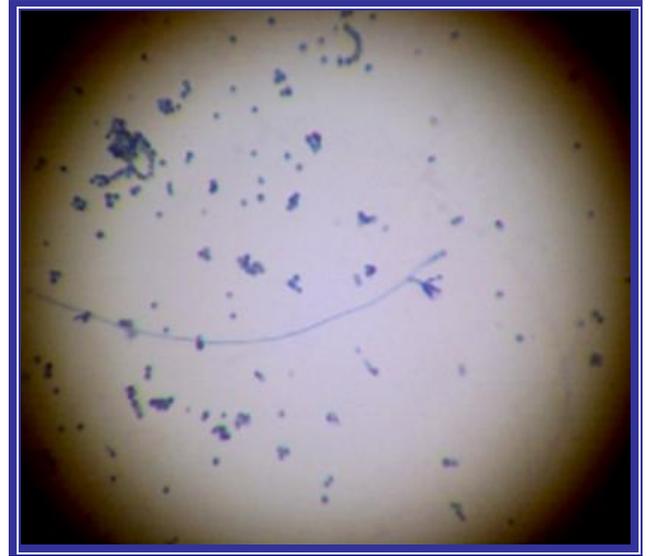
- Hyphae [single filament of a fungus] are septate and hyaline [colorless] and conidial heads [made up of a vesicle and chains of conidia as seen in *Aspergillus* species] are in the form of compact columnar and contains metulae which supports the phialides, also called as biseriate;
- Conidiophores [specialized hyphae upon which conidia develop] are smooth – walled, with length ranging from 70 - 300 µm long, and terminating in mostly globose vesicles;
- Conidia [asexual reproductive spores which function as organs of dissemination] are globose, smooth, and small with size of 2 – 2.5 µm in diameter; and
- Accessory conidia are hyaline, globose, sessile, with size of 2 – 6 µm, and are frequently produced on submerged hyphae.

Aspergillus versicolor



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Aspergillus versicolor* under 40X objective.



Asian Mold Inspector Laboratory Mold Species Documentation

Note the presence of a reduced *Penicillium* - like fruiting structure on the above picture, at the middle view.

Ecology

Aspergillus versicolor is a cosmopolitan fungus which is particularly common in temperate and colder areas. It is often found in buildings with problems on humidity and ventilation. *Aspergillus versicolor* is primarily isolated from plant materials and from soil.

Pathogenicity and Health Effects

Aspergillus versicolor rarely causes deep infections in humans. It is an occasional agent of onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus].

Macroscopic Appearance

- Growth rate is moderately rapid and texture of colonies is downy to powdery; and
- Surface colony color may range from white, yellow, beige, to yellow – green or emerald green, at times with a clear to wine – red exudate while the reverse is uncolored, yellowish to reddish.

Microscopic Appearance

- Hyphae are septate and hyaline and conidial heads are loosely radiate to columnar and biserial;
- Vesicles [a swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] are variably shaped, are small which measure 9 – 16 μm in diameter, and with metulae and phialides covering almost the entire vesicle;
- Conidiophores [specialized hyphae upon which conidia develop] are smooth – walled and brittle, hyaline to pale brown, and with length ranging from 120 – 700 μm long;
- Reduced conidial structures resembling those of *Penicillium* species are commonly observed;
- Conidia [asexual reproductive spores which function as organs of dissemination] are globose, appear in chains, more or less rough - walled, and with size of 2.5 – 3 μm in diameter; and
- Hülle cells [thick - walled cells developed by budding at the tips of specialized hyphae, with characteristic thin - walled pores, and may envelop the developing cleistothecium thus, may serve as nurse cells], when present, are globose.

Aspergillus ustus



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Aspergillus ustus*

Pathogenicity and Health Effects

Aspergillus ustus is a causative agent of fungal endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers] on a prosthetic valve, invasive disseminated disease, and of primary cutaneous disease in immunocompromised patients.

Macroscopic Appearance

- Growth rate is rapid and texture of colonies is wooly to cottony to somewhat granular; and
- Surface colony color is white to yellow to drab gray, which is the most common color, to brown, but never green while the reverse is yellow to brown with a yellow diffusing pigment.

Microscopic Appearance

- Hyphae are septate and hyaline and conidial heads are biserial and radiate to loosely columnar;
- Vesicles [swollen cells in which grow a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] are globose to sub – globose and measures 7 – 16 μm in diameter;
- Conidiophores [specialized hyphae upon which conidia develop] are smooth – walled, brown - colored, and with length ranging from 30 – 350 μm long;
- Metulae and phialides cover the upper portion of the vesicle;
- Conidia [asexual reproductive spores which function as organs of dissemination] are globose, very rough - walled, and with size of 3 – 4.5 μm in diameter; and
- Hülle cells [thick - walled cells developed by budding at the tips of specialized hyphae, with characteristic thin-walled pores, and may envelop the developing cleistothecium thus, may serve as nurse cells] are irregular to elongate in shape, however, must be searched for and may be light dependent.

Aureobasidium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euascomycetes
Order: Dothideales
Family: Dothioraceae
Genus: *Aureobasidium*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Aureobasidium pullulans* showing chains of 1 - to 2 - celled, darkly pigmented arthroconidia commonly called chlamydoconidia.

Ecology

Aureobasidium is a cosmopolitan, dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] fungus

which is frequently isolated from plant debris, soil, wood, textiles, and from indoor air environment.

Aureobasidium pullulans is commonly found on caulk or damp window frames in bathrooms and grows in cooler climates and found growing on siding together with *Cladosporium*.

Additionally, *Aureobasidium pullulans* commonly occurs indoors in areas of free water such as condensate pans. After a flood occurrence, this fungus is likely to act as primary colonizers and its spores only become airborne through mechanical disruption of contaminated materials or aspiration of contaminated water.

Species

There are fourteen species and one variety under the genus *Aureobasidium*. *Aureobasidium pullulans* is the most popular among these species.

Pathogenicity and Health Effects

Aureobasidium pullulans is one of the etiologic agents of phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. The fungus may also cause cutaneous mycoses, keratomycosis [a fungal infection of the cornea], pulmonary mycosis, and other opportunistic infections. *Aureobasidium pullulans* may also colonize hair, nails, and skin of humans. Additionally, it has also been isolated in patients suffering from peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen]. It must be noted, however, that *Aureobasidium* pathogenicity remains limited and rare. *Aureobasidium pullulans*, as a result, is commonly considered as a contaminant.

Aureobasidium pullulans is not considered as a primary human pathogen nor is it recognized as a producer of significant mycotoxins, however, high airborne levels of this fungus have been associated with allergic complaints probably due

to respiratory irritation induced by cell - wall components such as beta glucans, glycoproteins and it has also been known as an irritant.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Aureobasidium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colonies are flat, smooth, moist and yeast – like, shiny, mucoid to pasty, and leathery in texture;
- The colony diameter ranges from 1 to 3 cm following incubation for 7 days at 25°C grown on potato glucose agar; and
- Surface colony color is initially white, pale pink or yellow and it becomes brown to black with a grayish fringe at maturation while the reverse is uncolored or black.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate, hyaline initially and become dark brown by aging, width varies from 2 – 10 μm and thickness ranges between 15 – 20 μm ;
- No distinct conidiophores are observed and conidiogenous cells are either intercalary or located terminally in the hyphae;
- Conidia [asexual reproductive spores which function as organs of dissemination] are unicellular, hyaline, oval to cylindrical in shape, with size of 4 - 6 \times 2 - 3 μm , appear in clusters or may be located along the hyphae, and may form secondary blastoconidia through budding;
- Arthroconidia [thallic conidia released by either the splitting of a double septum or by the fragmentation or lysis of a disjunctive cell] are produced in old, mature colonies and are thick - and dark - walled, and are one – to two – celled; and
- Moist and yeast – like, unicellular budding yeast cells are the only ones present in young colonies; but as the colony matures, hyphae becomes visible and colony turns black and velvety.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

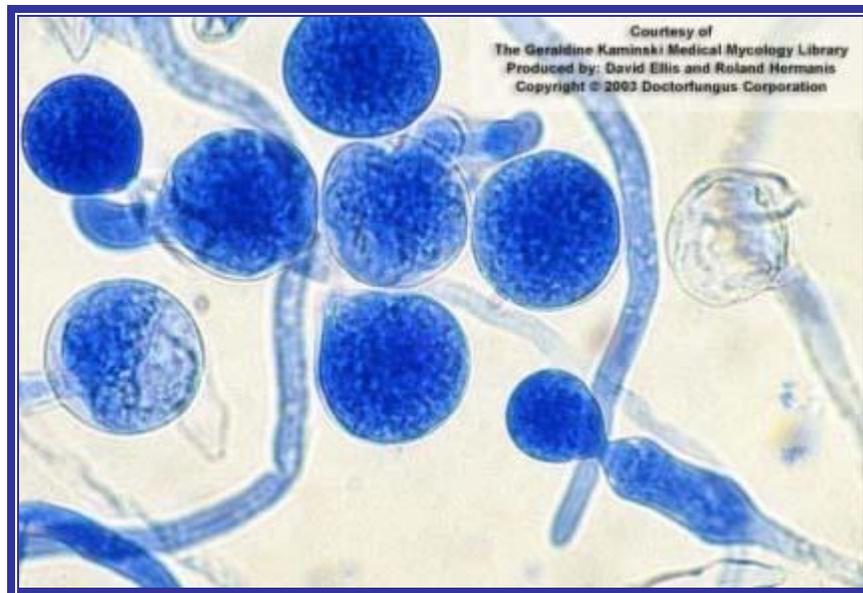
Susceptibility

No susceptibility data are available for *Aureobasidium* as *in vitro* susceptibility testing methods are not yet standardized for dematiaceous fungi.

Basidiobolus Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Sub - Phylum: Zygomycotina
Class: Zygomycetes
Order: Entomophthorales
Family: Basidiobolaceae
Genus: *Basidiobolus*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Basidiobolus* species showing globose, one - celled conidia that are forcibly discharged from a sporangiophore.

Ecology

Basidiobolus is a cosmopolitan fungus which is commonly isolated from the dung of amphibians and reptiles and as well as from plant debris or soil. Cases of

human infection are mostly from Africa, tropical Asia, and South America, despite its wide distribution.

Species

Formerly the pathogenic *Basidiobolus* isolates have once been identified as separate species namely, *Basidiobolus ranarum*, *Basidiobolus meristosporus*, and *Basidiobolus haptosporus*. However, due to recent antigen analysis result shows that all pathogenic *Basidiobolus* isolates only belong to one species, the *Basidiobolus ranarum*, based on the restriction analysis of their rDNA and isoenzyme banding.

Pathogenicity and Health Effects

Basidiobolus ranarum is the etiologic agent of a type of subcutaneous chronic zygomycosis which is characterized by its granulomatous nature and formation of hard, non – ulcerating subcutaneous masses at limbs, chest, back, and buttocks and by thickening of the adjacent muscles as well. This infection is termed as entomophthoromycosis basidiobolae. *Basidiobolus* is considered as a true pathogen due to its ability to cause infections in immunocompromised patients. However, *Basidiobolus* is emerging as an opportunistic pathogen [organism that attacks a compromised host] as well based on recent data on immunocompromised patients with angio - invasive infections caused by *Basidiobolus*. Other health effects in man due to *Basidiobolus* have also been reported such as gastrointestinal infections. Not only can *Basidiobolus* cause infections in man but in animals as well. Cases such as cutaneous lesions in amphibians, gastrointestinal lesions in dogs, and subcutaneous infection in horses have so far been reported.



(Image Courtesy of www.doctorfungus.org @ 2005)

Entomophthoromycosis caused by *Basidiobolus ranarum* showing ulcerated subcutaneous lesions on the abdomen of a young boy from Darwin.

Macroscopic Appearance

- Growth is moderately rapid with a colony diameter ranging from 1 to 3 centimeters;
- The colony is flat and thin, the texture is waxy, and the color is yellowish to grayish on the surface while pale or white on the reverse; and
- Satellite colonies are sometimes formed from the ejected germinated conidia.

Microscopic Appearance

- The hyphae are large ranging from 8 to 20 μm in diameter and more or less septated;
- Zygospores, the sexual spores, are thick-walled and smooth or have an undulating outer cell walls and with conjugation beaks which are the remnants of a copulatory tube;

- There are two types of *Basidiobolus* sporangiophores: One with inflated apices produces ejectible, unispored sporangioles which are also called ballistospores; the other one with adhesive apices produces passively liberated, unispored sporangioles; and
- The sporulation can be observed only in freshly isolated strains while it ceases as the colony gets older or is sub – cultured; Sporulation may be stimulated by using a special medium which contains glucosamine hydrochloride and casein hydrolysate.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

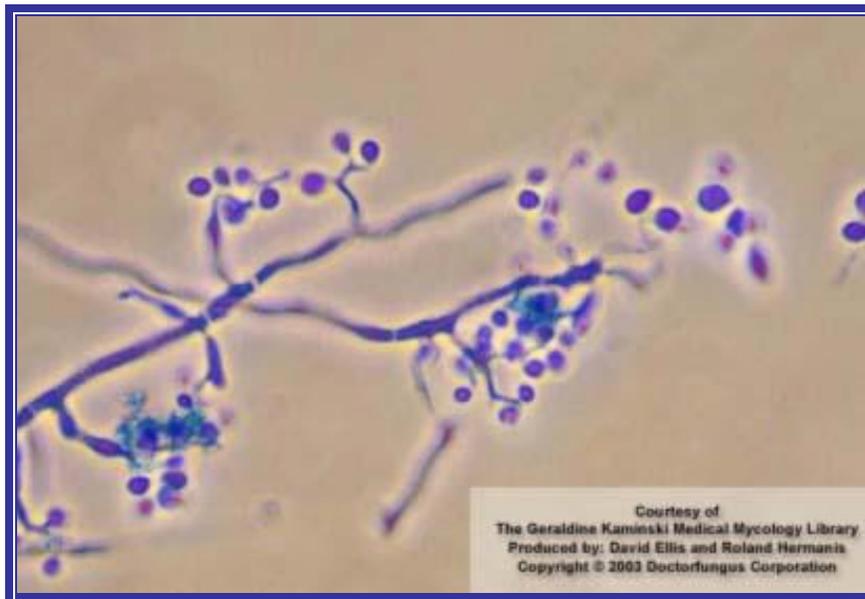
Based on the limited data obtained, flucytosine MICs are very high, while those of fluconazole, itraconazole, ketoconazole and miconazole are considerably low for *Basidiobolus* strains.

Basidiobolus – caused infections are difficult to treat. As a treatment, systemic potassium iodide solution and trimethoprim – sulfamethoxazole are usually referred. In some cases, oral ketoconazole and fluconazole may be of help. On the other hand, amphotericin B has almost no significant efficacy and surgery is not curative.

Beauveria Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euscomycetes
Order: Clavicipitales
Genus: *Beauveria*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Beauveria* species

Ecology

Beauveria species are cosmopolitan and are isolated from plant debris, from soil and from parasitized insects. *Beauveria* species are also isolated from foodstuff, and indoor air environment. *Beauveria bassiana* is a well known etiologic agent of the devastating muscardine disease of the silkworm.

Species

The genus *Beauveria* contains several species; however, the most common ones are *Beauveria bassiana* and *Beauveria alba*.

Pathogenicity and Health Effects

Beauveria is rarely responsible for infection in humans or animals. It may be associated with keratitis [wide variety of corneal infections, irritations and inflammations]. Aside from the mentioned infection, a case of pneumonia [an inflammation of one or both lungs with symptoms of chest pain, chills, cough with sputum production, fever, and shortness of breath] in an immunocompromised patient due to *Beauveria* has also been reported. Certain *Beauveria* species are important pathogens of insects.

Macroscopic Appearance

- Growth rate is moderately rapid with a colony diameter ranging from 1 to 3 centimeters and the colony texture is cottony to powdery to mealy; and
- Color is white becoming yellowish white or pale pinkish while pale on the reverse.

Microscopic Appearance

- The hyphae [single filament of a fungus] are hyaline, narrow and septate;
- Conidiogenous cells on the hyphae are inflated at the base and are typically flask – shaped and terminates in a thin zigzagging filament;
- Conidia [asexual reproductive spores which function as organs of dissemination] are hyaline, one – celled, globose - to ovoid - shaped, diameter ranges from 2 to 4 μm , and are produced from each bending point of the filament, this type of conidium production is called sympodial geniculate growth;

- The conidiogenous cells tend to form dense clusters which appear as small powdery balls in the aerial hyphae when viewed under a dissecting microscope; and
- Examination of young cultures is optimal for detailed microscopic view since the cluster formation makes it difficult to visualize the arrangement and structure of conidia.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

No available data.

Bipolaris Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eufungi
Order: Pleosporales
Family: Pleosporaceae
Genus: *Bipolaris*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic photograph of a *Bipolaris* species with conidia developing from a sympodial developing conidiophore.

Ecology

Bipolaris species are cosmopolitan, dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color], and

filamentous fungi isolated from grasses, plant debris, decaying food, and soil. It is commonly found on celery and rooted vegetables. Some *Bipolaris* species are mainly found in tropical or sub – tropical areas while other species exist as saprobes or pathogens of numerous plant species, particularly *Graminae*.

Species

There are several species belonging to the genus *Bipolaris*. Three well – known pathogenic species among these are *Bipolaris australiensis*, *Bipolaris hawaiiensis*, and *Bipolaris spicifera*.

Pathogenicity and Health Effects

Bipolaris is one of the occasional causative agents of diverse types of phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial], including allergic and chronic invasive sinusitis, endarteritis, endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], keratitis [wide variety of corneal infections, irritations and inflammations], meningoencephalitis, peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood], otitis media [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo] among agricultural field workers, and fungemia [the presence of fungi in the blood] as well as cutaneous and pulmonary infections and allergic bronchopulmonary disease. These infections have been observed in the immunocompromised patient as well as in the normal host.

Additionally, various species of *Bipolaris* can produce mycotoxin, called sterigmatocystin, which has been shown to cause damage on liver and kidney when ingested by laboratory animals and this can also alter human DNA.

Bipolaris species may be pathogenic to certain plant species, mainly to *Graminae* as well as to animals, such as the dog. Furthermore, it may also cause nasal mycotic granuloma in the cattle. *Bipolaris* may also be encountered as a laboratory contaminant.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Bipolaris mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Mold Tip

Bipolaris species are frequently found on celery and rooted vegetable thus, it would be wise to wash the fresh celery prior to consumption with "Grapefruit Seed Extract" (GSP) to kill the fungi, especially for people who have already been exposed to toxigenic molds. *Bipolaris* fungus is known to produce large – sized spores which would likely be deposited in the upper respiratory tract thus, hazardous to human health.

Macroscopic Appearance

- Growth rate is rapid with a colony diameter reaching 1 to 3 cm after seven days of incubation at 25°C and the texture is velvety to wooly; and
- The surface colony color is initially whitish becoming dark olive to black with a raised grayish periphery at maturity while the reverse is also darkly pigmented and olive - to black – colored.

Microscopic Appearance

- The hyphae are septate and brown – colored while the conidiophores are brown, 4.5 to 6 µm wide, may either be simple or branched, geniculate [bent like a knee] and sympodial, bending at the points where each conidium forms from, this, in turn, gives its zigzag appearance;
- Poroconidia are fusoid to cylindrical in shape, light to dark brown, three – to six – celled and have a sympodial geniculate pattern of growth, with size of 30 to 35 µm x 11 to 13.5 µm, distoseptate and with a scarcely

- protuberant, darkly pigment hilum which indicates the point of attachment to the conidiophore; and
- In the heterothallic - teleomorph production of *Bipolaris*, the perithecium [an enclosed ascocarp characterized by an apical ostiole and by asci arranged in a basal tuft or hymenium layer] present is round to ellipsoidal in shape and black in color; while the ascospores are filiform or flagelliform, hyaline and are found in clavate – shaped or cylindrical asci; and lastly, there are eight ascospores in each ascus [sac - like cell containing ascospores].

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

In vitro susceptibility testing methods for dematiaceous fungi have not yet been standardized. Very limited data are available regarding the susceptibility of *Bipolaris* and these data show that MICs of itraconazole and voriconazole are acceptably low.

For the treatment of *Bipolaris* infections, amphotericin B and ketoconazole are used. In some cases such as sinusitis, surgical debridement may be essential.

Blastomyces Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euscomycetes
Order: Onygenales
Family: Onygenaceae
Genus: *Blastomyces*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Blastomyces dermatitidis* showing a partial conversion of the filamentous phase to the yeast phase as demonstrated by the formation of broad-based budding yeasts.

Ecology

Blastomyces dermatitidis is a thermally dimorphic fungus [may exist as a yeast form or a mold form, depending on the temperature at which they are growing] which is rarely isolated from the environment, most likely a soil saprobe.

Endemic zones are chiefly found in North America and expand from East Central Canada to Central America. The greatest number of reported cases in the United States is from the Ohio, Mississippi, and Missouri valleys. A number of cases are also reported from Africa and the Middle East. It was shown, however, that the African *Blastomyces* strains are not identical with the North American strains thus; these two groups most probably comprise two distinct serotypes presenting geographic diversity.

Isolation from the environment is most likely when the sample contains a moist soil substrate, lacks exposure to sunlight, has a pH of less than 6.0 and is abundant in organic material such as animal feces, dust, insect remains, and plant debris.

The teleomorphic state (sexual) of *Blastomyces dermatitidis* belongs to the family Onygenaceae and is referred to as *Ajellomyces dermatitidis*. Ascospores are produced by this genus as its sexual spores.

Species

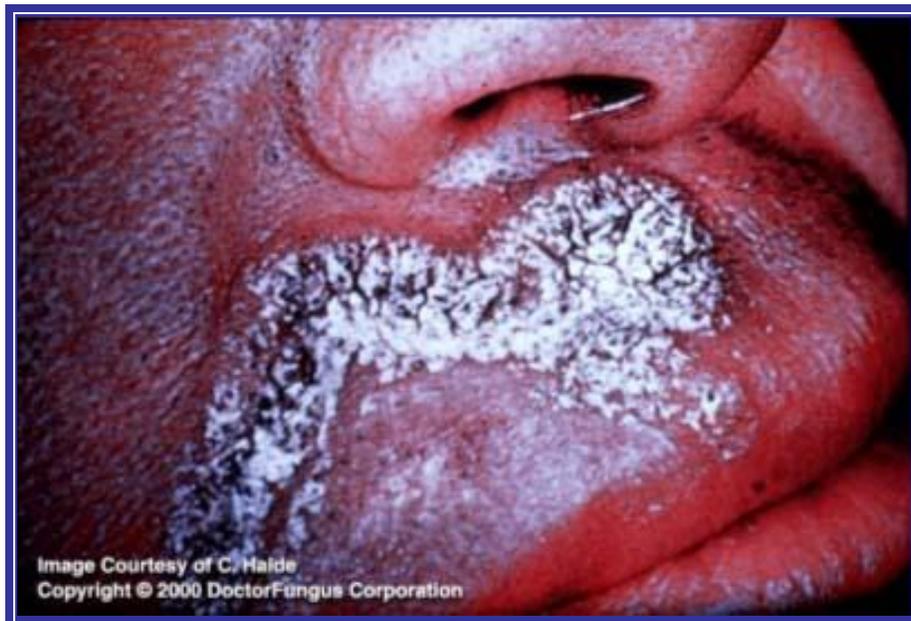
The genus *Blastomyces* only contains *Blastomyces dermatitidis* as its sole species.

Pathogenicity and Health Effects

Blastomyces dermatitidis is the etiologic agent of **blastomycosis**, primarily a pulmonary infection which may disseminate to other areas of the body, especially the skin and the bones. The two clinical forms of this disease are cutaneous and systemic (disseminated) blastomycosis. Generally, **blastomycosis** is acquired via inhalation. Direct inoculation of the fungus into the skin may also lead to primary cutaneous infection. Hematogenous spread of the fungus results in infection of bones, kidneys, skin, and male urogenital system. Cases of blastomycosis of the adrenal glands, central nervous system, eyes, gastrointestinal tract, kidneys, larynx, liver, paranasal sinuses, ovaries, uterus, and spleen have also been reported. Otitis media [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo], resulting in cranial osteomyelitis may also develop.

Blastomycosis occurs primarily among immunocompetent hosts and it may also affect immunocompromised patients as *Blastomyces dermatitidis* has now emerged as an opportunistic pathogen [organism that attacks a compromised host].

Dogs can also be infected by *Blastomyces dermatitidis*; the disease is called canine blastomycosis. Dogs can acquire the infectious particles through inhalation and dogs serve as good indicators of the presence of *Blastomyces dermatitidis* in the nearby environment. There is no evidence of animal – to – human transmission of the disease, however.



(Image Courtesy of www.doctorfungus.org @ 2005)

A blastomycosis infection characterized by cutaneous lesion which developed following dissemination of the fungus from the lungs.

Macroscopic Appearance

Blastomyces dermatitidis behaves diversely at different temperatures due to being a thermally dimorphic fungus. The fungal morphology at 25°C is mold – like while yeast – like at 37°C. Conversion from the mold form to yeast form is possible for few pathogenic isolates only. Methods of verification of the identification are through exo - antigen test, direct fluorescent antibody and nucleic acid probes.

At 25°C:

- Growth rate is slow to moderately rapid and the colony diameter reaches from 0.5 to 3 cm after a 7 – day incubation and texture is membranous and downy to wooly; and
- Surface colony color is white to beige while the reverse is pale to brownish.

At 37°C, on rich medium:

- Growth rate is slow to moderately rapid and the colony diameter reaches 0.5 to 3 cm after a 7 – day incubation and texture is creamy and yeast – like and appears granular to verrucose on the surface; and
- Surface colony color is white to beige.

Microscopic Appearance

At 25°C:

- Hyphae are hyaline [colorless] and septate;
- Conidiophores [specialized hyphae upon which conidia develop] are short and unbranched, and arise at right angles to the vegetative hyphae; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are hyaline, solitary, unicellular, pyriform – to globose – shaped.

At 37°C, on rich medium or in infected tissues:

- Appear as budding yeast cells with 8 to 12 µm diameter size, globose – shaped, typically have double – contoured refractile walls and a broad base attaching the bud to the parent cell.

Mold Analysis

Animal inoculation techniques are classical methods of isolating *Blastomyces dermatitidis* from environmental sources or soil wherein the material to be tested is place in a neutral aqueous solution containing allantoin, Tween 80, potassium

phosphate, magnesium sulphate, penicillin, and streptomycin and is incubated at 37°C for 22 days. After which, an amount of 100 µl of the solution is plated onto yeast – extract phosphate agar and incubated at 20°C. Colony growths of *Blastomyces dermatitidis* on yeast – extract phosphate agar are then inoculated onto the brain – heart infusion agar. In this manner, the conversion to yeast phase is demonstrated.

Laboratory Precautions

Blastomyces dermatitidis is potentially hazardous and entails biological safety cabinet for all laboratory analysis.

Susceptibility

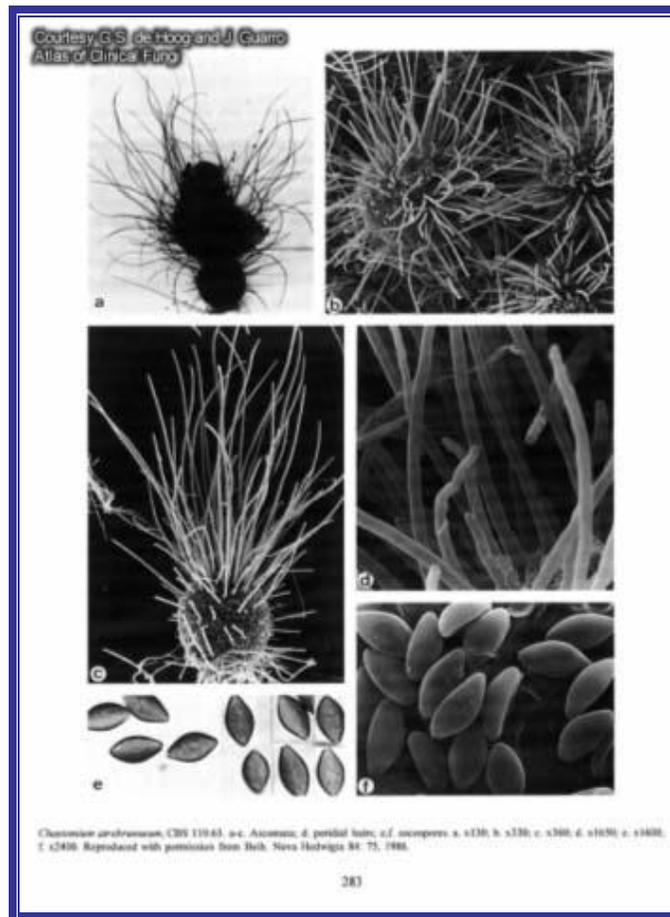
Testing procedures on *in vitro* susceptibility for *Blastomyces dermatitidis* have not yet been standardized as well as for the other thermally dimorphic fungi, except for the mycelial phase of *Sporothrix schenckii*. Generally, amphotericin B, ketoconazole and itraconazole are highly active on *in vitro* activity against *Blastomyces dermatitidis*. The novel agents such as caspofungin, posaconazole, VER – 002, and voriconazole appear active against *Blastomyces*.

Amphotericin B, ketoconazole and itraconazole are effective in treatment of blastomycosis. For the immunocompromised patients, amphotericin B should be preferred. Mild pulmonary blastomycosis, on the other hand, may clear spontaneously and no longer need antifungal therapy. Surgical excision of pulmonary lesions may be essential in some cases besides antifungal therapy.

Chaetomium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euscomycetes
Order: Sordariales
Family: Chaetomiaceae
Genus: *Chaetomium*



(Image Courtesy of www.doctorfungus.org @ 2005)

An Atlas Scan Images of a *Chaetomium* species.

Ecology

Chaetomium is a dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] filamentous fungus isolated from soil, air, and from decomposing plant debris, especially woody or straw – like materials and from herbivore dung. Aside from being a contaminant, *Chaetomium* species are also encountered as causative agents of infections in humans. Additionally, some species are thermophilic and neurotropic in nature.

Species

The genus *Chaetomium* contains a number of species. The most widespread ones are *Chaetomium atrobrunneum*, *Chaetomium funicola*, *Chaetomium globosum*, and *Chaetomium strumarium*.

Pathogenicity and Health Effects

Chaetomium species are among the fungi causing infections referred to as phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. Cases of fatal deep mycoses in an immunocompromised patient due to *Chaetomium atrobrunneum* have been reported. Brain abscess, peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], cutaneous lesions, and onychomycosis [is the term used both to refer to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus] may also develop due to *Chaetomium* species.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Chaetomium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colony texture is cottony; and
- Surface colony color is white initially but as colonies mature, color become gray to olive while tan to red or brown to black on the reverse.

Microscopic Appearance

- The hyphae are septate, hyaline to pale brown;
- Perithecia, asci and ascospores are present;
- Perithecia [enclosed ascocarps characterized by an apical ostiole and by asci arranged in a basal tuft or hymenium layer] are brown to black in color, large, fragile, globose to flask – shaped and surrounded by long, undulant, helical or erect, spine – like filamentous setae (hair – like appendages);
- Perithecia have small rounded openings called ostioles which contain asci and ascospores inside;
- Asci [sac - like cells containing ascospores] are clavate to cylindrical in shape and remain intact only for a short period of time after their formation (evanescent) and dissolve rapidly to release their ascospores which are usually four to eight in number;
- Ascospores [haploid spores produced within an ascus] are unicellular, brown in color, and usually lemon – shaped.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

There is no standard method for *in vitro* susceptibility testing of *Chaetomium* species as yet and very few data are available. When a small number of *Chaetomium atrobrunneum*, *Chaetomium funicola*, and *Chaetomium globosum* isolates were tested, it appears that MICs of amphotericin B, ketoconazole, itraconazole, and miconazole were acceptably low while those of fluconazole and flucytosine appeared very high.

Cladosporium Species

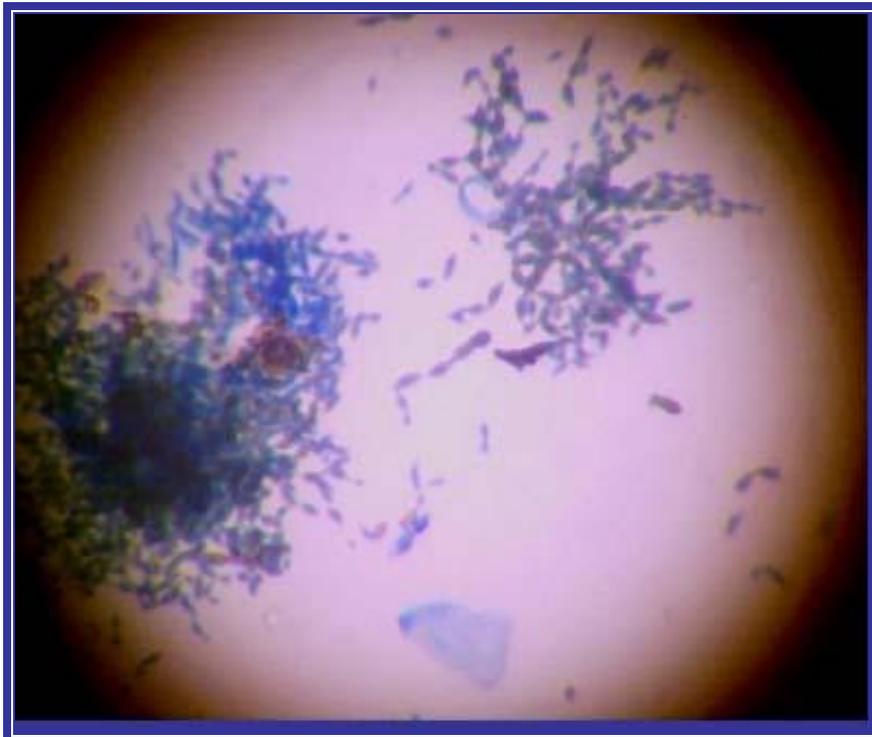
Taxonomic Classifications

Kingdom: Fungi

Phylum: Ascomycota

Sub – Phylum: Ascomycotina

Genus: *Cladosporium*



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Cladosporium* species

Ecology

Cladosporium is a cosmopolitan and dematiaceous fungus [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] which is widespread in nature. It is commonly isolated in soil, leaf surfaces, and in rotting organic material, and is frequently encountered as a contaminant on

foods. *Cladosporium* species is very frequently isolated from air, especially during seasons with high humidity level. Some species are chiefly found in tropical and sub – tropical regions.

Species

There are over thirty species belonging to the genus *Cladosporium*. The most commonly encountered are *Cladosporium elatum*, *Cladosporium herbarum*, *Cladosporium sphaerospermum*, and *Cladosporium cladosporioides*.

Pathogenicity and Health Effects

Cladosporium species are causative agents of skin lesions, keratitis [wide variety of corneal infections, irritations and inflammations], onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever] and pulmonary infections while *Cladosporium carrionii* is considered as an agent of chromoblastomycosis which is a subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells, which look like copper pennies, in tissues.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Cladosporium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is slow to rapid and colonies are velvety to powdery in texture;
- Surface colony color is olivaceous green to brownish - black while the reverse is black; and
- Most of the *Cladosporium* species do not grow at temperature above 35°C.

Microscopic Appearance

- Hyphae are septate and brown in color;
- Conidiophores [specialized hyphae upon which conidia develop] are generally brown in color and often septate; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are pale to dark brown in color, smooth – walled or occasionally echinulate, elliptical to cylindrical in shape, with dark hila, appear in very delicate branching chains that readily disarticulate.

Table 1. Differences in the microscopic characteristics of *Cladosporium* species.

<i>Cladosporium</i> species	Morphological Differences
<i>Cladosporium cladosporioides</i>	Conidiophores are not geniculate; produces unicellular conidia.
<i>Cladosporium sphaerospermum</i>	Conidiophores are not geniculate; produces elongate and septate shield cells known as ramoconidia.
<i>Cladosporium herbarum</i>	Conidiophores are geniculate and bear terminal and intercalary swellings; produces two – to four – celled conidia.

Laboratory Precautions

Cladosporium species must be analyzed and handled with caution in a biological safety cabinet.

Susceptibility

Very limited data are available on susceptibility profiles of *Cladosporium* species.

Cladophialophora Species

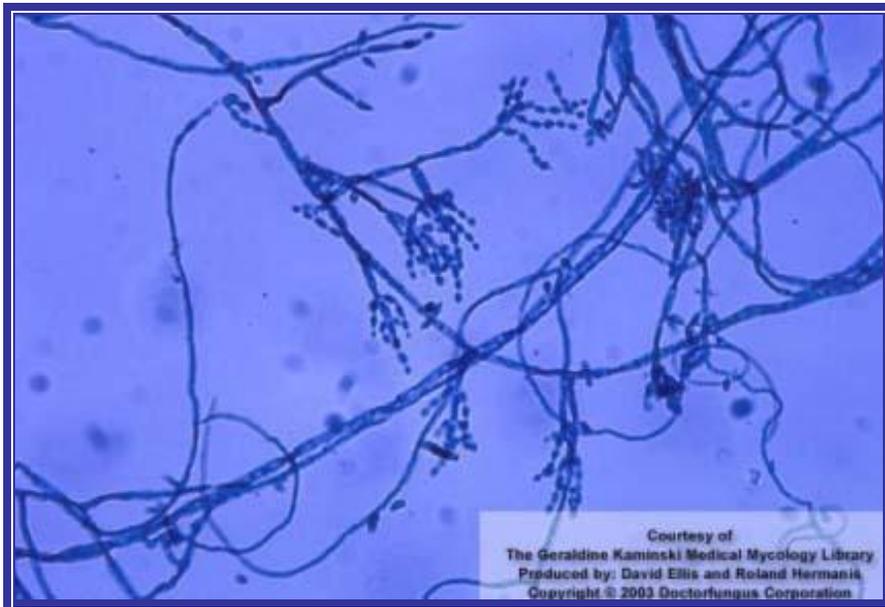
Taxonomic Classifications

Kingdom: Fungi

Phylum: Ascomycota

Sub – Phylum: Ascomycotina

Genus: *Cladophialophora*



(Image Courtesy of www.doctorfungus.org @ 2005)

A microscopic morphology of a *Cladophialophora* species

Ecology

Cladophialophora is a dematiaceous fungus [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] primarily isolated from soil and decomposing plant materials. Some species are prevalent in tropical and sub – tropical regions.

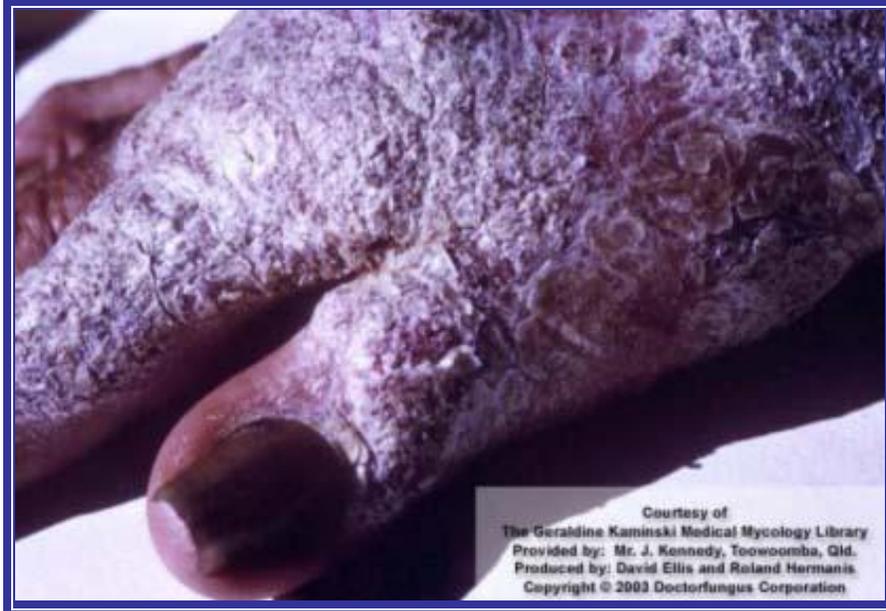
Species

There are six species classified under the genus *Cladophialophora* namely, *Cladophialophora carrionii*, *Cladophialophora bantiana*, *Cladophialophora boppii*, *Cladophialophora arxii*, and *Cladophialophora devriesii*.

Pathogenicity and Health Effects

Cladophialophora species is a causative agent of phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial], chromoblastomycosis [a chronic subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells in tissue which appear as similar to copper pennies], and mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and sclerotia]. *Cladophialophora bantiana* causes cerebral phaeohyphomycosis in the form of fatal brain abscess. *Cladophialophora bantiana* may also cause skin lesions. On the other hand, *Cladophialophora boppii* and *Cladophialophora carrionii* are both isolated from chromoblastomycosis – infected patients. *Cladophialophora devriesii* has been reported to cause disseminated phaeohyphomycosis.

Trauma and exposure to soil are considered as the main predisposing factors for acquiring *Cladophialophora carrionii* - caused infections while *Cladophialophora bantiana* is most likely acquired via inhalation.



(Image Courtesy of www.doctorfungus.org @ 2005)

**Chronic verrucous chromoblastomycosis of the hand due to
Cladophialophora carrionii.**

Macroscopic Appearance

- Growth rate of colony varies from one species to another;
- Colony texture is powdery to wooly and spreading; and
- Surface colony color is olivaceous green to black and reverse is black in color.

Note: *Cladophialophora bantiana* has a special feature of possessing urease activity.

Table 1. Growth Rate Differences of *Cladophialophora* species.

<i>Cladophialophora</i> species	Growth Rate
<i>Cladophialophora boppi</i>	Grows moderately rapidly on potato dextrose agar at 25°C.
<i>Cladophialophora bantiana</i>	Grows moderately rapidly on potato dextrose agar at 25°C; Has the ability to grow at temperatures as high as 42 -43°C.
<i>Cladophialophora carrionii</i>	Grows slowly on potato dextrose agar at 25°C and does not grow at temperatures beyond 35 - 36°C.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate, brown in color while conidiophores are frequently not differentiated from the vegetative hyphae;
- Conidia [asexual reproductive spores which function as organs of dissemination] are unicellular, pale to dark brown, and often form chains from which the conidia readily disarticulate wherein the youngest conidium is located at the tip of the chain, and no attachment scars are observed; and
- *Cladophialophora bantiana* and *Cladophialophora boppi* may also produce chlamydoconidia.

Table 2. Microscopic Differences of Conidia produced by *Cladophialophora* species.

<i>Cladophialophora</i> species	Characteristics of Produced Conidia
<i>Cladophialophora boppi</i>	Smooth – walled conidia in long chains, unbranched, 2 – 3 x 3 - 4 µm in size, unicellular, directly arise from the conidiophores, and no observed shield cells.
<i>Cladophialophora bantiana</i>	Conidia are unicellular, smooth and lemon – shaped in long chains, 6 – 11 x 2.5 - 5 µm in size, and no shield cells on conidiophores supporting conidia formation.
<i>Cladophialophora carrionii</i>	Lemon – shaped, unicellular conidia in long and abundantly branching chains, 4.5 – 6 x 2 - 3 µm in size, and may be smooth or occasionally echinulate.

Laboratory Precautions

Cladophialophora bantiana is an extremely hazardous fungus that should be analyzed only in a biological safety cabinet. *Cladophialophora carrionii* should also be handled in a biological safety cabinet carefully.

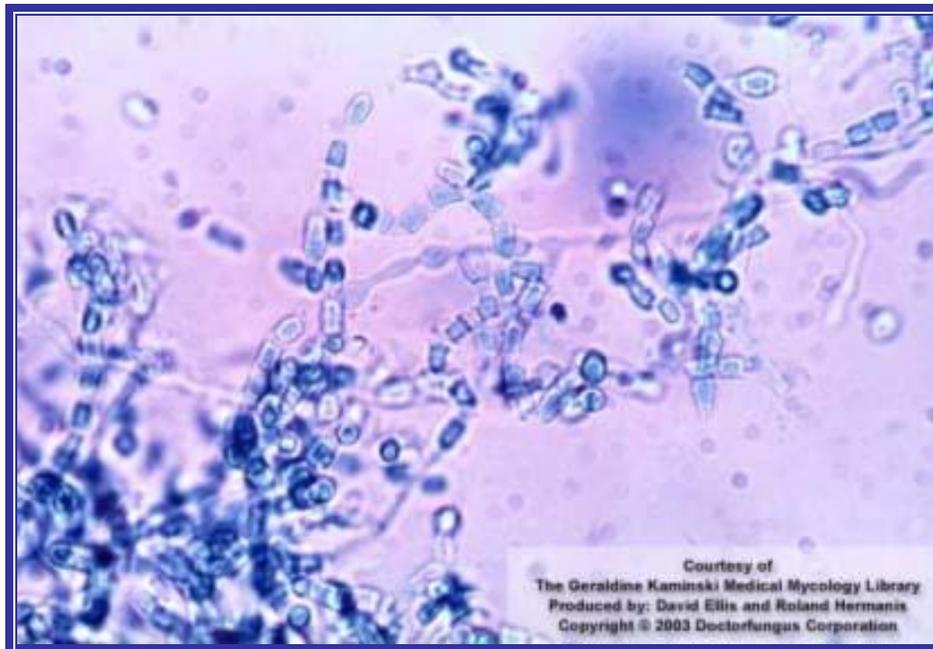
Susceptibility

In vitro susceptibility testing methods for testing *Cladophialophora* species are not yet standardized and available data are very limited. For *Cladophialophora bantiana*, MICs and MLCs of posaconazole are low while MICs and MLCs of caspofungin and anidulafungin are high. Itraconazole and voriconazole show fungicidal effect on *Cladophialophora bantiana* strains. MICs of itraconazole is generally low for both *Cladophialophora bantiana* and *Cladophialophora carrionii* while MICs of amphotericin B for *Cladophialophora carrionii* isolates appear somewhat higher compared to those of *Cladophialophora bantiana*.

Coccidioides immitis

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Onygenales
Family: Onygenaceae
Genus: *Coccidioides*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Coccidioides immitis* showing typical single - celled, hyaline, rectangular to barrel - shaped, alternate arthroconidia, separated from each other by a disjunction cell.

Ecology

Coccidioides immitis is a thermally dimorphic [may exist as a yeast form or a mold form, depending on the temperature at which they are growing] soil

saprobe particularly isolated from the depauperate soils of hot, semi – arid, dry regions having low rainfall, high summer temperatures, and low altitude where its growth is favored by the low degree of competition from other soil microorganisms.

Coccidioides immitis specifically is an alkaline – loving soil fungus. It is isolated in rodent burrows at desert – like areas of southwestern United States. It is widespread at Southwestern United States, Northern Mexico, and certain parts in Central and South America. Imported cases may be observed following travel to endemic areas.

Species

Coccidioides immitis and *Coccidioides posadasii* are the only species included in the genus *Coccidioides*.

The description of *Coccidioides immitis* and *Coccidioides posadasii* as separate species did not occur until 2002, although, it was recognized for some years that *Coccidioides immitis* contained two generic subgroups. The two groups were simply known initially as the California and non – California variants of *Coccidioides immitis*. Basically, therefore, all prior literature treats them as a single species. The two species can only be distinguished by genetic analysis and different rates of growth in the presence of high salt concentrations.

Pathogenicity and Health Effects

Coccidioides is the etiologic agent of **coccidioidomycosis**, an often benign and transient respiratory system infection which assumes, in some cases, an acute form and may spread to infect the bones, skin, joints, and urogenital and central nervous systems due to the inhalation of the dry arthroconidia of *Coccidioides*, which are carried by dust storms. Coccidioidomycosis is considered as one of the true systemic mycoses. Development of airway coccidioidomycosis involving the endotracheal and endobronchial tissues may also occur.

The infection remains as an acute and self – limited respiratory infection, however, it progresses to a chronic and, at times, a fatal disease in others.

Dissemination is likely to occur particularly during the pregnancy period and carries a high risk of mortality.

Coccidioidomycosis infection not only affects healthy immunocompetent hosts but may also develop among immunocompromised patients such as those with AIDS and those who have undergone organ transplant operation. It is without doubt the most virulent of the pathogenic fungi. Furthermore, activities and jobs related to tillage of the soil, such as agricultural work, archeology, telephone post – digging, or merely playing with soil appear to be linked with the occurrence of coccidioidomycosis infection.

Coccidioidomycosis infection has also been observed in warm – blooded animals such as bottlenose dolphins and horses.



Image Courtesy of www.doctorfungus.org @ 2005)

Extension of pulmonary coccidioidomycosis showing a large superficial, ulcerated plaque.

Macroscopic Appearance

- Growth rate is moderately rapid to rapid and colonies are initially moist, membranous, glabrous, and grayish while white and cottony aerial mycelium comes into view at maturation; and

- Surface colony color is white, to beige, cinnamon, pink, brown or yellow while the reverse is pale, sometimes orange or dark brown.

Microscopic Appearance

It must be noted that the microscopic appearance of *Coccidioides* depends on the temperature of isolation.

At 25°C:

- Septate and hyaline hyphae are produced, racquet hyphae may at times be observed on slides that are prepared from young cultures; and
- Arthroconidia [thallic conidia released by either the splitting of a double septum or by the fragmentation or lysis of a disjunct cell] are barrel-shaped, thick-walled, with size of 2 - 4 × 3 - 6 μm, appear alternately with empty disjunction cells, and with presence of annular frills as remnants of the disjunction cells upon the release of the arthroconidia.

At 37°C:

- Spherules are round, large, thick-walled, filled with endospores, and with diameter size of 10 - 80 μm; Production of spherules *in vitro* requires inoculation into a special synthetic medium such as converse liquid medium, an incubation temperature range of 37 - 40°C, and presence of CO₂ at a concentration as high as 20%; and
- Endospores measure 2 - 5 μm in diameter.

Laboratory Precautions

All analysis and handling activities of *Coccidioides* species should be done with caution in a biological safety cabinet as its arthroconidia are very infectious.

Susceptibility

Amphotericin B, itraconazole, and voriconazole appear active *in vitro* against *Coccidioides* species. Amphotericin B, however, is less active against some of the *Coccidioides* isolates. Conversely, itraconazole and voriconazole are not effective against *Coccidioides immitis* / *posadasii*.

Antifungal therapy is not usually required by patients with self – limited disease or relatively localized acute pulmonary infections; however, it must be given to patients with disseminated disease or are at risk of complications due to their immunosuppression and other factors. For treatment of coccidioidomycosis, amphotericin B, fluconazole, itraconazole, and ketoconazole are used. Fluconazole is chosen as treatment for cases with meningitis.

Conidiobolus Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Sub - Phylum: Zygomycotina
Order: Entomophthorales
Family: Anylistaceae
Genus: *Conidiobolus*



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the microscopic morphology of *Conidiobolus coronatus* showing several mature, spherical sporangiola (conidia) with hair - like appendages, called villae.

Ecology

Conidiobolus is a cosmopolitan fungus commonly found in humid soils and decaying plant material. It is also isolated from parasitized insects and

amphibians. The majority of human infection cases come from tropical and sub-tropical regions and particularly at Central America, equatorial Africa, and India.

Species

The genus *Conidiobolus* contains a number of species. The most widespread ones are *Conidiobolus coronatus*, *Conidiobolus incongruus* and *Conidiobolus lamprauges*.

Pathogenicity and Health Effects

Conidiobolus species is a causative agent of subcutaneous infection in humans which involves the nasal mucosa and maxillofacial tissues. This chronic inflammatory granulomatous infection is also referred to as entomophthoromycosis conidiobolae. It involves facial subcutaneous tissues and paranasal sinuses and is characterized by the formation of firm, subcutaneous nodules or polyps. The infection may be acquired through breathing in of airborne mold spores or through a minor trauma such as an insect bite. The infected host is commonly a healthy individual working outdoors in tropical areas. However, the infection may also develop in patients with underlying pathologies such as neutropenia or Burkitt's lymphoma. Thus, the species is considered as an opportunistic pathogen as well. Fatal, deeply invasive infections are encountered very seldom. Health cases involving pulmonary and pericardial have also been reported.

Conidiobolus species are the causative agents of infections in humans, sheep, dogs, deer, and horses.



(Image Courtesy of www.doctorfungus.org @ 2005)

Entomophthoromycosis caused by *Conidiobolus coronatus*.

Macroscopic Appearance

- Colonies grow very rapid and are initially glabrous and waxy in texture and become powdery after aerial hyphae development;
- Surface colony color is white becoming beige to brown by aging and while pale on the reverse; and
- Satellite colonies are formed due to discharged sporangioles by the sporangiophores.

Microscopic Appearance

- More or less septated hyphae, unbranched sporangiophores, conidia spores with diameter ranging from 10 - 30 μm , zygosporangia, and chlamydoconidia are present;
- The sporangiophores with size ranging from 18 to 22 x 60 – 90 μm are scarcely differentiated from vegetative hyphae and are slightly tapered towards the tip which carry unicellular round primary spores that are forcibly discharged at maturity;

- One – spored sporangioles called ballistospores are ejectible, round to pyriform in shape but with a prominent papilla which is the site of former attachment to the sporangiophore;
- Villose sporangioles are formed in old cultures and have smooth surface and covered with hair-like appendages;
- The primary sporangioles may germinate and produce spore – bearing sporangiophores and some primary sporangioles themselves may also produce numerous secondary sporangioles which, in turn, form a “corona” around the primary sporangioles; and
- Zygosporangia are commonly thick – walled, globose to elongate in shape, and without beaks.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

Data on *in vitro* activity of anti – fungal agents isolated of *Conidiobolus* are very limited. Generated considerably high MICs for limited colonies of *Conidiobolus coronatus* and *Conidiobolus lamprauges* isolates tested are amphotericin B, flucytosine, fluconazole, itraconazole, ketoconazole, and miconazole.

Potassium iodide, trimethoprim-sulfamethoxazole, and azole derivatives have been used as treatment; however, there is yet no standard regimen for treatment of *Conidiobolus* infections.

Cunninghamella Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Order: Mucorales
Family: Cunninghamellaceae
Genus: *Cunninghamella*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Cunninghamella bertholletiae* showing simple sporangiophores forming a swollen, terminal vesicle around which single-celled, globose to ovoid, sporangia develop on swollen denticles.

Ecology

Cunninghamella is a filamentous fungus which is isolated from plant material and in soil. It is mainly found in the Mediterranean and sub – tropical regions. *Cunninghamella* species has also been recovered from animal material, Brazil nuts, and cheese. Aside from being a contaminant, it is also considered as an

opportunistic fungus that may cause infections among immunocompromised patients.

Species

There are seven species belonging to the genus *Cunninghamella*. The most common species encountered are *Cunninghamella bertholletiae*, *Cunninghamella elegans*, and *Cunninghamella echinulata* while *Cunninghamella bertholletiae* is considered as the only known animal and human pathogen.

Pathogenicity and Health Effects

Cunninghamella species are occasional causative agents of pulmonary or disseminated zygomycosis [refers to the angiotropic, a blood vessel – invading, infection produced by the various Zygomycetes fungi; this disease is also sometimes referred to as mucormycosis, but the term zygomycosis is preferred] in the severely debilitated patient. Diabetes mellitus, desferoxamine therapy, trauma, immunosuppression due to various reasons, such as AIDS, hematological malignancies, and organ transplant operations, are the major influential factors for the occurrence of zygomycosis. A number of cases receiving antifungal prophylaxis with itraconazole have been reported to have *Cunninghamella* infections.

Specifically, *Cunninghamella bertholletiae* is a causative agent of rhinocerebral, cutaneoarticular, and disseminated forms of zygomycosis. The infection is acquired via inhalation of the *Cunninghamella* spores or inoculation of the fungus succeeding the primary breakdown of the skin due to a trauma.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Cunninghamella mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colonies mature within four days and are cottony in texture;
- Surface colony color is white to tannish - gray while the reverse is pale, however, *Cunninghamella elegans* produces purely gray – colored colonies only; and
- *Cunninghamella bertholletiae* has the capacity to grow at temperatures as high as 45°C while *Cunninghamella elegans* fails to grow at this kind of condition.

Microscopic Appearance

- Hyphae are broad, aseptate or with very infrequent septa;
- Sporangiohores [specialized hyphae that bears a sporangium] are branched, erect, and form lateral branches terminating in a swollen vesicle;
- Vesicle [swollen cell in which grows a line of phialides that produce chains of conidia or spores as seen in *Aspergillus* species] has spine – like denticles on the surface, with size of 30 - 65 µm in diameter;
- Sporangioles are one – spored, round – to oval – shaped, measure 5 - 8 x 6 - 14 µm, and are formed on denticles on the vesicle surface; and
- Sporangiospores [asexual spores produced within a sporangium] are globose to ovoid in shape, one – celled, appear solitary, and walls often have needle – like crystals.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

There are very few data pertaining to the *in vitro* susceptibility testing of *Cunninghamella* species and there is no standard method as yet. The rank of

MICs was found to be voriconazole, ketoconazole, amphotericin B, itraconazole based on the *in vitro* study conducted on two *Cunninghamella echinulata* strains that were tested.

However, amphotericin B, ketoconazole, and itraconazole yielded notably high MICs for some *Cunninghamella* species isolates in other workers' hands.

Curvularia Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euascomycetes
Order: Pleosporales
Family: Pleosporaceae
Genus: *Curvularia*



(Image Courtesy of www.doctorfungus.org)

Geniculate conidiophore producing curved conidia as a result of the enlarged and darker middle cell.

Ecology

Curvularia is a dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] filamentous fungus, mostly are facultative pathogens of cereals, plants, and soil of tropical or sub – tropical regions, but a few are commonly isolated in temperate agricultural zones. Aside from being a contaminant, it is also considered as an opportunistic fungus

[organism that is generally harmless but becomes pathogenic in a compromised host] that may cause infections in both humans and animals.

Species

There are several species under the genus *Curvularia* namely, *Curvularia brachyspora*, *Curvularia clavata*, *Curvularia geniculata*, *Curvularia lunata*, *Curvularia pallescens*, *Curvularia senegalensis*, and *Curvularia verruculosa*. The most common disease – causing species is *Curvularia lunata* which affects both humans and animals.

Pathogenicity and Health Effects

Curvularia species are considered as occasional causative agents of phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial] and other human infections such as onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and sclerotia], keratitis [wide variety of corneal infections, irritations and inflammations], endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], cerebral abscess, allergic sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever], cerebritis, pneumonia, allergic bronchopulmonary disease, dialysis – associated peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], and disseminated infections. It must be noted that infections frequently develop in immunocompetent patients. *Curvularia* species, however, has emerged as an opportunistic pathogen as well that can infect immunocompromised hosts.

Additionally, *Curvularia* – induced mycetomas are most commonly encountered in animals.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Curvularia mold health effects include

hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org)

Endophthalmitis due to *Curvularia* species

Macroscopic Appearance

- Growth rate is rapid at 25°C on potato dextrose agar and colonies are woolly in texture; and
- Surface colony color is initially white to pinkish – gray becoming olive brown or black at maturation while the reverse is dark brown to black.

Microscopic Appearance

- Hyphae are septate and brown in color;
- Conidiophores [specialized hyphae upon which conidia develop] are brown in color, geniculate – bent at the points where the conidia originates, simple or branched;
- Conidia [asexual reproductive spores which function as organs of dissemination] also called poroconidia are slightly but distinctly curved,

- brown – colored, multi – septate, measure 8 - 14 x 21 - 35 μm , and with a darker central cell typically expanded and darker than the other cells; and
- Septa are transverse and divide each conidium into multiple cells; *Curvularia lunata* has three septa and four cells while *Curvularia geniculata* has four septa and five cells.

It must be noted that the most important microscopic attributes that aid in the differentiation of *Curvularia* species from one another are the septa number in their conidia, conidial shape and color, presence of dark median septum, and the prominence of geniculate growth pattern.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

There are very few data pertaining to the *in vitro* susceptibility testing of *Curvularia* species and there is no standard method as yet. Importantly, flucytosine yielded very high MICs for the tested isolates of *Curvularia* as well as those of fluconazole. Conversely, amphotericin B, ketoconazole, miconazole, itraconazole, and voriconazole showed favorable activity for most of the *Curvularia* isolates by generating acceptably low MICs.

Treatments for *Curvularia* infections have not yet been standardized. So far, amphotericin B, itraconazole, and terbinafine have been used to treat *Curvularia* infections but with usually poor prognosis, especially for immunocompromised patients. Surgical treatment and steroid administration are usually required for treatment of allergic sinusitis as well as antifungal therapy. Surgery may also be essential in other infections such as keratitis and localized cutaneous infections.

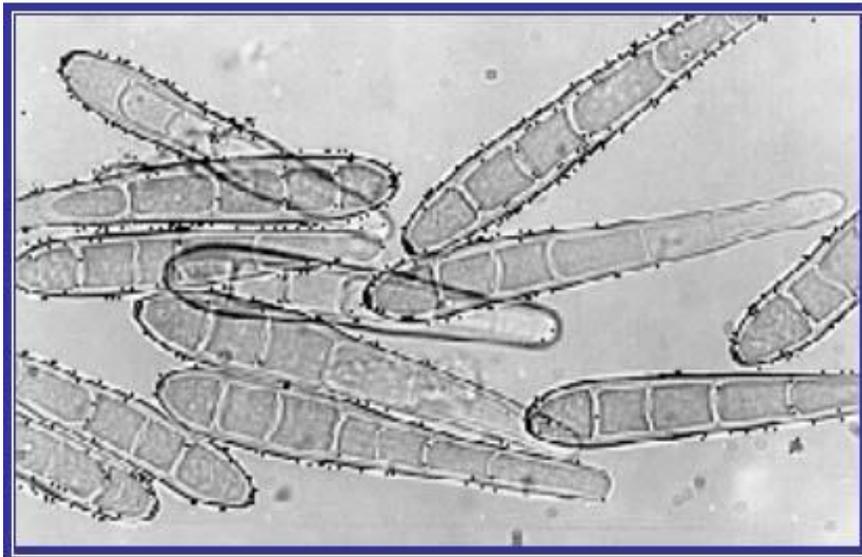
Drechslera Species

Taxonomic Classifications

Kingdom: Fungi

Phylum: Fungi Imperfecti

Genus: *Bipolaris* and *Exserohilum* at Present



(Image Courtesy from the University of Adelaide, Mycology Online)

Conidia of *Drechslera* species

Ecology

Drechslera is a cosmopolitan fungus, dematiaceous fungus [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] primarily isolated from plants and soil. Some species are considered as plant pathogens.

Species

This genus lacks a known sexual state and is generally classified as a dark – walled dematiaceous fungus. McGinnis et. al. (1986) have reviewed the *Drechslera* isolates from human and animal disease and concluded that all pathogenic species are today considered as members of the genera *Bipolaris* and *Exserohilum*.

Pathogenicity and Health Effects

Drechslera biseptata is isolated from a brain abscess [caused by inflammation and collection of infected material coming from local sources which include ear infection, infection of paranasal sinuses, infection of the mastoid air cells of the temporal bone, epidural abscess; or from remote infectious sources, such as lung, heart, kidney, and etc., within the brain tissue; the infection may also be introduced through a skull fracture following a head trauma or surgical procedures] recently in a patient evidently lacking any predisposing condition. *Drechslera biseptata* is the sole species known to cause human or animal disease.

Macroscopic Appearance

- Growth is rapid colony texture is velvety to wooly; and
- Both surface and reverse colony color is initially white becoming olive brown to black.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate and brown in color;
- Conidia [asexual reproductive spores which function as organs of dissemination] are pale to dark brown in color, cylindrical or sub – cylindrical in shape, straight and smooth – walled, without a protuberant hilum, and arise through a pore in a sympodially elongating geniculate [bent like a knee] conidiophore;

- Conidiophores [specialized hyphae upon which conidia develop] are brown in color, simple or branched and geniculate; and
- Germ tubes are observed developing perpendicularly to the long axis of the conidium.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Emmonsia Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Onygenales
Family: Onygenaceae
Genus: *Emmonsia*



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the microscopic morphology of *Emmonsia parva* showing one - celled conidia that are formed on short conidiophores.

Ecology

Emmonsia is a cosmopolitan filamentous fungus commonly isolated from soils and from numerous mammalian species, such as small rodents. It has the ability to produce a distinctive structure known as adiaspore [a large, globose, thick-walled conidium produced in the lungs of humans and animals] at 37 – 40°C

thus, considered as a dimorphic fungus [having two different morphological forms] as well. *Emmonsia* species is an occasional causative agent of animal and human infections. *Emmonsia parva* is known to be prevalent in Australia, Southwestern USA, and Eastern Europe while *Emmonsia crescens* has been reported worldwide.

Species

The genus *Emmonsia* currently consists of four species, namely: *Emmonsia parva*, *Emmonsia parva* var. *crescens*, *Emmonsia parva* var. *parva*, and *Emmonsia pasteuriana*. *Emmonsia parva* is occasionally referred to as *Chrysosporium parvum*.

Pathogenicity and Health Effects

Emmonsia species is the etiologic agent of adiaspiromycosis [a pulmonary disease of many species of rodents and occasionally of humans, caused by the inhalation of spores of the fungus *Emmonsia parva* and *E. crescens*; it is marked by huge spherules in the lungs, with symptoms ranging from the sub - clinical to a bilateral pneumonia] in animals and more rarely in humans and is described as asymptomatic pulmonary infection which may disseminate in immunocompromised patients, such as those with AIDS. The said infection develops after breathing in of *Emmonsia* conidia. Then, these conidia, which are also called as adiaspores, enlarge in the alveoli and hinder regular pulmonary functions. Additionally, adiaspores only remain at their primary implantation site and do not reproduce and eventually, become calcified and lead to a minimal reaction in the host tissue. *Emmonsia parva* var. *crescens* is the primary species isolated from humans while *Emmonsia parva* var. *parva* is mostly isolated from animals. Additionally, *Emmonsia pasteuriana* has recently been isolated from a cutaneous disseminated infection in an HIV – infected patient.

Macroscopic Appearance

- Growth rate is moderately rapid and colonies have glabrous to velvety texture; and
- Surface colony color is white and may have buff to pale brown center and while cream to pale brown on the reverse.

Microscopic Appearance

- Hyaline septate hyphae, conidiophores, and aleuriconidia are present while adiaspores are only formed at 37 – 40°C *in vivo* or on blood or brain heart infusion agar *in vitro*;
- Conidiophores [specialized hyphae upon which conidia develop] are simple or sometimes branching at right angles;
- Aleuriconidia [thallic conidia released by lysis or fracture of the supporting cell] are hyaline, unicellular, round in shape and lightly roughened, sessile or located on slender stalks, usually solitary or may form two to three – celled chains, and 2 - 5 x 2 - 4 µm in size;
- The conidia asexual reproductive spores which function as organs of dissemination] tend to swell and give rise to adiaspores which are thick - walled, big conidia liberated at 37 - 40°C;
- The only *Emmonsia* species which do not produce adiaspores is *Emmonsia pasteuriana* which only produces budding cell – like cells structures at 37°C on brain – heart infusion agar;
- Adiaspores of the two varieties of *Emmonsia parva* may differ in size, structure and in their required temperature for their optimum growth; For *Emmonsia parva* var. *parva*, adiaspores are uninucleate, may reach 25 µm *in vitro* and 40 µm *in vivo* and are formed at 40°C while the adiaspores of *Emmonsia parva* var. *crescens* are multinucleate, may be bigger compared to those of *Emmonsia parva* var. *parva* and are formed at 37°C.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

No data available.

Epidermophyton Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Onygenales
Family: Arthrodermataceae
Genus: *Epidermophyton*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of an *Epidermophyton* species showing smooth, thin - walled macroconidia.

Ecology

Epidermophyton is a cosmopolitan dermatophyte [fungi that require keratin for growth and can cause superficial infections of the skin, hair and nails], filamentous fungus. *Epidermophyton floccosum* is the only species considered as pathogenic as its primary host is human thus, it is also known as anthropophilic

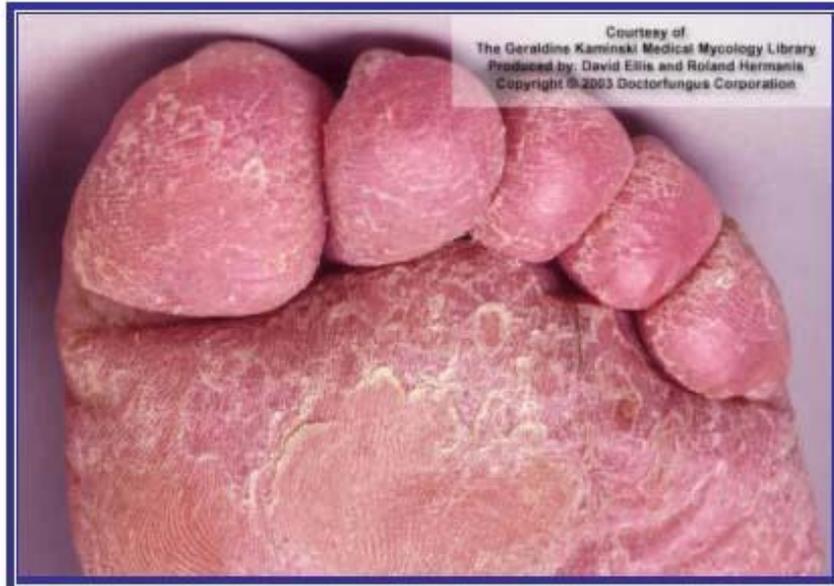
[organisms which are attracted to humans especially, as a source of food]. Soil is the natural habitat of the related but the non - pathogenic species *Epidermophyton stockdaleae*.

Species

The genus *Epidermophyton* contains two species only, namely: *Epidermophyton floccosum* and *Epidermophyton stockdaleae*. *Epidermophyton stockdaleae* is known to be non - pathogenic, leaving *Epidermophyton floccosum* as the only anthropophilic species causing infections in humans.

Pathogenicity and Health Effects

Epidermophyton floccosum is one of the causative agents of cutaneous infections, dermatophytosis [are referred to as "tinea" infections; a characteristic feature is an inflammatory pattern at the edge of the skin lesion, noted by redness and scaling or occasionally, blister formation] in healthy individuals which particularly infects the skin. Skin infections include the body surface - tinea corporis [a fungal infection involving areas of the skin not covered by hair, characterized by a pink to red rash and often considerable itching], groin [tinea cruris], feet [tinea pedis] and nails – onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus]. The fungus lacks the ability to penetrate the viable tissue of the immunocompetent host thus, the infection is only restricted to the non – living cornified layers of epidermis. However, infection due to invasive *Epidermophyton floccosum* has been reported in an immunocompromised patient with Behcet's syndrome. Furthermore, *Epidermophyton floccosum* infections are communicable and can be transmitted by contact, particularly in common showers and gym facilities.



(Image Courtesy of www.doctorfungus.org @ 2005)

Severe tinea of the foot (tinea pedis) caused by *Epidermophyton floccosum* showing extensive scaling.

Macroscopic Appearance

- Growth rate is moderately rapid and colonies mature within 10 days;
- Colonies' texture is flat, initially grainy and becoming radially grooved, felty and velvety by maturation and quickly become downy and sterile; and
- Surface colony color is brownish yellow to olive gray or khaki and while orange to brown on the reverse with an occasional yellow border.

Microscopic Appearance

- Hyaline septate hyphae, macroconidia, and occasionally, chlamydoconidium – like cells are present while microconidia are typically absent;
- Macroconidia [larger of two different types of conidia produced by a fungus in the same manner] are club – shaped with thin, smooth walls, three to five – celled, with size of 10 to 40 x 6 to 12 μm , and may be solitary or in groups; and

- Chlamydoconidium – like cells and arthroconidia [thallic conidia released by either the splitting of a double septum or by the fragmentation or lysis of a disjunct cell] are formed in mature cultures.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

In vitro antifungal susceptibility testing methods have not been standardized for *Epidermophyton floccosum*. However, some reports on *in vitro* activity of various antifungal drugs are also available. Most of these studies have utilized the modifications of the NCCLS M 38P methodology documented for conidium - forming filamentous fungi. The results of these analyses show that, ketoconazole, itraconazole, terbinafine, and voriconazole generate low MICs and appear active *in vitro* against *E. floccosum* while griseofulvin is less active than the other mentioned compounds. On the other hand, fluconazole generates the highest MICs and appears to have the lowest activity among the others. Furthermore, amorolfine and naftifine also exhibit *in vitro* activity against *E. floccosum*.

Exophiala Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Order: Chaetothyriales
Genus: *Exophiala*



(Image Courtesy of www.doctorfungus.org @ 2005)

A microscopic morphology of an *Exophiala* species

Ecology

Exophiala is a cosmopolitan, dematiaceous fungus [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] isolated from soil, decaying wood material, plants, and surfaces in contact with cool, fresh water. In addition to being a saprophyte in nature, it is the causative agent of various human infections particularly involving the feet and nails.

Species

The genus *Exophiala* contains numerous species. The most common ones are *Exophiala castellanii*, *Exophiala jeanselmei* (which currently has two varieties namely: *Exophiala jeanselmei* var. *heteromorpha* and *Exophiala jeanselmei* var. *lecanii-corni*), *Exophiala moniliae*, *Exophiala pisciphila*, *Exophiala salmonis*, and *Exophiala spinifera*.

Pathogenicity and Health Effects

Exophiala species are among the fungi - causing infections referred to as phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. *Exophiala* isolates may cause subcutaneous infections such as mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and sclerotia] and chromoblastomycosis [a chronic subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells in tissue which appear as similar to copper pennies]. These infections are usually obtained via traumatic implantation and are associated with the existence of local or systemic immunosuppression, such as organ transplantation. Cases such as infection and abscess formation in subcutaneous tissues, prosthetic valvular vegetations, fungemia [the presence of fungi in the blood], and disseminated infections due to *Exophiala* species have also been reported. Aside from humans, fish are also infected by the neurotropic *Exophiala pisciphila*.



(Image Courtesy of www.doctorfungus.org @ 2005)

Phaeohiphomyces lesion in an immunologically compromised patient due to
Exophiala spinifera

Macroscopic Appearance

- Growth rate is slow and the texture is mucoid becoming velvety due to short, grayish aerial hyphae formation; and
- Colony surface color is dark brown to olivaceous black while black on the reverse.

Microscopic Appearance

- Yeast cells are present at the beginning of colony formation and are either unicellular or bicellular and often appear in long chains;
- Pale brown, septate hyphae are eventually formed as the culture matures and which bear conidiogenous cells also referred to as the annellides;
- The annellides [specialized conidiogenous cells producing conidia] are cylindrical or slightly inflated, with brown pigmentation and which typically tapers to form a narrow elongated tip, the entire structure are often slightly differentiated from the vegetative hyphae; and

- Conidia [asexual reproductive spores which function as organs of dissemination] are hyaline or pale brown, ellipsoidal in shape, size ranging from 3 × 3 to 6 µm, may either be unicellular or bicellular, and accumulate in clusters at the tip of the annellides or at the sides of the conidiophore.

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

There are a limited data available on a limited number of isolates. Fluconazole yielded very high MICs for *Exophiala jeanselmei* while flucytosine and miconazole appeared lower than fluconazole but were still relatively high. MICs of amphotericin B, ketoconazole, and voriconazole were similar and relatively low. Itraconazole and terbinafine yielded the lowest MICs. *Exophiala jeanselmei* showed decreased susceptibility to both amphotericin B deoxycholate and ABLC in other workers' hands. On the other hand, the echocandin, caspofungin yielded favorable *in vitro* activity against *Exophiala jeanselmei* isolates. Furthermore, MICs of amphotericin B, itraconazole, and voriconazole for *Exophiala spiniphora* were similar and encouragingly low.

The correlation of *in vitro* susceptibility with clinical outcome for *Exophiala* is not yet known. Combination of surgical and anti – fungal treatment is usually done for subcutaneous *Exophiala* infections as there is no standard treatment yet. Amphotericin B with or without flucytosine, itraconazole, and terbinafine have been used as well. The combination of amphotericin B, flucytosine and itraconazole appeared effective in a case with subcutaneous infection due to *Exophiala jeanselmei*.

Exserohilum Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Eumycota
Sub – Phylum: Deuteromycotina (Fungi Imperfecti)
Class: Hyphomycetes
Order: Hyphales
Genus: *Exserohilum*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Exserohilum* species

Ecology

Exserohilum is a cosmopolitan environmental fungus primarily isolated as a plant pathogen and a resident of soil.

Species

There are three known species under the genus *Exserohilum* namely, *Exserohilum longirostratum*, *Exserohilum mcginnisii*, and *Exserohilum rostratum*.

Pathogenicity and Health Effects

Several *Exserohilum* species have been reported to cause subcutaneous or deep phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial] in both humans and animals. Clinical manifestations include endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], mycotic keratitis [wide variety of corneal infections, irritations and inflammations], sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever], subcutaneous phaeohyphomycosis, and osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood]. *Exserohilum* – induced infections occur on both immunosuppressed patients and immunocompetent hosts.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Exserohilum mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



Image Courtesy of www.doctorfungus.org @ 2005)

Phaeohyphomycosis lesion involving the arm of a heart transplant patient

Macroscopic Appearance

- Growth rate is moderately rapid and colonies are velvety in texture; and
- Both surface and reverse colony color is olive to black.

Microscopic Appearance

- Hyphae are septate and brown in color;
- Conidiophores [specialized hyphae upon which conidia develop] are brown in color, geniculate at the apex; and
- Conidia also called poroconidia are cylindrical to ellipsoidal, curved or slightly bent, straight, multicellular, with a protuberant truncated hilum at the base wherein the septum above the hilum is usually thickened and dark, paler end cells than the other cells, and are formed apically through a pore on a sympodially elongating geniculate [bent like a knee] conidiophore.

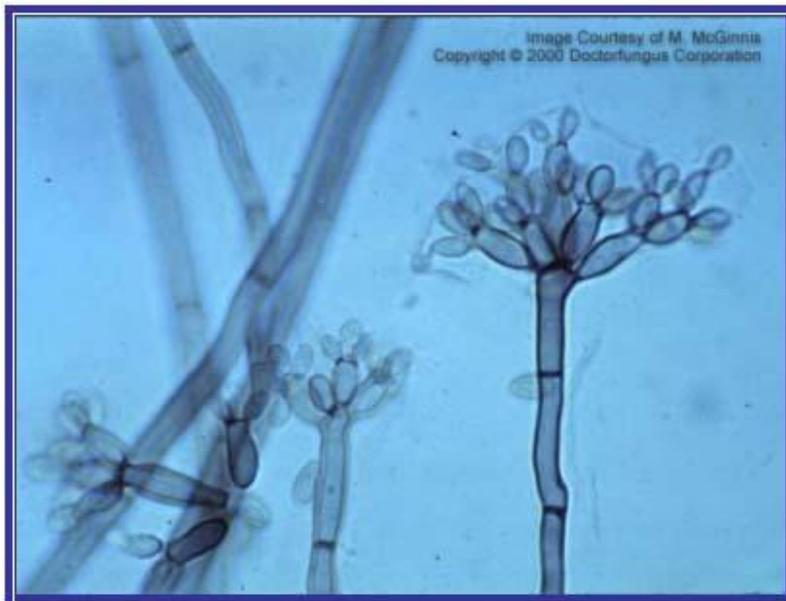
Remarks

The genus *Exserohilum* is distinguished from the closely related genera *Bipolaris* and *Drechslera* by their conidia with a protuberant truncated hilum. The hilum is the scar on the conidium at the point of attachment to the conidiophore. *Bipolaris* species have a slightly protruding hilum while the hilum of *Drechslera* species does not protrude at all.

Fonsecaea Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eufungi
Order: Chaetothyriales
Family: Herpotrichiellaceae
Genus: *Fonsecaea*



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the microscopic morphology of *Fonsecaea pedrosoi* showing the conidia developing from sympodial conidiogenous cells.

Ecology

Fonsecaea is a pigmented filamentous fungus isolated from soil, rotten wood, and decomposing plant material. Aside from being a saprophyte [utilizes dead organic matter for food], it causes infections in humans as well. Cold – blooded

animals living in swamps may also be infected. Most cases of infection come from tropical and subtropical regions. *Fonsecaea* exhibits *in vivo* dimorphism as it forms sclerotic fission cells only in tissue but grows as a mold in laboratory conditions.

Species

The genus *Fonsecaea* only contains two species namely, *Fonsecaea compacta* and *Fonsecaea pedrosoi*.

Pathogenicity and Health Effects

Fonsecaea is one of the causative agents of chromoblastomycosis [a chronic subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells in tissue which appear as similar to copper pennies] which is described as a post – traumatic, chronic infection of subcutaneous tissues. The infection is characterized by verrucous cauliflower – like lesions and the formation of brown, sclerotic fission cells which appear like copper pennies in the tissue.

Most cases of infection come from tropical and sub - tropical regions. *Fonsecaea pedrosoi* is one of the major causative agents of chromoblastomycosis, particularly in South America and Japan. On the other hand, *Fonsecaea compacta* is a rare cause of chromoblastomycosis in tropical Central and North America. Systemic invasion succeeding chromoblastomycosis is very seldom.

Fonsecaea species may cause other human infections as well aside from chromoblastomycosis which include paranasal sinusitis, keratitis [wide variety of corneal infections, irritations and inflammations], and fatal brain abscesses [caused by inflammation and collection of infected material coming from local sources which include ear infection, infection of paranasal sinuses, infection of the mastoid air cells of the temporal bone, epidural abscess; or from remote infectious sources, such as lung, heart, kidney, and etc., within the brain tissue; the infection may also be introduced through a skull fracture following a head trauma or surgical procedures] following hematogenous dissemination have been reported.



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the nodular lesions involving a chronic case of chromoblastomycosis due to *Fonsecaea pedrosoi*.

Macroscopic Appearance

- Growth rate is slow and colonies are restricted, flat to raised and folded with velvety to cottony texture on potato dextrose agar at 25°C;
- Both surface and reverse is brownish black, olive, gray black or jet black in color; and
- The filamentous appearance is maintained upon cultivation at a temperature of 25, 30, or 37°C.

Microscopic Appearance

- Hyphae are septate, dark brown and conidiophores are cylindrical, pale brown, septate, sub – erect, slightly inflated at the tip, and sympodial with conidiogenous zones confined at the upper portion;
- Blastoconidia are unicellular, ellipsoidal to round in shape and are formed in ranks successively; and

- Conidia [asexual reproductive spores which function as organs of dissemination] are brown and barrel – shaped with size ranging from 1.5 - 3 x 2.5 – 6 µm. There are four types of conidiogenesis that are observed among *Fonsecaea* species:
1. ***Fonsecaea* type:** One – celled conidia arise upon swollen denticles that are located at the conidiophore tips. These primary conidia become irregularly swollen at their apices and function as sympodial conidiogenous cells as well. Then, these conidia give rise to secondary conidia that are one – celled, pale brown on swollen denticles. Tertiary series of conidia are often produced by the secondary conidia which are similar to those formed by the primary conidia, resulting in a complex conidial head. This type of conidiogenesis does not form long chains of conidia and is primarily observed among the strains under the genus *Fonsecaea*.
 2. ***Cladosporium* type:** Conidiophores give rise to primary shield – shaped conidia which produce long, branching chains of oval, dematiaceous conidia. This type of conidiogenesis is primarily observed for the strains under the genus *Cladosporium*, however, may also be observed in *Fonsecaea* strains.
 3. ***Phialophora* type:** Vase – shaped conidia with collarettes are located at the tip of the phialides. This type of conidiogenesis is primarily observed for the strains of the genus *Phialophora* and may rarely be observed in strains of *Fonsecaea* as well.
 4. ***Rhinocladiella* type:** One – celled, pale brown conidia are formed by the conidiophores which are sympodial and with denticles. These conidia may be located at the tips and along the sides of conidiophores. Secondary conidia are formed rarely. This type of conidiogenesis is primarily observed for the strains of the genus *Rhinocladiella*, but *Fonsecaea* strains may also exhibit such.

Laboratory Precautions

Analyses involving *Fonsecaea* species must be carefully conducted in a biological safety cabinet.

Susceptibility

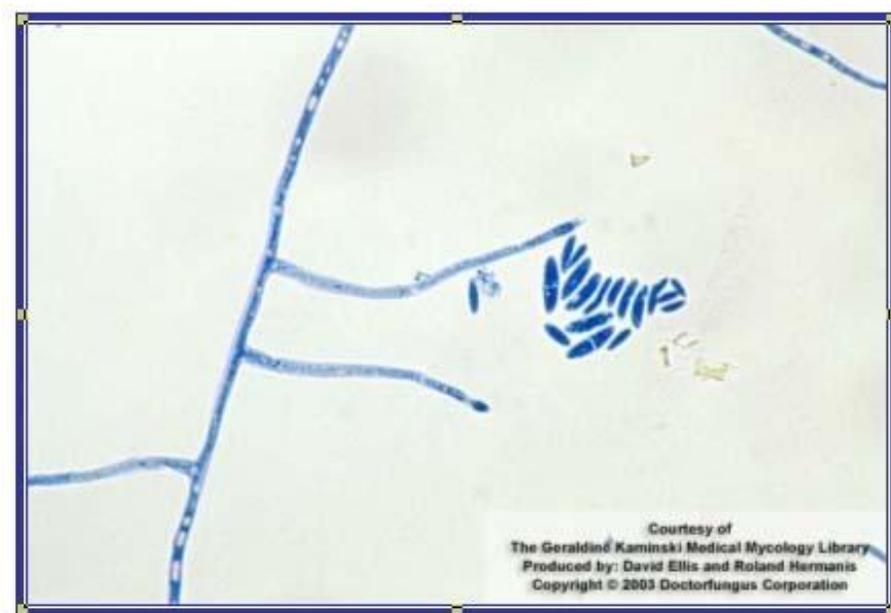
There are a limited data available and there is no standard method as yet for *in vitro* susceptibility testing of *Fonsecaea* species. Low MICs were generated by amphotericin B, ketoconazole, miconazole, itraconazole, voriconazole, and terbinafine for isolates of *Fonsecaea*. Itraconazole and voriconazole appear to have better *in vitro* activity than amphotericin B. Also active *in vitro* against *Fonsecaea pedrosoi* is caspofungin. On the other hand, fluconazole has no practical *in vitro* activity against *Fonsecaea*.

Currently used to treat chromoblastomycosis are cryosurgery and itraconazole. The former is preferred for small lesions while the latter is applied to larger lesions. The combination of the two therapeutic modalities may also be used. In addition, terbinafine also shows promising response in treatment of chromoblastomycosis. In spite of this, chromoblastomycosis infection is difficult to treat and most therapeutic approaches provide only a modest success rate.

Fusarium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Order: Hypocreales
Family: Hypocreaceae
Genus: *Fusarium*



(Image Courtesy of www.doctorfungus.org)

Microscopic morphology of *Fusarium solani*

Ecology

Fusarium is a cosmopolitan filamentous fungus widespread in nature, frequently isolated from soil and from plants. *Fusarium* fungus is part of the normal mycoflora of a variety of food supplies such as bean, rice, soybean, and other

crops. Most *Fusarium* species are prevalent in tropical and sub – tropical regions while some are common inhabitants of the soil in areas with cold climates.

Certain species are important plant pathogens while others produce mycotoxins in grains or stored animal feeds. Aside from being a common contaminant and a well – known plant pathogen, *Fusarium* species may cause various human infections and furthermore, it is considered as one of the emerging causes of opportunistic mycoses.

Species

There are over twenty species under the genus *Fusarium* and the most common among these are *Fusarium solani*, *Fusarium oxysporum*, and *Fusarium chlamydosporum*.

Pathogenicity and Health Effects

Fusarium species are occasional causative agents of cutaneous infections, keratitis [wide variety of corneal infections, irritations and inflammations], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and scleroticia], onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], pulmonary infections, endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], fungemia [the presence of fungi in the blood], otitis media [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo], peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], septic arthritis, central venous catheter infections, and disseminated infections in humans. **Fusariosis** is the collective term used to refer to all the infections caused by *Fusarium*. The major predisposing factor for the development of *Fusarium* – caused cutaneous infections is through trauma, on the other hand, disseminated opportunistic infections may develop in immunosuppressed patients, particularly in neutropenic and transplant patients.

Certain *Fusarium* species are mycotoxin – producers. Ingestion of mycotoxin – contaminated grains may result to allergic symptoms and may be carcinogenic due to long – term consumption. *Fusarium moniliforme* and *Fusarium proliferatum* produced mycotoxins called fumonisins in maize and ingestion of fumonisin toxins may cause oesophageal cancer. **Zearalenones** is another group of mycotoxins produced by *Fusarium* species in grains.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Fusarium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org)

Endophthalmitis due to *Fusarium* species

Macroscopic Appearance

- Growth rate is rapid at 25°C on Sabouraud dextrose agar, while *Fusarium dimerum* is the only slow – growing species, and colonies are wooly to cottony in texture and at times mucoid, spreading and flat; and
- Surface colony color is white, yellow, pink, purple, tan, salmon, cinnamon while the reverse is pale, violet, red, tan, or brown.

Microscopic Appearance

- Hyphae are septate and hyaline;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are either long or short, cylindrical, may appear solitary or as a component of a complex branching system, with a scarcely discernible collarette at the apex;
- Macroconidia [larger of two different types of conidia produced by a fungus in the same manner] are curved, multicellular with 2 or more cells, thick – walled, smooth, with diameter size of 3 - 8 x 11 - 70 µm, with distinct basal foot cell and pointed distal ends, and tend to accumulate in balls or rafts;
- Microconidia [smaller of two different types of conidia produced by a fungus in the same manner] are unicellular, smooth, hyaline, ovoid to ellipsoidal, formed on long or short conidiophores, measure 2 - 4 x 4 - 8 µm in size, and are arranged in balls;
- Chlamydospores are thick – walled, hyaline, sparse, appear in pairs, clumps or in chains, and are only occasionally present.

The key features for the differentiation of *Fusarium* species from one another include colony color, length and shape of the macroconidia, the number, shape and arrangement of microconidia, and presence or absence of chlamydospores.

Laboratory Precaution

General laboratory precautions are required, no special safety measures needed.

Susceptibility

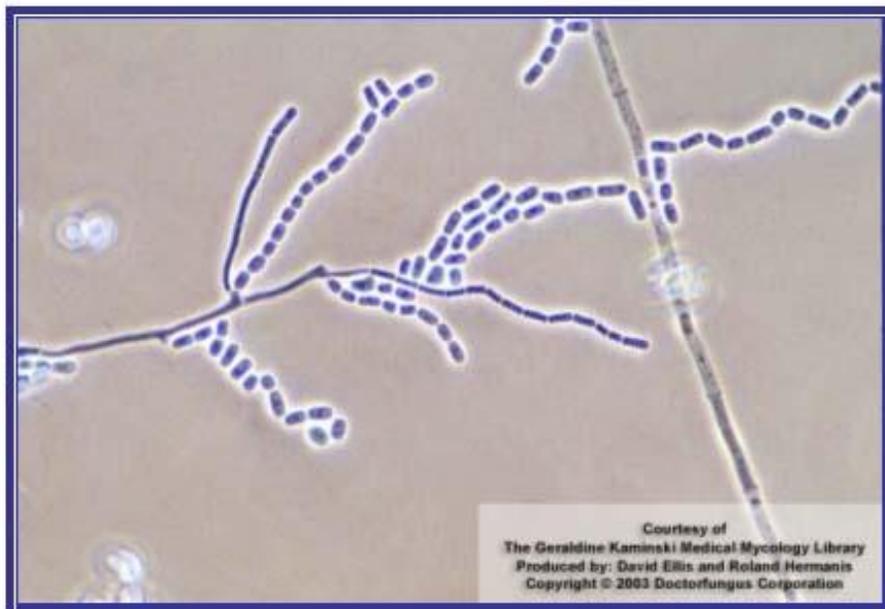
Fusarium is one of the most – resistant fungi and *Fusarium solani* among all tends to be the most resistant *Fusarium* species, generally. Flucytosine, fluconazole, ketoconazole, miconazole, itraconazole, and posaconazole yield high MICs for *Fusarium* strains. The only antifungal drugs that yield relatively low MICs for *Fusarium* strains are amphotericin B, voriconazole, and natamycin.

Fusarium infections are difficult to treat and the invasive forms are frequently fatal. The most common antifungal drug used for treatment of systemic fusariosis is amphotericin B alone or in combination with flucytosine or rifampin. Additionally, posaconazole appears effective against murine fusariosis. For the treatment of keratitis, topical natamycin is used while itraconazole is used for treatment of mycetoma.

Geotrichum Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Sub – Phylum: Ascomycotina
Order: Saccharomycetales
Family: Endomycetaceae
Genus: *Geotrichum*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic Morphology of *Geotrichum* species

Ecology

Geotrichum is a cosmopolitan yeast saprobe primarily found in soil, water, air, and sewage and frequently isolated from cereals, milk, and milk products.

Geotrichum candidum is found in normal human microbiota and it is commonly isolated from sputum samples, feces, urine and vaginal secretions.

Species

There are several species under the genus *Geotrichum* and the most common ones are *Geotrichum candidum*, *Geotrichum clavatum* and *Geotrichum fici*.

Pathogenicity and Health Effects

Geotrichum species may cause opportunistic infections in immunocompromised host which can be acquired through ingestion or inhalation and these infections are referred to as geotrichosis. Infections due to *Geotrichum* include bronchial, pulmonary, and disseminated infections as well as fungemia. *Geotrichum* species has also been isolated from infections acquired through a trauma.

Macroscopic Appearance

- Growth rate is rapid and colonies are creamy becoming powdery to cottony in texture, however, when disturbed on the surface the colonies become yeast-like;
- Both surface and reverse colony color is white; and
- Optimal growth is acquired at 25°C and most strains do not have the capacity to grow or may only grow weakly at 37°C.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate and hyaline; and
- Arthroconidia [thallic conidia released by either the splitting of a double septum or by the fragmentation or lysis of a disjunctive cell] are rectangular in shape or rounded at the ends, unicellular, hyaline, appear in chains, and liberated by the fission of double walls.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

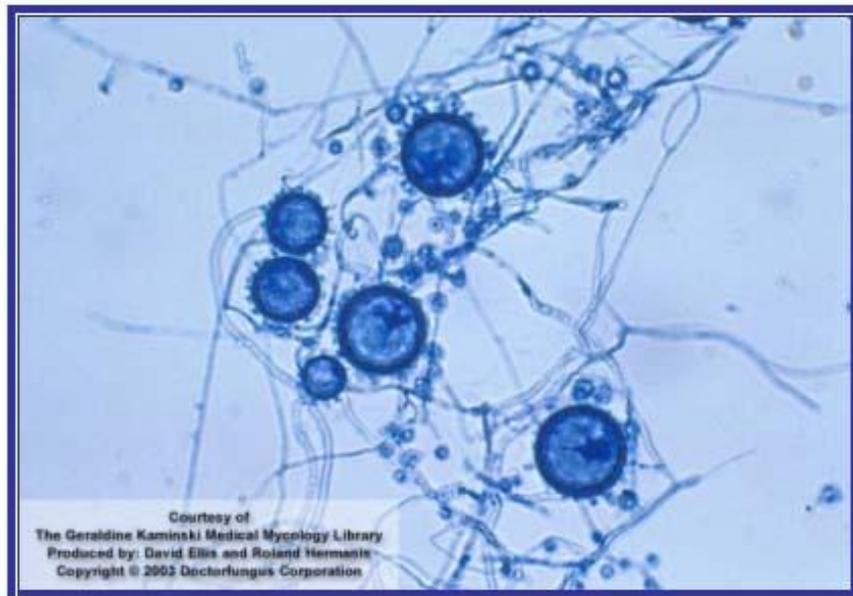
Susceptibility

There are very few data pertaining to the *in vitro* activity of antifungal agents against *Geotrichum* isolates. Voriconazole yields the lowest MICs, followed by ketoconazole and itraconazole. The standard therapeutic regimen for geotrichosis treatment is not yet available. Amphotericin B with or without flucytosine as well as itraconazole can be considered as treatment, however, prognosis of disseminated geotrichosis is usually poor with as high as 75% mortality rate.

Histoplasma Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Sub – Phylum: Ascomycotina
Class: Ascomycetes
Order: Onygenales
Family: Onygenaceae
Genus: *Ajellomyces* (*Histoplasma*)



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Histoplasma capsulatum*

Ecology

Histoplasma is a thermally dimorphic fungus [may exist as a yeast form or a mold form, depending on the temperature at which they are growing] mostly

isolated from nitrogen – rich soils contaminated with excrement of bats and bird droppings. The fungus is often encountered in tropical or sub – tropical areas and in several large basins in temperate regions despite the claim that it is distributed worldwide. Furthermore, it is prevalent in the valleys of the Mississippi and the Ohio rivers in the United States.

Species

The genus *Histoplasma* only has *Histoplasma capsulatum* as its sole species member. *Histoplasma capsulatum* contains two varieties namely, *Histoplasma capsulatum* var. *capsulatum* and *Histoplasma capsulatum* var. *duboisii*. The genus also has a teleomorph [the sexual form or morphology of a fungus] referred to as *Ajellomyces capsulatus*.

Pathogenicity and Health Effects

Histoplasma capsulatum is the etiologic agent of **histoplasmosis** [causes acute or chronic lung disease and progressive disseminated histoplasmosis affecting a number of organs; and can be fatal if untreated], a true systemic mycosis. It is an infection most often presenting in an acute benign pulmonary infection but progresses to a chronic pulmonary or to life – threatening fatal disseminated disease which particularly affects the reticuloendothelial system. Furthermore, *Histoplasma capsulatum* may also rarely involve the thyroid glands and may be isolated in fungemia [the presence of fungi in the blood]. The infection is acquired by the inhalation of the conidia.

Given the true systemic nature of histoplasmosis, otherwise immunocompetent individuals are affected. The dissemination and fatal form, however, are more common in the immunocompromised and elderly patients.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Histoplasma mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

Histoplasmosis of the lower gum showing ulcer around base of tooth.

Macroscopic Appearance

At 25°C *Histoplasma capsulatum* grows in mold form while in yeast – form at 37°C due to being a thermally dimorphic fungus.

At 25°C

- Growth rate is slow and colonies are woolly to granular in texture;
- The surface colony color is initially white becoming brownish with age while the reverse is yellowish; and
- The colonies are not sensitive to cycloheximide in the culture media; inoculation on brain heart infusion agar enhances culture growth more efficiently as compared to when inoculated on Sabouraud dextrose agar.

At 37°C

- Growth rate is slow and colonies are moist and yeast – like in texture; and
- Both surface and reverse colony color is cream.

Microscopic Appearance

At 25°C

- Hyphae [single filament of a fungus] are septate and hyaline;
- Conidiophores [specialized hyphae upon which conidia develop] are hyphae – like, arise to the parent hyphae at right angles, and have both macroconidia and microconidia;
- Macroconidia [larger of two different types of conidia produced by a fungus in the same manner] also called macroaleurioconidia, are unicellular, hyaline, round, thick – walled, smooth or warty due to finger – like projections on the surface; and
- Microconidia [smaller of two different types of conidia produced by a fungus in the same manner] also called microaleurioconidia, are hyaline, unicellular, round – shaped, and may be smooth – or rough – walled.

At 37°C

- Yeast cells are narrow – based, budding, and ovoid; *Histoplasma* var. *capsulatum* produces smaller yeast cells measuring 2 - 4 µm as compared to *Histoplasma* var. *duboisii* with yeast cells measuring 12 - 15 µm.

Laboratory Precautions

Histoplasma isolates must be analyzed and handled with caution in a biological safety cabinet.

Susceptibility

There are very few data pertaining to the *in vitro* activity of antifungal agents against *Histoplasma capsulatum* isolates. Amphotericin B, itraconazole, posaconazole, and voriconazole yield relatively low MICs for *Histoplasma capsulatum*. Fluconazole usually appears active, however, resistance may develop.

The currently used antifungal drugs as treatment for histoplasmosis are amphotericin B, fluconazole and itraconazole. Fluconazole, however, is less active than itraconazole, thus considered as a second – line agent only.

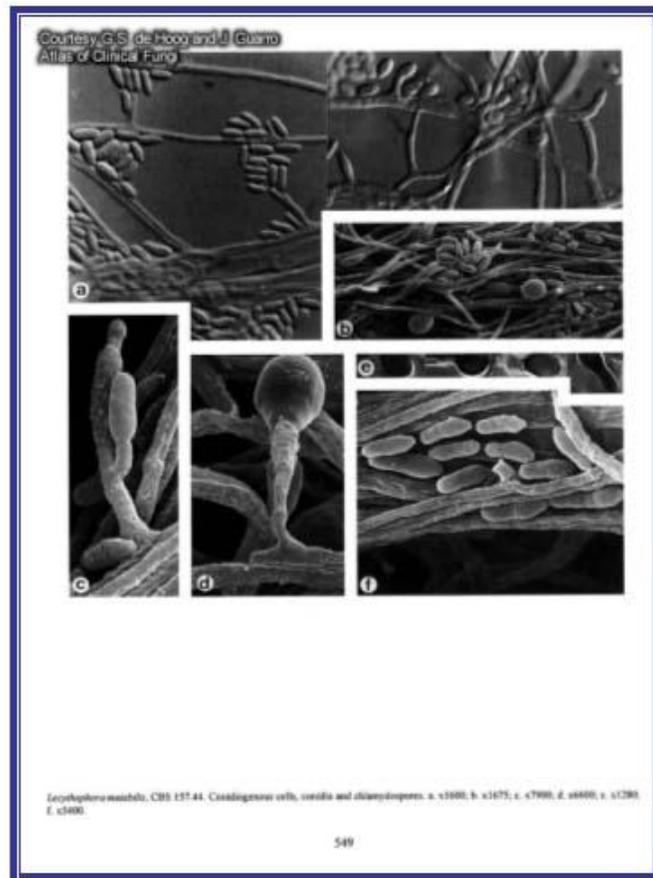
Lecythophora Species

Taxonomic Classifications

Kingdom: Fungi

Phylum: Deuteromycota (Fungi Imperfecti)

Genus: *Lecythophora*



(Image Courtesy of www.doctorfungus.org @ 2005)

Atlas Scan Images of the conidiogenous cells, conidia, and chlamydospores of
Lecythophora mutabilis.

Ecology

Lecythophora species are cosmopolitan and are occasionally isolated from soil and from plant debris.

Species

The genus *Lecythophora* is a mold that lacks a known sexual state thus, is categorized under Fungi Imperfecti. It is generally classified as a dematiaceous fungus which is mainly attributed to its darkly colored fungal body due to the presence of melanin in the cell walls of its conidia, hyphae or both. There are three species classified under this genus namely, *Lecythophora hoffmannii*, *Lecythophora lignicola*, and *Lecythophora mutabilis*.

Pathogenicity and Health Effects

Only two cases of cases of endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers] have been reported from humans, one of gluteal abscess - and one of peritonitis which is an inflammation of the peritoneum tissue lining of the abdominal wall and most of the organs in the abdomen.

Macroscopic Appearance

- Growth rate is moderately rapid and texture is initially slimy becoming lightly downy at the center of the colony; and
- Both surface and reverse colony color is pale pink to salmon, however, becoming pale to deep brown at times.

Microscopic Appearance

- Hyaline and septate hyphae, adelophialides, conidia and chlamydospores are present;

- Adelophialides are type of phialides which are not septated at the base, short, cylindrical or conical in form, may often appear solitary, sometimes in groups that are arranged in short lateral filaments, however, phialides with septate bases are sometimes present;
- Conidia [asexual reproductive spores which function as organs of dissemination] are hyaline, ellipsoidal to cylindrical in shape but may be slightly curved at times, and may give rise to secondary conidia occasionally; and
- Brown – colored chlamydospores may sometimes be present.

Table 1. Differences in microscopic morphology of *Lecythophora* species.

<i>Lecythophora</i> species	Differences in Microscopic Appearance
<i>Lecythophora hoffmannii</i>	Produces pink colonies
<i>Lecythophora lignicola</i>	Produces brown mature colonies due to its formation of numerous brown chlamydospores
<i>Lecythophora mutabilis</i>	Produces colonies which become brown, however, in this case the brown – colored pigment develops in the hyphae alone, since chlamydospores are absent

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

Susceptibility

No available data.

Madurella Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Dothideales
Family: Lophiostomataceae
Genus: *Madurella*



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the microscopic morphology of *Madurella mycetomatis* showing phialides.

Ecology

Madurella is a dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color], filamentous fungus found in soil with distribution restricted to certain tropical and subtropical areas of Africa, India, and South America. *Madurella* is pathogenic for humans and causes infections.

Species

The genus *Madurella* contains two species namely, *Madurella mycetomatis* and *Madurella grisea*.

Pathogenicity and Health Effects

Madurella species are among the fungi responsible for mycetoma infection [a clinical syndrome characterized by tumefaction, draining sinuses and sclerotia] in humans. Strains belonging to this genus are isolated particularly from cases with black – grain eumycetoma. The fungus spores enter the body via trauma and the development of the mycetoma infection is very slow which may take several years. The infection involves the cutaneous and subcutaneous tissues, the fascia, and the bones and the infection remains localized only. Other effects include tumefaction and draining sinuses.

(Image Courtesy of



www.doctorfungus.org @ 2005)

Mycetoma with multiple draining sinuses, swollen tissue, and sclerotia are present due to *Madurella mycetomatis*.

Macroscopic Appearance

- Growth rate is slow and colonies are raised to heaped and at times radially folded with glabrous to wooly texture;
- The surface colony color is from white to yellow – brown to dark gray or olive brown while the reverse is dark brown in color and sometimes with the production of a brown diffusible pigment; and
- Exposure at 37°C leads to an optimum growth of *Madurella mycetomatis* while *Madurella grisea* grows poorly or does not grow at all at this temperature.

Microscopic Appearance

- Septate, sterile hyphae, chlamydospores, and sclerotia (large and black hyphal masses) are present;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] with vase – shaped collarettes are occasionally produced by *Madurella mycetomatis* on weak media which bear round or oval conidia at their tips; and
- *Madurella* strains are dematiaceous and sterile under laboratory conditions.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Few data are available. Ketoconazole and itraconazole MICs appeared to be lower than those of econazole and miconazole in a previous *in vitro* assay. In a more recent study, voriconazole MICs were found to be noticeably low, while those of itraconazole were variable.

A combination of antifungal and surgical therapy is usually ideal for treatment of mycetoma infections. Ketoconazole gives favorable response rates when used

for prolonged period of time of as long as 8 to 24 months while griseofulvin may be used in patients who do not have any reactions to ketoconazole.

Microsporium Species

Taxonomic Classifications

Kingdom: Fungi

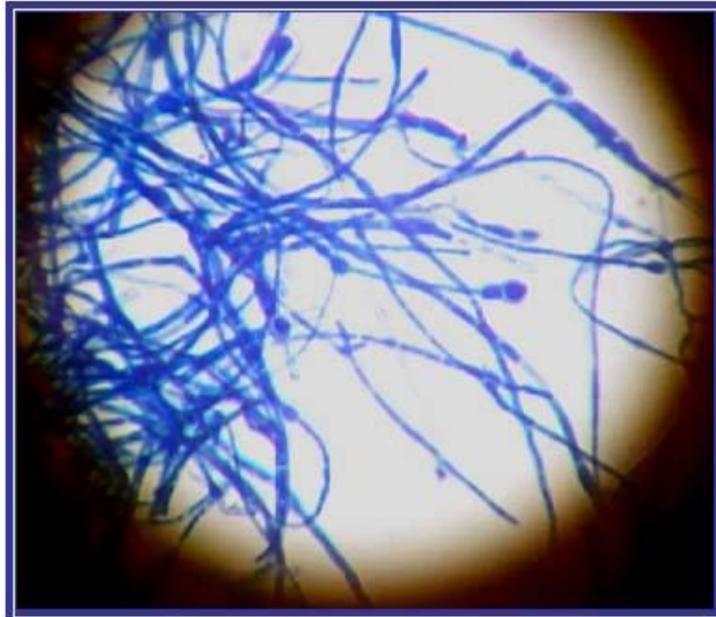
Phylum: Ascomycota

Class: Eueascomycetes

Order: Onygenales

Family: Arthrodermataceae

Genus: *Arthroderma* (*Nannizia*, *Microsporium*, *Epidermophyton*, *Trichophyton*)



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic morphology of a *Microsporium* species

Ecology

The genus *Microsporium* includes anthropophilic [organisms which are attracted to humans especially, as a source of food], geophilic [species that is usually recovered from the soil], and zoophilic species [organisms which prefer lower animals to humans as a source of food]. Some species are cosmopolitan while others have geographically restricted distributions. Geophilic *Microsporium*

species inhabit the soil, the zoophilic species affect animals, and the anthropophilic species primarily affect humans. However, there are some species that are isolated from both soil and animals. *Microsporum* is the asexual state of the fungus and the teleomorph phase is referred to as genus *Arthroderma*.

Species

There are seventeen conventional species under genus *Microsporum* and among these, there are nine significant species namely, anthropophilic *Microsporum audouinii*, zoophilic *Microsporum canis* isolated from cats and dogs, geophilic *Microsporum cookei* isolated from furs of cats, dogs, and rodents, *Microsporum distortum*, anthropophilic *Microsporum ferrugineum*, zoophilic *Microsporum gallinae* mainly isolated from fowl, zoophilic *Microsporum gypseum* isolated from fur of rodents, *Microsporum nanum* which is both geophilic and zoophilic in nature are isolated from swine, and zoophilic *Microsporum persicolor* isolated from vole and field mouse. Molecular studies for taxonomic re – classification of *Microsporum* species are still in progress.

Pathogenicity and Health Effects

Microsporum is one of the three genera that cause dermatophytosis [are referred to as "tinea" infections; a characteristic feature is an inflammatory pattern at the edge of the skin lesion, noted by redness and scaling or occasionally, blister formation] which is the general term referring to the infection that occurs in hair, skin or nails caused by any dermatophyte species. *Microsporum* species has the ability to degrade keratin and thus, can dwell on skin and its appendages and still remains non – invasive. The fungus is bestowed with virulence factors such as its keratinase enzyme, proteinases, and elastases. *Microsporum* species particularly infect the hair and skin, except for *Microsporum persicolor* which does not infect the hair. The pathogenesis of the infection depends on the natural reservoir of the species in such a way that the geophilic species are acquired through contact with soil, zoophilic species are transmitted from the infected animal, and direct or indirect human – to – human transmission is of concern for anthropophilic species. Infections involving the nails are rare. Immunocompromised patients are infected as well as the otherwise healthy hosts.



(Image Courtesy of www.doctorfungus.org @ 2005)

A five week - old baby showing typical *Microsporum canis* lesions with raised, erythematous advancing borders following contact with several Siamese cats.

Macroscopic Appearance

- Growth rate may range from being slow to rapid, and colonies are glabrous, downy, or wooly, and diameter varies within 1 – 9 cm after seven – day incubation at 25°C;
- Surface colony color ranges from white, beige, to cinnamon or rusty while the reverse may be yellow to red – brown; and
- The ability to grow on rice grains, or referred to as the hair perforation test, and also at 37°C help in the differentiation of *Microsporum* species from one another.

Microscopic Appearance

- Septate hyphae, microaleurioconidia, macroaleurioconidia, and hyphae – like conidiophores are present;
- Microaleurioconidia are hyaline, solitary, smooth, oval to clavate in shape, unicellular, and thin – walled;

- Macroaleurioconidia are hyaline, typically fusiform (spindle in shape), echinulate to roughened, thin – to thick – walled, multicellular with 2 to 15 cells, often with annular frill; and
- Inoculation on specific media, such as potato dextrose agar or Sabouraud dextrose agar, added with 3 – 5% sodium chloride may be necessary to promote macroconidia production of some strains; and
- Differences in macroconidia shape and abundance in microconidia aid in species differentiation.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Availability data on *in vitro* susceptibility tests for dermatophytes [fungi that require keratin for growth and can cause superficial infections of the skin, hair and nails] are limited and susceptibility tests are not yet standardized. Terbinafine and itraconazole show active *in vitro* against *Microsporum* species. However, in one of the *in vitro* studies it was observed that this fungus was fungus was found to the least terbinafine – susceptible dermatophyte.

Griseofulvin was once the drug of choice for treating infections caused by *Microsporum* as well as other dermatophyte – caused infections. However, safer and more effective alternatives are now available and preferred such as oral therapy with terbinafine and itraconazole which are commonly used for treatment of *Microsporum* infections.

Specific Profiles of the Different *Microsporium* Species

Microsporium audouinii



Asian Mold Inspector Laboratory Mold Species Documentation

A microscopic photograph of *Microsporium audouinii* showing several thick - walled intercalary chlamydoconidia and a terminal chlamydoconidium.

Ecology

Microsporium audouinii is a cosmopolitan fungus which is considered as an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation]. It is uncommonly isolated in North America and Europe but is mainly present in Africa, Haiti, and Rumania as it is widely eradicated in much of the world.

Pathogenicity and Health Effects

Microsporum audouinii is primarily isolated from pre - pubescent children with tinea infection of the scalp and of the glabrous skin. Under a Wood's light [ultraviolet light produced by Wood's lamp], infected areas of the scalp and plucked hairs are fluorescent when examined.



(Image Courtesy of www.doctorfungus.org @ 2005)

Take note of the lesions on the scalp of the boy due to *Microsporum audouinii*.

Macroscopic Appearance

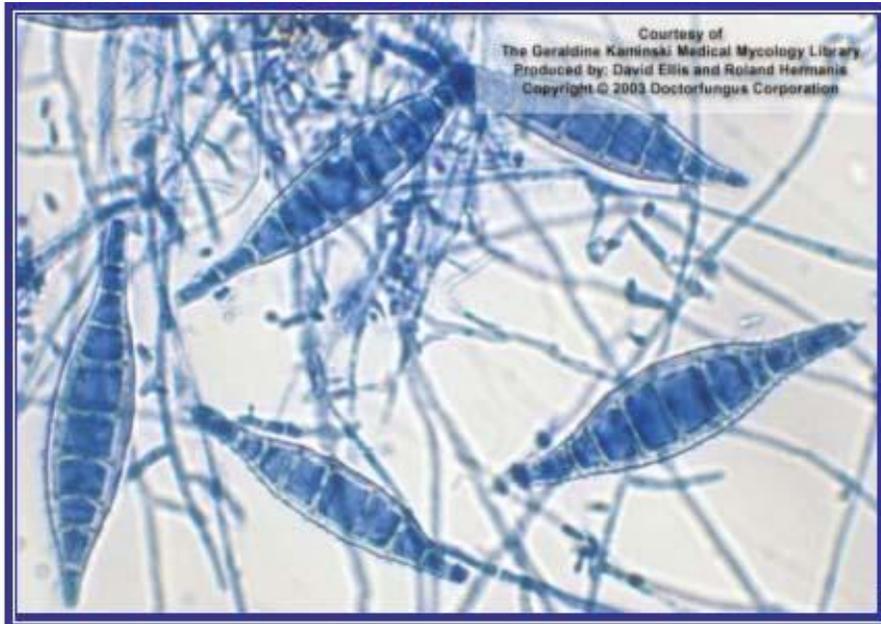
- Growth rate is slow and colonies are flat, dense, spreading, and texture is felty to downy with a fur – like mat with radiating edges; and
- The surface colony color ranges from grayish white, beige, and rarely rusty while the reverse is salmon pink, peach to rose brown.

Microscopic Appearance

- Septate hyphae, sometimes pectinate or with racquet cell are produced by *Microsporum audouinii*;

- Terminal chlamydoconidia [thick-walled, thallic conidia formed within the vegetative hyphae] are often present which have short, spine – like projections showing a pointed appearance at the tip
- Smooth to sparsely echinulate, essentially spindle – shaped but usually deformed, thick - walled macroconidia are rarely present; and
- Microconidia [smaller of two different types of conidia produced by a fungus in the same manner] are unicellular, ovoid to clavate in shape, are rarely present.

Microsporum canis



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of the zoophilic dermatophyte *Microsporum canis* showing typical spindle - shaped, verrucose, thick - walled macroconidia with 5 - 15 cells.

Ecology

Microsporum canis is a cosmopolitan fungus which is considered as a zoophilic dermatophyte [found in association with animals and can cause marked inflammatory reactions in humans who have contact with infected cats, dogs, cattle, horses, birds, or other animals]. It is commonly isolated from cats and dogs.

Pathogenicity and Health Effects

Microsporum canis is a frequent causative agent of tinea of the scalp and of the glabrous skin in humans. Under a Wood's light [ultraviolet light produced by Wood's lamp], infected areas of the scalp and plucked hairs are fluorescent when examined. The species is also considered as an agent of infection in animals.



(Image Courtesy of www.doctofungus.org @ 2005)

Severe inflammatory kerion lesion and suppurative folliculitis due to infection by *Microsporum canis*.

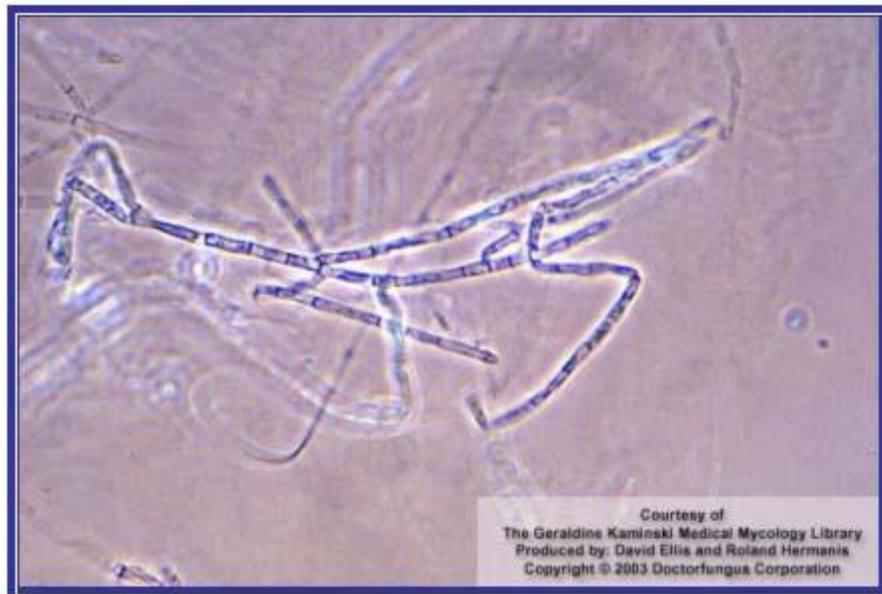
Macroscopic Appearance

- Growth rate is rapid and colonies are flat to sparsely grooved, texture is downy to wooly, and the diameter ranges from 3 to 9 cm after incubation on Sabouraud dextrose agar for 7 days at 25°C; and
- The surface colony color is white to yellowish while the reverse ranges from deep yellow to yellow – orange, occasionally pale.

Microscopic Appearance

- Septate hyphae, macroconidia, and microconidia are present;
- Macroconidia are numerous, spindle – shaped with somewhat re - curved at the apex, with a thick and echinulate cell wall containing 6 to 15 cells; and
- Microconidia are unicellular, clavate to pyriform in shape, and are rarely present.

Microsporum ferrugineum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Microsporum ferrugineum* showing irregular branching hyphae with prominent cross walls ("bamboo" hyphae).

Ecology

Microsporum ferrugineum is a cosmopolitan fungus which is considered as an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation]. It is commonly encountered in Africa, East Asia, and Eastern Europe.

Pathogenicity and Health Effects

Microsporum ferrugineum is a frequent causative agent of tinea infection of the scalp in human adolescents in certain prevalent regions.

Macroscopic Appearance

- Growth rate is slow to very slow and diameter of colonies ranges from 0.5 to 1 cm incubated on Sabouraud dextrose agar at 25°C for 7 days;
- There are two types colonies depending on their physical appearance;
- The first type of colony is heaped, wrinkled, glabrous, and commonly with furrows and folds, and the surface colony color is yellow to rust and the reverse is observed with dull orange pigmentation; and
- The second type of colony is flat, with texture of leathery to downy, spreading, and white in color.

Microscopic Appearance

- Septate and sterile hyphae is produced by *Microsporium ferrugineum* which is commonly deformed and irregularly branched showing a bamboo – like appearance;
- Hyper - segmented, long, straight, and thick – walled hyphae are frequently present; and
- *Microsporium ferrugineum* do not produce macroconidia nor microconidia, however, spindle – shaped macroconidia may be produced on rice grains or in diluted Sabouraud agar.

Microsporium gallinae



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Microsporium gallinae* showing blunt - tipped, cylindro - fusiform shaped macroconidia.

Ecology

Microsporium gallinae is a cosmopolitan fungus which is considered as a zoophilic dermatophyte [found in association with animals and can cause marked inflammatory reactions in humans who have contact with infected cats, dogs, cattle, horses, birds, or other animals] primarily associated with fowl.

Pathogenicity and Health Effects

Microsporium gallinae is a known causative agent of dermal infection in fowl, particularly chickens and turkeys.

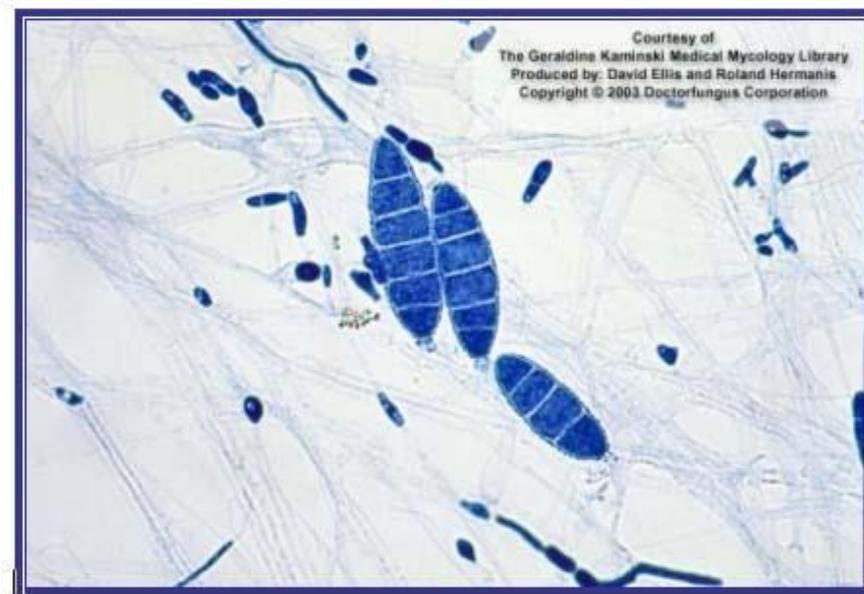
Macroscopic Appearance

- Growth rate is moderately rapid and diameter of colonies ranges from 1 to 3 cm. incubated on Sabouraud dextrose agar at 25°C for 7 days;
- Colonies are moderately wrinkled and with velvety to wooly or cottony texture; and
- The surface colony color is white to gray turning pink to buff as it matures and the reverse is observed with diffusing deep strawberry – red pigment.

Microscopic Appearance

- Septate hyphae, macroconidia and macroconidia are present;
- Macroconidia are club – shaped, commonly curved or narrow at the tip, with a smooth or echinulate cell wall containing 2 to 10 cells, and may be rare or numerous; and
- Microconidia are ovoid to pyriform in shape, unicellular, and may be rare or numerous.

Microsporum gypseum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology *Microsporum gypseum* showing abundant, symmetrical, ellipsoidal, thin - walled verrucose 4 to 6 - celled macroconidia.

Ecology

Microsporum gypseum is a cosmopolitan fungus which is considered as a geophilic dermatophyte [found in association with soil but occasionally infects humans and animals; it may cause a marked inflammatory reaction, which limits the spread of the infection and may lead to a spontaneous cure but may also leave scars]. It is commonly isolated from soil and from fur of small rodents.

Pathogenicity and Health Effects

Microsporum gypseum is an occasional causative agent of scalp or the glabrous skin infections in humans. Infected hairs show little or no fluorescence when examined under the Wood's light [ultraviolet light produced by Wood's lamp]. Additionally, a great variety of animals is infected or may serve as a vector of the fungus.



(Image Courtesy of www.doctorfungus.org @ 2005)

Microsporium gypseum was isolated from the large, circular, erythematous pustular lesion on the wrist of an adult.

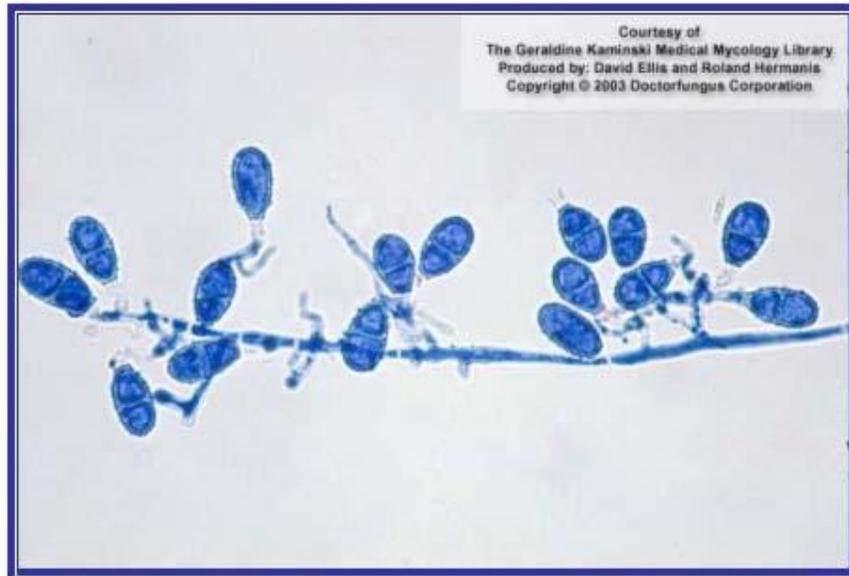
Macroscopic Appearance

- Growth rate is rapid and the texture of the colonies ranges from powdery to granular; and
- The surface colony color is beige to cinnamon brown and the reverse is yellow to brownish red.

Microscopic Appearance

- Septate hyphae, macroconidia and microconidia are present;
- Macroconidia are typically abundant, ellipsoidal to fusiform and symmetrical in shape and with rounded ends, thin – walled containing three to six cells; and
- Microconidia are moderately abundant in number, located along the hyphae, and are club - shaped.

Microsporium nanum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Microsporium nanum*

Ecology

Microsporium nanum is a dermatophyte fungus [fungus that requires keratin for growth and causes superficial infections of the skin, hair and nails] which is both geophilic [species that is usually recovered from the soil] and zoophilic [organisms which prefer lower animals to humans as a source of food] in nature. It is commonly associated with swine.

Pathogenicity and Health Effects

Microsporium nanum is a major cause of tinea infection of the pig. The infection is seldom transmitted to humans.

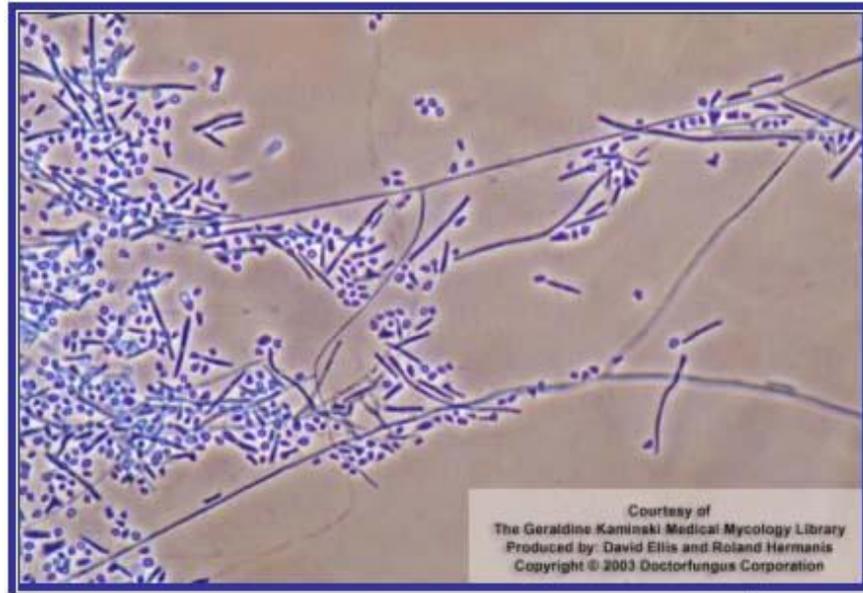
Macroscopic Appearance

- Growth rate is moderately rapid and colonies are powdery, cottony to velvety in texture, may appear thin, spreading, or flat and frequently shows radial, shallow furrows;
- The colony diameter ranges from 1 to 3 cm. at 25°C incubated for 7 days on Sabouraud dextrose agar; and
- The surface colony color is white to beige and the reverse is reddish brown.

Microscopic Appearance

- Septate hyphae, macroconidia and microconidia are present;
- Microconidia are present abundantly, and are club – shaped; and
- Macroconidia are thin – walled, containing one to four cells but normally two cells only, oval to elliptical in shape, and may appear numerous to rare.

Microsporum persicolor



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Microsporum persicolor* showing abundant, spherical to pyriform microconidia.

Ecology

Microsporum persicolor is a dermatophyte fungus [requires keratin for growth and causes superficial infections of the skin, hair and nails] which is zoophilic in nature, having its principal reservoir in small rodents such as the field mouse and vole.

Pathogenicity and Health Effects

Microsporum persicolor is a periodic cause of infection of the scalp, the glabrous skin and the feet in humans. *Microsporum persicolor* – induced animal infections,

principally associated with certain bats and rodents, are also found in dogs at times.

Macroscopic Appearance

- Growth rate is rapid and texture of colonies varies from downy to powdery; and
- The surface colony color is yellowish to rosy and the reverse is uncolored to pink to red.

Microscopic Appearance

- Spiral hyphae are frequently present;
- Microconidia are present abundantly, and are club – shaped or round; and
- Macroconidia appear in primary isolates, smooth – walled, fusiform or bullet – shaped, finely roughened at the tips, and regularly contain six cells.

Mucor Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Order: Mucorales
Family: Mucoraceae
Genus: *Mucor*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of a *Mucor* species showing erect, simple sporangiophores forming a terminal, globose sporangium, packed with sporangiospores and with a well - developed subtending visible columella.

Ecology

Mucor is a cosmopolitan, filamentous, saprobic fungus isolated from soil, decaying organic material, plants, and from most normal stool specimens. *Mucor*

species is widespread in nature and can be encountered as a common laboratory contaminant as well. It may cause infections in humans and animals.

Species

There are several species under the genus *Mucor* and the most common ones are *Mucor amphibiorum*, *Mucor circinelloides*, *Mucor hiemalis*, *Mucor indicus*, *Mucor racemosus*, and *Mucor ramosissimus*.

Mucor strains isolated from human infection are considered as one of the few species that are thermotolerant while most species are unable to grow at 37°C.

Pathogenicity and Health Effects

Mucor species are one of the fungi that can result to zygomycosis infections [refers to the angiotropic, a blood vessel - invading infection, produced by the various Zygomycetes fungi; this disease is also sometimes referred to as mucormycosis, but the term zygomycosis is preferred] which include renal infections, gastritis, septic arthritis, dialysis – related peritonitis, mucocutaneous and rhinocerebral infections, and pulmonary infections. The most frequent influential factors for the development of zygomycosis are immunosuppression and ketoacidosis. Renal failure, extensive burns, desferoxamine treatment, and use of intravenous drugs may also predispose the occurrence of zygomycosis. The common sites of infection are the lung, nasal sinus, brain, eye, and skin. *Mucor* - infections may also have multiple sites.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Mucor mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid at a temperature range of 25 - 30°C and colonies are wooly and fluffy with a height of several cm which resembles a cotton candy;

- Surface colony color is initially white and turning brownish gray at maturation and the reverse is pale; and
- The aromatic *Mucor indicus* may grow at temperatures as high as 40°C, on the other hand, *Mucor racemosus* and *Mucor ramosissimus* at a temperature of 37°C may grow weakly or do not grow at all.

Microscopic Appearance

- Hyphae are non - septate or scarcely septate, broad, and measure 6 - 15 µm in size;
- Sporangiohores [specialized hyphae that bears a sporangium] are short, taper towards their apices, may be branched or unbranched, erect, and may form short sympodial branches;
- Columella [a sterile dome - like structure at the tip of a sporangiophore or within a sporangium] is hyaline or dematiaceous and hardly discernible if the sporangium has not been ruptured;
- Sporangia [sac-like structures producing asexual spores endogenously by cytoplasmic cleavage] are round – shaped, gray to black in color, with size of 50 - 300 µm in diameter, and are filled with sporangiospores;
- Sporangiospores [asexual spores produced within a sporangium] are round to ellipsoidal and with size of 4 - 8 µm in diameter;
- Collarette may at times be left at the base of the sporangium after its rupture; and
- Apophysis, rhizoid and stolon are absent while zygosporangia, if present, arise from the mycelium.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

There are only a few available data on the *in vitro* susceptibility testing of *Mucor* species isolates. Amphotericin B yielded the lowest MICs against *Mucor* species as based on the study conducted on the *in vitro* activity of amphotericin B, ketoconazole, itraconazole, and voriconazole

Treatment of *Mucor* infections remains difficult due to its characteristic of being able to invade the vascular tissues thus, the infarction of the infected tissue is common and mortality rates are very high. Surgical debridement and antifungal therapy are usually required. The most commonly used antifungal agent is amphotericin B.

Paecilomyces Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eufungi
Order: Eurotiales
Family: Trichocomaceae
Genus: *Paecilomyces*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Paecilomyces variotii* showing chains of single celled phialoconidia (ameroconidia) produced in basipetal succession from a phialide.

Ecology

Paecilomyces is a cosmopolitan filamentous fungus which is isolated from soil and decaying plant material and often associated in decay of food products and cosmetics. Certain species of *Paecilomyces* parasitize insects. *Paecilomyces* is

usually considered as a contaminant as well as a rare pathogenic fungus in humans.

Species

The genus *Paecilomyces* contains several species. The most common are *Paecilomyces lilacinus* and *Paecilomyces variotii*. The colony morphology and microscopic features of the different *Paecilomyces* species aid in distinguishing the species from one another. Thermophilicity is another helpful feature that helps in species identification. *Paecilomyces crustaceus* and *Paecilomyces variotii* are both thermophilic [organism that thrives at a temperature of 50°C or higher] and grow well at temperatures as high as 50°C and possibly at 60°C.

Pathogenicity and Health Effects

Paecilomyces species can cause various infections in humans which are referred to as **paecilomycosis**. The infection ranges from corneal ulcer to keratitis [wide variety of corneal infections, irritations and inflammations], and to endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes] which is due to the growth of *Paecilomyces* following an extended contact lens use or ocular surgery. Additionally, *Paecilomyces* is among the emerging causative agents of opportunistic mycoses in immunocompromised hosts wherein direct cutaneous inoculation may lead to these infections and may involve almost any organ or system of human body. Other infections which have been reported due to *Paecilomyces* include soft tissue, pulmonary, and cutaneous infections, cellulitis, onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus], sinusitis [an inflammation of the paranasal sinuses which may be associated with viral respiratory infections and seasonal allergic problems or hay fever], otitis media [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo], endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood], peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], and catheter - related fungemia [the

presence of fungi in the blood]. *Paecilomyces* species can also cause allergic alveolitis which is an allergic disorder.

Furthermore, *Paecilomyces* can cause infections in animals as well such as hyalohyphomycosis in cats, laboratory rats, turtles, and goats.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Paecilomyces mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colonies are flat, powdery or velvety in texture and mature within three days;
- The surface colony color is initially white becoming yellow, yellow – green, yellow – brown, olive – brown, pink, or violet, depending on the species while reverse is dirty white, buff or brown; and
- A sweet aromatic odor may be observed with older cultures.

Microscopic Appearance

- Septate hyaline hyphae, conidiophores, phialides, conidia, and chlamydospores are present;
- Conidiophores [specialized hyphae upon which conidia develop] are often branched and carry the phialides at their tips, and with size ranging from 3 – 4 x 400 - 600 μm;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are thin, swollen at their bases, elongated at their tips, and are usually grouped in brush – like structures at the ends of the conidiophores;
- Conidia [asexual reproductive spores which function as organs of dissemination] are oval to fusoid in shape, unicellular, hyaline to darkly colored, smooth or rough, and appear in long chains; and
- Chlamydospores are sometimes present.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Limited data are available. Data on *Paecilomyces fumosoroseus*, *Paecilomyces javanicus*, *Paecilomyces lilanicus*, *Paecilomyces marquandii*, and *Paecilomyces variotii* are the ones included. Except for strains of *Paecilomyces lilanicus*, the MICs of amphotericin B tended to be very low while the MICs of flucytosine tended to be very high except for strains of *Paecilomyces variotii*. For all species tested, fluconazole yielded considerably high MICs. Itraconazole and ketoconazole MICs were lowest for *Paecilomyces variotii* compared to other species. Voriconazole has been tested against *Paecilomyces lilanicus* and *Paecilomyces variotii* and has yielded low MICs for both of these species. Appeared active *in vitro* against *Paecilomyces* were posaconazole, the novel triazole UR-9825, and terbinafine. On the other hand, caspofungin lacks positive response against *Paecilomyces lilanicus* but was active *in vitro* against *Paecilomyces variotii*.

Amphotericin B and flucytosine has been successfully used in treatment of some paecilomycosis cases due to *Paecilomyces lilanicus* regardless of high MICs *in vitro*. Additionally, caspofungin combined with itraconazole has also been found to be effective in treating infection caused by *Paecilomyces lilanicus*.

Paracoccidioides Species

Taxonomic Classifications

Kingdom: Fungi

Phylum: Ascomycota

Sub - Phylum: Ascomycotina

Genus: *Paracoccidioides*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Paracoccidioides brasiliensis* showing its multiple, narrow base, budding yeast cells "steering wheels".

Ecology

The natural habitat of *Paracoccidioides* remains unknown, although it has been isolated only on a few occasions from non – medical sources, primarily from humid soil rich in proteins and from the digestive tract of some animals. It has been cultivated from fruit bats and armadillos. *Paracoccidioides* is a thermally dimorphic fungus [may exists as a yeast form or a mold form, depending on the temperature at which they are growing]. Its geographic distribution is restricted

to South America where the majority of cases have been reported, particularly from Brazil, Venezuela, and Colombia. Recently, through random amplified polymorphic DNA analysis, the geographic discrimination of the strains has been made possible.

Species

The genus *Paracoccidioides* contains only one species, *Paracoccidioides brasiliensis*. *Paracoccidioides brasiliensis* is an anamorphic fungus and has no known teleomorph.

Pathogenicity and Health Effects

Paracoccidioides brasiliensis is the etiologic agent of a true systemic mycosis called **paracoccidioidomycosis**. The range of infection of this chronic illness is wide, varying from an asymptomatic infection or progression in the form of a pulmonary or disseminated infection which is characterized by formation of secondary lesions of the buccal, nasal or gastrointestinal mucosa and may also be infected are the lymph nodes and aortitis. Diagnosis of **paracoccidioidomycosis** is often complicated. The infection may become evident several years after exposure to *Paracoccidioides brasiliensis* thus, suggesting the likelihood of a long latent period. This chronic illness is acquired via inhalation of the conidia, followed by primary infection of the lungs. The extent of pathogenicity may differ and appears strain – dependent. The fungal exocellular enzyme called serine – thiol proteinase is a significant virulence factor for tissue invasion. Acute pulmonary and disseminated **paracoccidioidomycosis** may rarely develop in immunocompromised patient. Given the true systemic nature of paracoccidioidomycosis, otherwise healthy individuals are affected.



(Image Courtesy of www.doctorfungus.org @ 2005)

Granulomatous lesion involving the nose following dissemination from the lungs due to *Paracoccidioides brasiliensis*.

Macroscopic Appearance

- *Paracoccidioides brasiliensis* grows in mold form at 25°C and in its yeast form at 37°C due to its characteristic of being a thermally dimorphic fungus;
- At 25°C, the colonies are glabrous and velvety, slow – growing, with diameter ranging from 1 – 2 cm within two to three weeks, the surface color is white, tan or brown while the reverse is yellowish brown to brown;
- At 37°C, the colonies are yeast – like with creamy texture, white in color, heaped, wrinkled or folded; and
- Enriched medium such as brain heart infusion agar supports mold to yeast conversion within ten to twenty days of incubation.

Microscopic Appearance

- At 25°C, formation of hyaline septate hyphae which are sterile and do not sporulate and the conidia produced are oval – shaped, unicellular,

- truncate, with a broad base and rounded tip, and are found along the hyphae; and
- At 37°C, formation of daughter cells which are attached to the mother cell by narrow neck portion which resembles a steering wheel and secondary cells in short chains are formed before the detachment of the original daughter cells from the mother cell.

Laboratory Precautions

Isolates of *Paracoccidioides brasiliensis* must be handled with caution in a biological safety cabinet, even though, most strains are sterile and do not sporulate.

Susceptibility

There are limited *in vitro* data on susceptibility activity of *Paracoccidioides brasiliensis*. Reference method is not standardized as yet and the methods that have been employed for susceptibility analysis also vary thus, meaningful comparisons are difficult to obtain. Generally, amphotericin B, ketoconazole, itraconazole, fluconazole, and voriconazole relatively yielded low MICs against the yeast phase of *Paracoccidioides brasiliensis*. However, higher itraconazole and fluconazole values have been reported for some isolates in another study. Additionally, cilofungin provided high MICs. Itraconazole now emerges as the drug of choice for treatment of paracoccidioidomycosis aside from amphotericin B, sulphonamides, and ketoconazole.

Penicillium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Eurotiales
Family: Trichomaceae
Genus: *Penicillium*



Asian Mold Inspector Laboratory Mold Species Documentation

Microscopic photograph of *Penicillium* species

Ecology

The members of the genus *Penicillium* are all filamentous except for *Penicillium marneffe* which is a thermally dimorphic fungus [may exist as a yeast form or a mold form, depending on the temperature at which they are growing]. *Penicillium* species is cosmopolitan and predominant in regions of temperate

climate. *Penicillium* species figure among the common types of fungi isolated from the environment. It is primarily isolated from soil, decaying vegetation, and from the air.

Penicillium marneffe is prevalent specifically in Southeast Asia where it infects bamboo rats which serve as epidemiological vectors and reservoirs for human infections. Cases of infections due to *Penicillium marneffe* are reported from the mountainous provinces of northern Thailand, Laos, Myanmar, and southeastern China. Additionally, *Penicillium marneffe* is known as pathogenic particularly in patients with AIDS and its detection from blood is considered as an HIV marker in endemic areas.

Some *Penicillium* species, out of the approximately 150 species recognized, are frequently associated in the deterioration of food products, where they may produce mycotoxins while others are known as penicillin – producers.

Species

There are several species under the genus *Penicillium* and the most common ones are *Penicillium chrysogenum*, *Penicillium citrinum*, *Penicillium janthinellum*, *Penicillium marneffe*, and *Penicillium purpurogenum*.

Pathogenicity and Health Effects

Penicillium species are occasional causative agents of human infections and the collective term used to refer to these infections is called **penicilliosis** which include keratitis [wide variety of corneal infections, irritations and inflammations], endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], necrotizing esophagitis, pneumonia, peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen], otomycosis [a superficial infection of the outer ear canal which may which may either be sub – acute or acute and is characterized by inflammation, pruritus, scaling, and severe discomfort], and urinary tract infection. Most reported *Penicillium* infections are encountered in immunosuppressed hosts.

Penicillium verrucosum, aside from being a potential health hazard, produces mycotoxin, called ochratoxin A, which is known as a carcinogen. Mycotoxin production in cereal grains commonly occurs at cold climates.

Penicillium marneffe is a pathogenic fungus which specifically infects AIDS patients who reside at or visit Southeast Asia where the fungus is prevalent, particularly in Thailand and in neighboring countries such as Taiwan and India. **Penicilliosis marneffe** is the collective term used to refer to the variety of infections caused by *Penicillium marneffe*. *Penicillium marneffe* – caused infections are acquired through inhalation and results in initial pulmonary infection, followed by fungemia [the presence of fungi in the blood] and dissemination of the infection wherein complications in the lymphatic system, liver, spleen and bones are frequently encountered. Furthermore, formation of acne – like skin papules on face, trunk, and extremities are observed as symptoms of the infection. Infection due to *Penicillium marneffe* is often fatal.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Penicillium mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

"Molluscum contagiosum" like lesions caused by *P. marneffeii* on the neck of an HIV - positive patient.

Macroscopic Appearance

Penicillium species:

- Growth rate is moderately rapid to rapid and colonies are velvety to powdery in texture and are filamentous and flat; and
- Surface colony color is green, blue – green, gray – green, white, or pinkish and the reverse is pale to yellowish, at times red or brown.

Penicillium marneffeii:

- At 25°C, colonies are flat, filamentous, and radially sulcate and surface colony color is bluish – gray – green at the center and white at the border and the reverse is observed with red, rapidly diffusing soluble pigment;
- At 37°C, colonies are glabrous to convoluted in texture and colony color is cream to slightly pink.

Microscopic Appearance

Penicillium species:

- Hyphae are septate and hyaline, and measure 1.5 to 5 µm in diameter;
- Conidiophores [specialized hyphae upon which conidia develop] may be simple or branched;
- Metulae [sterile cells below the phialides of some *Aspergillus* and *Penicillium* species] are secondary branches that arise from the conidiophores and carry the flask – shaped phialides; and
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length], also referred to as penicilli, appear in brush – like clusters;
- Conidia [asexual reproductive spores which function as organs of dissemination] are round to ovoid, hyaline or pigmented, unicellular,

measure 2.5 to 5µm in diameter, may be rough – or smooth – walled, and appear as unbranching chains at the phialide tips.

Penicillium marneffe

- In a filamentous phase, it is microscopically similar to the other *Penicillium* species;
- In a yeast phase, globose to elongated sausage – shaped cells are observed which measure 3 to 5 µm in diameter and multiply by fission; and
- Arthroconidial yeast – like state, the formation of yeast – like structures and hyphae with arthroconidia, can be achieved by sub – culturing *Penicillium marneffe* to an enriched Brain Heart Infusion medium and incubating it at 35°C for 7 days.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

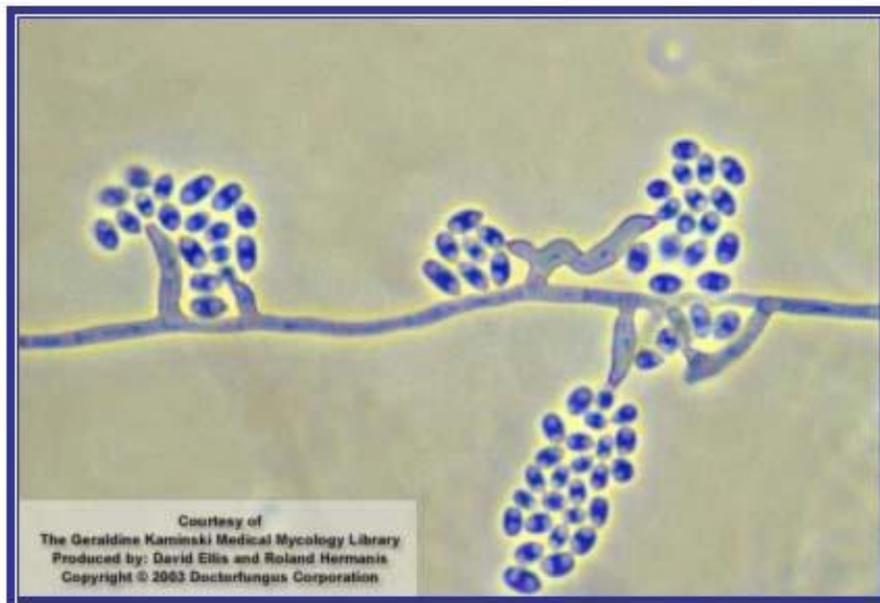
There are only a few available data on the *in vitro* susceptibility testing of *Penicillium* species. MICs of amphotericin B, ketoconazole, itraconazole, and voriconazole for *Penicillium chrysogenum* are acceptably low, while the indicated MICs for *Penicillium griseofulvum* are higher than those for *Penicillium chrysogenum*. MICs of amphotericin B, flucytosine, and fluconazole are relatively high for *Penicillium marneffe* while MICs of itraconazole, ketoconazole, voriconazole, and terbinafine, on the other hand, are relatively low. It must be noted that further data are still required to provide a more accurate susceptibility testing profile for various *Penicillium* species.

For the treatment of **penicilliosis marneffe**, amphotericin B, oral itraconazole, and oral fluconazole have so far been used. Oral itraconazole showed effective result when used prophylactically against penicilliosis marneffe in HIV – infected patients.

Phialophora Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Chaetothyriales
Family: Herpotrichiellaceae
Genus: *Phialophora*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopy morphology of a *Phialophora* sp. showing clusters of single - celled phialoconidia (ameroconidia) produced in basipetal succession from a phialide.

Ecology

Phialophora species is a cosmopolitan, saprobic, dematiaceous filamentous fungus commonly found in soil, decomposing wood, and sub – aquatic debris in bodies of cold fresh water. A dematiaceous fungus is characterized by its darkly

colored fungal body called as thallus due to the presence of melanin in the cell walls of its conidia, hyphae, or both.

Species

The genus *Phialophora* has eight active species namely, *Phialophora americana*, *Phialophora bubakii*, *Phialophora europaea*, *Phialophora parasitica*, *Phialophora reptans*, *Phialophora repens*, *Phialophora richardsiae*, and *Phialophora verrucosa*. *Phialophora europaea* is a newly introduced species. The shape of the collarettes, organization of the phialides, existence of chlamydospores are the morphological features that help in differentiation of the species from one another as well as the species biochemical features such as the melibiose assimilation.

Pathogenicity and Health Effects

Phialophora species are among the causative agents of chromoblastomycosis [a chronic subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells in tissue which appear as similar to copper pennies] and phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. Chromoblastomycosis is a chronic subcutaneous infection characterized by verrucous lesions and the formation of brown, sclerotic fission cells which appear similar to copper pennies. *Phialophora verrucosa* is the chief causative agent of chromoblastomycosis in tropical and sub – tropical areas, especially in Japan and South America. The genus includes several species as well that are known to cause diverse clinical forms of phaeohyphomycosis which includes arthritis, cerebral infection, cutaneous infections, endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], fatal hemorrhage, keratitis, subcutaneous cysts, osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood], and disseminated infection. Additionally, *Phialophora europaea* has been isolated from cutaneous and nail infections in Northwestern Europe



(Image Courtesy of www.doctorfungus.org @ 2005)

Chronic verrucose chromoblastomycosis of the foot due to *Phialophora verrucosa*

Macroscopic Appearance

- Growth rate is moderately slow and the colony texture is woolly to velvety and may be heaped and granular in some isolates;
- Colonies attain a diameter of 2 – 3 cm. following an incubation at 25°C for seven days; and
- Surface colony color is initially white becoming dark gray – green, brown or black while reverse is iron gray to black.

Microscopic Appearance

- Septate hyphae, phialides, and conidia are present;
- The hyphae are hyaline to brown, branched and measures up to 5 µm wide;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are pale brown to brown in color, typically flask – or bottle – shaped, are terminally or laterally located on the hyphae, and with varying length;

- Clearly visible collarettes are found at the tips of the phialides and the collarettes shape varies from one species to another; and
- Conidia are hyaline or brown, smooth, unicellular, with diverse shapes ranging from round to oval or cylindrical, and accumulate in masses at the tips of phialides with collarettes giving the appearance of a vase of flowers.

Table 1. Differences in Microscopic Morphology of *Phialophora* species

<i>Phialophora</i> species	Differences in Microscopic Appearance
<i>Phialophora parasitica</i>	Phialides are longer than 20 µm and spine – shaped and collarettes are narrow with almost parallel contours
<i>Phialophora repens</i>	Phialides are shorter than 20 µm Collarettes are narrow with almost parallel contours
<i>Phialophora verrucosa</i>	Collarettes are vase – shaped
<i>Phialophora richardsiae</i>	Collarettes are saucer - or vase - shaped

Laboratory Precautions

Only general laboratory precautions are required, no special safety measures needed.

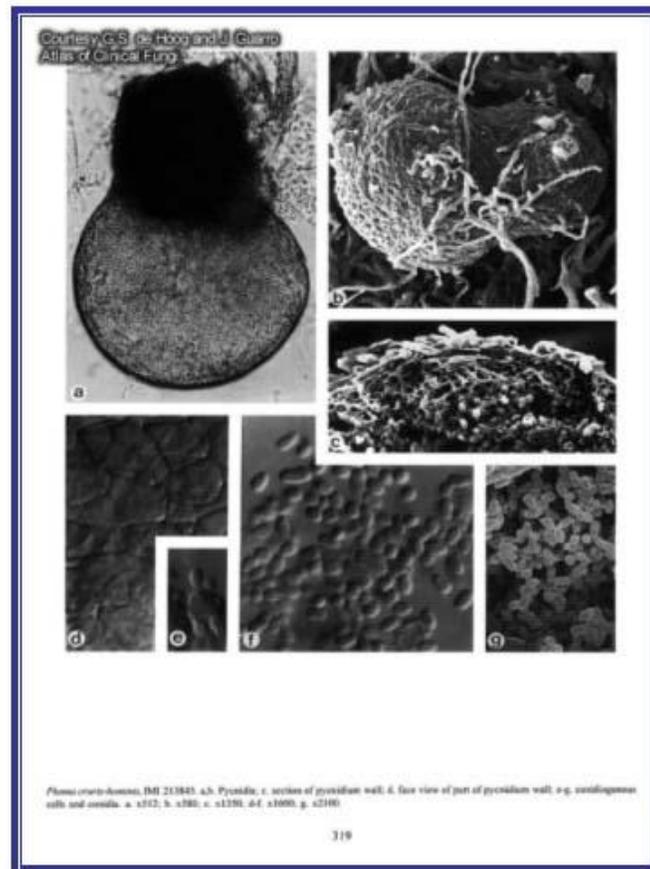
Susceptibility

Very limited data are available. The data show that amphotericin B, itraconazole, terbinafine, and voriconazole are active *in vitro* against *Phialophora americana*, *Phialophora repens*, *Phialophora richardsiae*, and *Phialophora verrucosa*. It is also observed that the MICs of amphotericin B and itraconazole are relatively higher for *Phialophora parasitica* compared to other species. On the other hand, voriconazole is active against *Phialophora parasitica* as well as other *Phialophora* species. Also active against *Phialophora parasitica* is the novel triazole, Syn – 2869. Furthermore, posaconazole shows promising activity against *Phialophora* species.

Phoma Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Order: Pleosporales
Family: Pleosporaceae
Genus: *Phoma*



(Image Courtesy of www.doctorfungus.org @ 2005)

Atlas Scan Images of the microscopic morphology of *Phoma*

Ecology

Phoma is a cosmopolitan, dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color] filamentous fungus that inhabits the soil and plant material. *Phoma* species are common plant pathogens. While they are commonly considered as contaminants, *Phoma* species may cause infections in humans in exceptional cases.

Species

The genus *Phoma* contains several species. However, most of the strains isolated from human infections have not been identified to species level. The morphological features such as the color of the colony, morphology of the conidia, existence and structure of chlamydospores help in species differentiation.

Pathogenicity and Health Effects

Phoma species are among the rarely encountered agents of phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. The infection commonly develops after a trauma. Additionally, immunosuppression is considered a major risk factor for its development. These infections may be cutaneous, subcutaneous, corneal, or (rarely) systemic.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Phoma mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colonies are flat, powdery to velvety in texture, spreading, and frequently submerged in the medium; and
- The surface colony color is initially white becoming olive gray, sometimes with a tint of pink while reverse is dark brown to black with a brown diffusible pigment in some species such as *Phoma cruris - hominis* and

Phoma herbarum which produce a reddish – purple to yellowish – brown diffusible pigment on the reverse.

Microscopic Appearance

- Septate hyphae, pycnidia, conidia, and sometimes, chlamydospores are present;
- Hyphae are septate, hyaline to brown while pycnidia are the fruiting bodies that are large, dark in color, round to pyriform in shape and with size ranging from 70 – 100 μm in diameter, and with one to several openings called the ostioles on their surface from which the conidia are released outside;
- Conidia are hyaline, oval – shaped, unicellular and each conidium usually has two oil droplets inside; and
- Chlamydospores are brown, may appear in long chains or solitary, and may either be unicellular or multicellular and alternarioid which resembles *Alternaria* in appearance.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

No data are available.

Rhinocladiella Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Fungi Imperfecti
Genus: *Rhinocladiella*



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Microscopic morphology of *Rhinocladiella*

Ecology

Rhinocladiella is a cosmopolitan fungus which can be found in soil, herbaceous substrates, and decaying wood.

Species

This genus lacks a known sexual state and is generally classified as a dark – walled dematiaceous fungus. There are two existing species under the *Rhinocladiella* genus namely, *Rhinocladiella aquaspersa* and *Rhinocladiella atrovirens* while the remaining five species have been obsolete and have been only considered by experts as synonyms for a few species under *Fonsecaea* and *Exophiala* genera.

Pathogenicity and Health Effects

To date, there are only three cases of subcutaneous infection that have been reported as caused by *Rhinocladiella aquaspersa*.

Macroscopic Appearance

- Growth rate is slow to moderately rapid;
- Colony texture is velvety;
- Both surface and reverse colony color is olive black.

Microscopic Appearance

- Hyphae are septate and brown in color;
- Conidia [asexual reproductive spores which function as organs of dissemination] are pale brown in color, ellipsoidal to club – shaped, unicellular mostly or maybe bicellular at times, borne on denticles, and are arranged in a closely spaced series at and beneath the tip of the conidiophore; and
- Conidiophores [specialized hyphae upon which conidia develop] are brown in color, simple, and cylindrical in shape.

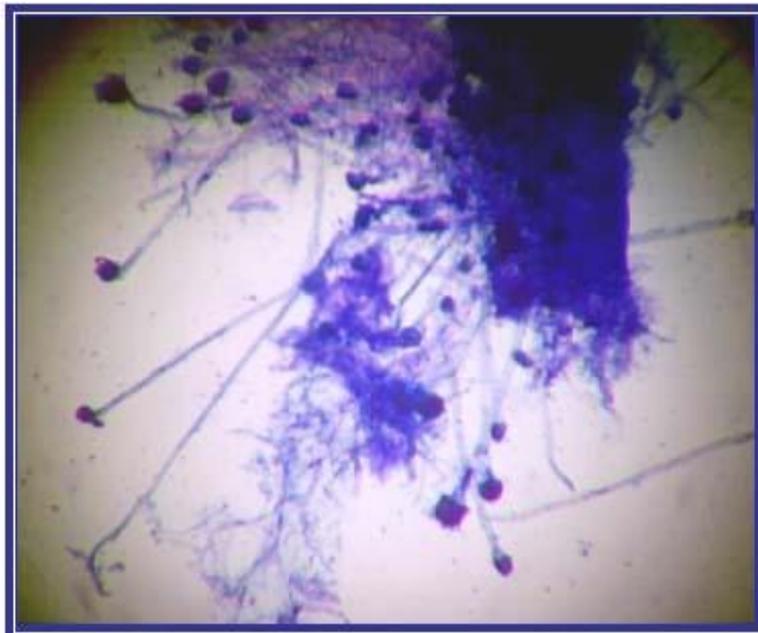
Remarks

Rhinocladiella, unlike *Fonsecaea*, does not have secondary ranks of conidia arising out of the initially formed conidia. Only a single rank of conidia is observed at the tip of the conidiophore. It should be also noted, however, that *Rhinocladiella* forms are also occasionally observed in polymorphous fungi such as *Exophiala* and *Fonsecaea*.

Rhizomucor Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Order: Mucorales
Family: Mucoraceae
Genus: *Rhizomucor*



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Note the poorly developed rhizoid of *Rhizomucor* species as seen on the bottom left - side of the microscopic photograph above, viewed under 40X objective.

Ecology

Rhizomucor is a cosmopolitan filamentous fungus that thrives in soil and decomposing fruit and vegetable matter. *Rhizomucor* species are often isolated from composting or fermenting organic matter and they are also rare agents of serious to fatal infections in humans. Except for *Rhizomucor variabilis*, *Rhizomucor*

species are thermophilic [organism that thrives at a temperature of 50°C or higher] in nature and can grow at temperatures as high as 54°C.

Species

The genus *Rhizomucor* contains three species namely, *Rhizomucor pusillus*, *Rhizomucor miehei*, and *Rhizomucor variabilis*. *Rhizomucor variabilis* is very close to *Mucor hiemalis* phylogenetically. Maximum growth temperature, biochemical assimilation profile, thiamine dependency, and the diameter of the sporangia are the characteristics that aid in the differentiation of the three *Rhizomucor* species from each other. *Rhizomucor miehei* is homothallic while *Rhizomucor pusillus* is either homo - or heterothallic.

Pathogenicity and Health Effects

Rhizomucor species are occasional agents of angio – invasive disease referred to as zygomycosis, which is often considered as fatal. The most frustrating features of this disease are vascular invasion that causes necrosis of the infected tissue, and perineural invasion. *Rhizomucor pusillus* is seldom an agent of cutaneous, pulmonary, rhinofacial, and disseminated zygomycosis especially infecting neutropenic patients with hematological malignancies and diabetes mellitus. Otherwise healthy individuals have been reported with cutaneous infections caused by *Rhizomucor variabilis*. Aside from human infections, animal infections are common as well such as bovine mycotic abortion due to *Rhizomucor* species.

Macroscopic Appearance

- Growth rate is very rapid and colonies are typically cotton – candy like in texture;
- The surface colony color is initially white becoming gray to yellowish brown in time while reverse is white to pale; and
- *Rhizomucor* species other than *Rhizomucor variabilis* are thermophilic and yield optimum growth at temperatures as high as 54°C.

Microscopic Appearance

- Non – septate or scarcely septate broad hyphae, rudimentary rhizoids, sporangiophores, sporangia, and sporangiospores are present;
- Rudimentary rhizoids [short branching root-like hyphae seen in some Zygomycetes] are located on stolons between the sporangiophores but are often rare or difficult to recognize;
- Sporangiophores [specialized hyphae that bears a sporangium] are irregularly branched, with branches sometimes arranged in an umbel at the apex;
- Sporangia [sac-like structures producing asexual spores endogenously by cytoplasmic cleavage] are brown in color, round - shaped, with well – developed columella, and with diameter ranging from 40 – 80 μm ;
- Sporangiospores are small, round or oval in shape, unicellular, and with diameter ranging from 3 – 4 μm ;
- Apophysis [funnel - shaped swelling of a sporangiophore, immediately below the columella, seen in some Zygomycetes] is absent;
- If present, zygospores are formed in the aerial hyphae, round to slightly compressed, and dark brown to blackish in color;
- The microscopic morphology of *Rhizomucor* appears to be intermediate between that of *Rhizopus* and *Mucor*;
- *Rhizomucor* species differ from *Mucor* by having the ability to grow at 50 - 55°C and by having rhizoids and stolons;
- *Rhizomucor* species differ from *Rhizopus* by having branched sporangiophores and rhizoids not arising opposite the sporangiophores; and
- *Rhizomucor* species differ from *Absidia* by having globose sporangia and sporangiophores that are not swollen where they join together with the columellae.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

In vitro susceptibility data are not available for *Rhizomucor* species.

Treatment of *Rhizomucor* infections includes antifungal and surgical therapy, which is also similar to the treatment of zygomycosis caused by fungi belonging to class Zygomycetes. For antifungal treatment, amphotericin B is most commonly used such as liposomal amphotericin B. Early diagnosis and treatment are vital and mortality rate is high.

Rhizopus Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Zygomycota
Order: Mucorales
Family: Mucoraceae
Genus: *Rhizopus*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Rhizopus oryzae*

Ecology

Rhizopus is a cosmopolitan filamentous fungus frequently isolated from soil, decaying fruit and vegetables, seeds, nuts, animal feces, and old bread. *Rhizopus* as an indoor environment mold monster – guest is commonly found in house dust, vegetable garbage, and forgotten leftover foods.

Aside from being known as common contaminants, *Rhizopus* species are also occasional causes of serious, and often fatal, infections in humans. Certain species are plant pathogens as well.

Species

The genus *Rhizopus* contains several species. The most common ones are, namely, *Rhizopus arrhizus*, *Rhizopus azygosporus*, *Rhizopus microsporus*, *Rhizopus schipperae*, and *Rhizopus stolonifer*.

Morphological features, such as the length of rhizoids and sporangiophores, the shape of columellae, the diameter of sporangia, and the size, shape and surface texture of sporangiospores, help in species differentiation of *Rhizopus*. Maximum growth temperature also varies from species to another.

Pathogenicity and Health Effects

Rhizopus species are among the fungi causing the group of infections referred to as zygomycosis [refers to the angiotropic, a blood vessel - invading infection, produced by the various Zygomycetes fungi]. Zygomycosis is now the preferred term over mucormycosis for this angio – invasive disease. *Rhizopus arrhizus* is the most common cause of zygomycosis and is followed by *Rhizopus microsporus* var. *rhizopodiformis*.

Zygomycosis infection includes mucocutaneous, rhinocerebral, genitourinary, gastrointestinal, pulmonary, and disseminated infections. The most frequent predisposing factors for zygomycosis include diabetic ketoacidosis and immunosuppression due to various reasons, such as organ transplantation and other factors such as desferoxamine treatment, renal failure, extensive burns, trauma, and intravenous drug use which may also predispose to development of zygomycosis. Heat stroke has been described as a risk factor for disseminated zygomycosis as well. Contaminated adhesive tapes and wooden tongue depressors have been reported to lead to nosocomial outbreaks of zygomycosis. Vascular invasion that causes necrosis of the infected tissue, and perineural

invasion are the most frustrating features of these infections. Zygomycosis is frequently considered as fatal infection.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Rhizopus mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

Rhinocerebral zygomycosis caused by *Rhizopus oryzae* extensive involvement of the orbit and associated MRI image.

Macroscopic Appearance

- Growth rate is very rapid and colonies are typically cotton – candy like in texture;
- The surface colony color is initially white becoming gray to yellowish brown in time while reverse is white to pale; and
- Pathogenic *Rhizopus* species can grow well at a temperature of 37°C.

Microscopic Appearance

- Non – septate or scarcely septate broad hyphae with diameter ranging from 6 – 15 μm , rhizoids, sporangiophores, sporangia, and sporangiospores are present;
- Sporangiophores [specialized hyphae that bears a sporangium] are usually unbranched, brown in color, solitary or appear in clusters;
- Rhizoids [sac-like structures producing asexual spores endogenously by cytoplasmic cleavage] are found at the point where the stolons and sporangiophores meet;
- Sporangia are round with flattened bases, located at the tip of the sporangiophores, and with diameter ranging between 40 - 350 μm ;
- Sporangiospores [asexual spores produced within a sporangium] are unicellular, hyaline to brown in color, smooth or striated in texture, and with size ranging between 4 - 11 μm in diameter; and
- Apophysis [funnel - shaped swelling of a sporangiophore, immediately below the columella, seen in some Zygomycetes] is absent or rarely evident while the columellae are hemispherical.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Limited data are available on the *in vitro* susceptibility profile of *Rhizopus* species. Amphotericin B, based on the study comparing the *in vitro* activity of amphotericin B, ketoconazole, itraconazole, and voriconazole against *Rhizopus arrhizus* strains, yielded low MICs. The MICs of ketoconazole, itraconazole, and voriconazole were similar to one another while slightly higher than those of amphotericin B. Considerably high MICs were detected against *Rhizopus arrhizus* by fluconazole.

Caspofungin and anidulafungin appeared to have limited activity against *Rhizopus* species. Azasordarin derivatives and posaconazole, on the other hand, were found to be active *in vitro* against *Rhizopus arrhizus*. Appeared to be active

against *Rhizopus* species were posaconazole and ravuconazole compared to voriconazole as well.

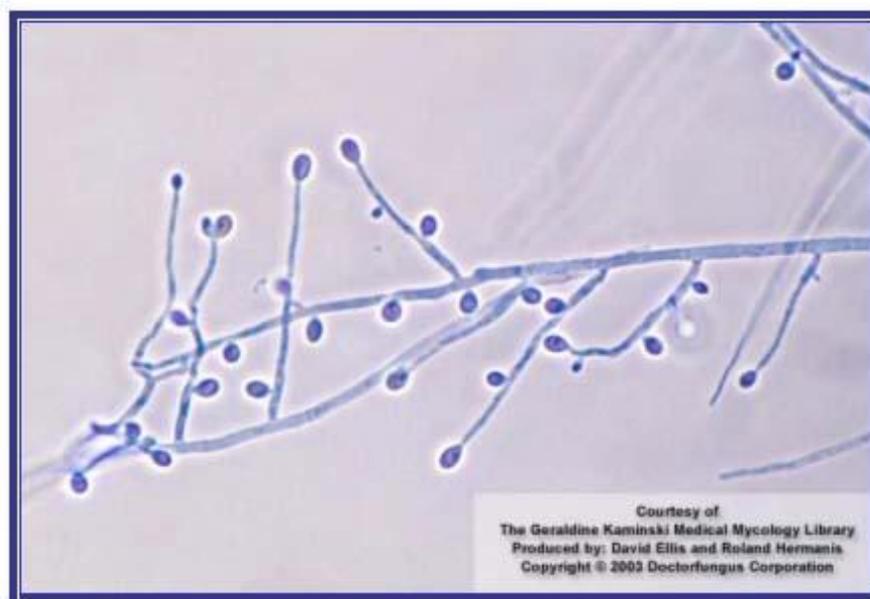
Treatment of *Rhizopus* infections remains difficult due to its ability to invade vascular tissues, infarction of the infected tissue is common and mortality rates are very high. Surgical debridement or surgical resection and well as antifungal therapy are usually required. The most commonly used antifungal agent is amphotericin B. In some cases of zygomycosis, liposomal amphotericin B and other lipid – based amphotericin B formulations such as amphotericin B colloidal dispersion have also been used as treatment.

Frequently, clinical response to therapy is unsatisfactory in zygomycosis. Enhanced clinical response has been anecdotally associated with adjuvant therapy with cytokines, especially the colony stimulating factors. For further validation is the successful use of fluconazole and terbinafine as treatment for zygomycosis. Furthermore, a combination of fluconazole with trovafloxacin or ciprofloxacin proved to be effective in a murine model of pulmonary zygomycosis.

Scedosporium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euascomycetes
Order: Microascales
Family: Microascaceae
Genus: *Scedosporium*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of the anamorphic state *Scedosporium apiospermum* showing numerous, single - celled, pale brown, broadly clavate to ovoid conidia.

Ecology

Scedosporium is a cosmopolitan filamentous fungus which is commonly isolated from rural soils, from polluted water, from composts, and from manure of cattle and fowl. *Scedosporium* occasionally causes infections in humans.

Species

The genus *Scedosporium* contains two species namely, *Scedosporium apiospermum* and *Scedosporium prolificans*. There is no sexual form or teleomorph known for *Scedosporium prolificans* while *Pseudallescheria boydii* is the teleomorph of *Scedosporium apiospermum*.

Pathogenicity and Health Effects

Both immunocompetent and immunocompromised hosts can be infected by *Scedosporium prolificans*. Subcutaneous infections, osteomyelitis [an acute or chronic bone infection, usually caused by bacteria; the infection that causes osteomyelitis often is in another part of the body and spreads to the bone via the blood], and arthritis are commonly post – traumatic and may affect otherwise healthy individuals.

Due to various reasons, on the other hand, disseminated infections which are often fatal are generally encountered in immunosuppressed neutropenic patients. *Scedosporium prolificans* is now the known common causative agent of disseminated phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial]. *Scedosporium prolificans* has been reported to cause ocular infections (keratouveitis) and colonization. Cases with pneumonia [an inflammation of one or both lungs with symptoms of chest pain, chills, cough with sputum production, fever, and shortness of breath], meningoencephalitis [inflammation of the brain and meninges], and endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers] have also been reported.



(Image Courtesy of www.doctorfungus.org @ 2005)

Scedosporium Brain Abscess

Macroscopic Appearance

- Growth rate is very rapid at 25°C and colonies are initially cottony and moist (yeast – like) becoming flat with fine, short, mycelial tufts in texture in maturation; and
- The surface colony color is light gray to black becoming dark gray to black in time while reverse is gray to black;

Microscopic Appearance

- Septate hyaline hyphae, conidiogenous cells (annellides), and conidia are present;
- Annellides [specialized conidiogenous cells producing conidia] may form directly from hyphae or are formed at the tips of the conidiophores, flask – shaped with swollen base part and elongated neck;
- Conidia [asexual reproductive spores which function as organs of dissemination] are oval – shaped, olive to brown in color, with a slightly narrowed, truncated base, unicellular, with size of 2 – 5 x 3 – 13 µm, and

- appear in clusters at the tips of the annellides; Additionally, some isolates may produce round, thick – walled conidia which are formed directly from the hyphae (present in *Scedosporium* asexual state); and
- After two to three weeks of incubation, brown cleistothecia are often present in the sexual state of *Pseudallescheria boydii*.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Scedosporium prolificans is resistant to amphotericin B, flucytosine, ketoconazole, miconazole, fluconazole, and itraconazole. Showed no or very limited *in vitro* activities against *Scedosporium prolificans* isolates are voriconazole, the novel triazole Syn – 2869 and caspofungin.

Although either itraconazole or terbinafine has no activity against most isolates of *Scedosporium prolificans*, the combination of these two drug agents proved to be active in *in vitro* 95% of the isolates after 48 hours of incubation. Additionally, in this combination study antagonism was not observed.

Treatment of infections caused by *Scedosporium prolificans* is difficult due to its primary multi – resistant nature. Therapy of amphotericin B alone or in combination with flucytosine, fluconazole, or itraconazole has been used in *Scedosporium prolificans* - infection cases. The mortality rate, however, has been very high in most disseminated infection cases. Liposomal amphotericin B combined with G - CSF seemed to improve survival in an immunocompromised murine model with disseminated *Scedosporium prolificans* infection. Post – traumatic infections which include arthritis in immunocompetent cases have responded to fluconazole or surgical debridement alone.

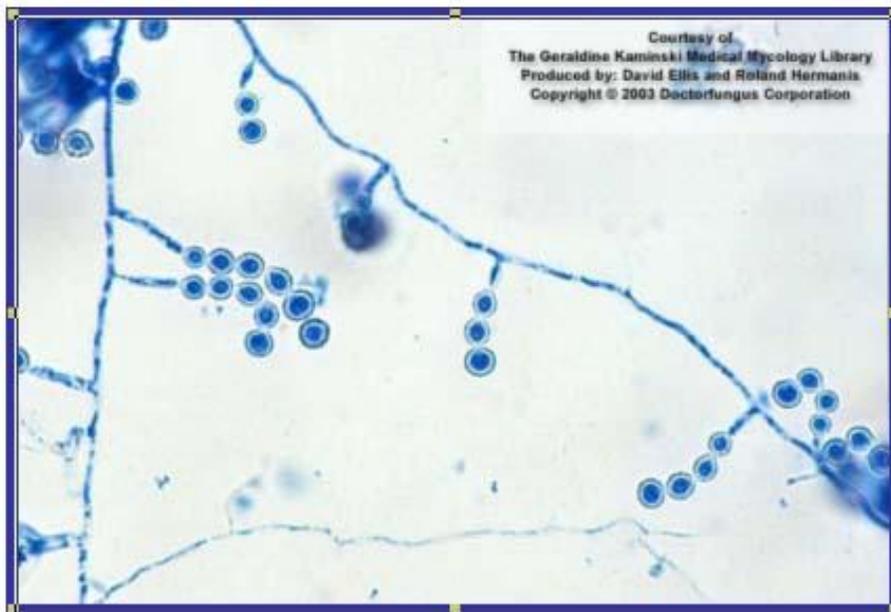
Optimal treatment of *Scedosporium prolificans* infections remains yet unidentified and there is a great demand for novel agents with positive activity. Significantly, the clinical outcome is closely linked with the immune status of the host, degree of the infection, and viability of concomitant surgical debridement.

Finally, optimal treatment of *Scedosporium prolificans* infections remains yet unknown and there is a great demand for novel agents with favorable activity. Significantly, the clinical outcome is closely associated with the immune status of the host, extent of the infection, and feasibility of concomitant surgical debridement.

Scopulariopsis Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Euascomycetes
Order: Microascales
Family: Microascaceae
Genus: *Scopulariopsis*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Scopulariopsis brevicaulis* showing chains of single-celled annelloconidia.

Ecology

Scopulariopsis is a cosmopolitan filamentous fungus that thrives in soil, plant material, feathers, and insects. *Scopulariopsis* species, aside from being considered as contaminants, are agents of infections in humans, particularly in immunocompromised patients. Certain *Scopulariopsis* species attack bee larvae

and silkworms as well. Additionally, *Scopulariopsis* is a weakly keratinolytic fungus which is highly resistant to benomyl. Several species of *Scopulariopsis* have teleomorphs which are placed under the genus *Microascus*.

Species

The genus *Scopulariopsis* is distinctive as it contains both moniliaceous (hyaline) and dematiaceous species [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color], wherein some are considered as clinically important. The most common is *Scopulariopsis brevicaulis* which is a hyaline [colorless] fungus. Other hyaline species include *Scopulariopsis candida*, which maintains its white color at maturity rather than becoming buff - colored, *Scopulariopsis koningii*, *Scopulariopsis acremonium*, and *Scopulariopsis flava*. Dematiaceous species include *Scopulariopsis cinerea* which is the anamorph of *Microascus cirrosus*, *Scopulariopsis brumptii*, *Scopulariopsis chartarum*, *Scopulariopsis fusca*, and *Scopulariopsis asperula*.

Pathogenicity and Health Effects

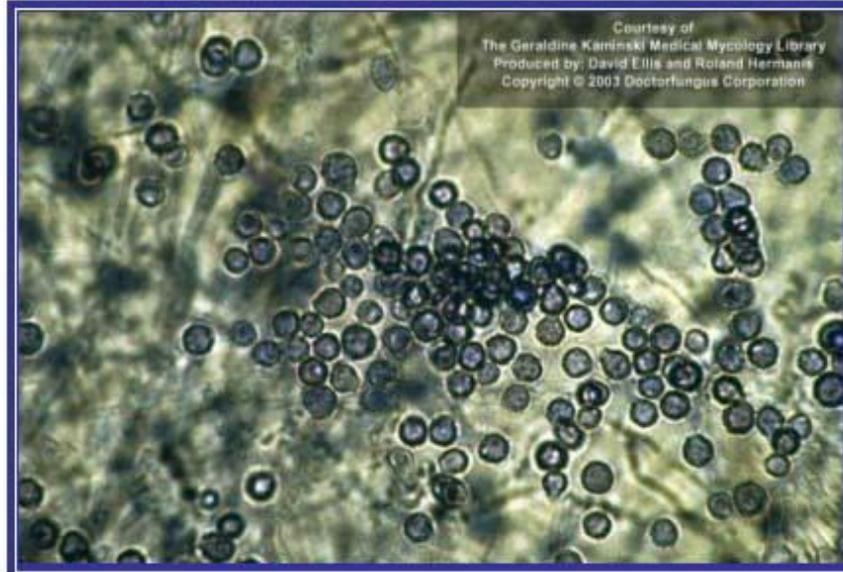
Scopulariopsis species is rarely a cause of human infection. Onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus] especially of the toe nails by *Scopulariopsis* is occasionally reported. Skin lesions, brain abscess [caused by inflammation and collection of infected material coming from local sources which include ear infection, infection of paranasal sinuses, infection of the mastoid air cells of the temporal bone, epidural abscess; or from remote infectious sources, such as lung, heart, kidney, and etc., within the brain tissue; the infection may also be introduced through a skull fracture following a head trauma or surgical procedures], mycetoma [a clinical syndrome characterized by tumefaction, draining sinuses and scleroticia], keratitis [wide variety of corneal infections, irritations and inflammations], endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers], endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], invasive sinusitis, and disseminated infections due to *Scopulariopsis* species have been rarely reported. Infections caused by *Scopulariopsis* are observed mainly in immunocompromised patients such as bone marrow transplant recipients.

The association with human deaths by producing arsine gas from arsenate dyes found in wall paper is considered as one of the striking features of *Scopulariopsis brevicaulis*. Volatilization and methylation of dimethylarsinic acid and methylation of arsenate and arsenite naturally occur in soil. These biochemical reactions have production of trimethylarsine and dimethylarsine as the end - products. Arsenic is found in pesticides as well. **Arsine** [a colorless, flammable, very poisonous gas, H₃As, having an odor like - garlic and used in chemical warfare, as a solid - state doping agent, and in organic synthesis is the most toxic form of arsenic]. It gives off garlic – like odor at concentrations above 0.5 ppm and it is still toxic at concentrations even lower than 0.5 ppm.

In the 1810s, arsenate dyes were manufactured and incorporated into wallpapers and the most famous was **Schweinfurter green**. The widespread use of these green – colored wallpapers has led to the illnesses, such as tubular necrosis and renal failure, and death of people who slept in green wall – papered rooms. Emission of garlic – like odor in some rooms was noted as well. In 1897, B. Gosio, an Italian chemist, showed that the cause of the deaths was due to the production of a gas which could not be identified at that time thus, led to the so – called **Gosio gas**. Then in 1945, Frederick Challenger was able to identify the gas as trimethylarsine which was produced by the mold fungus *Penicillium brevicaulum* which is known today as *Scopulariopsis brevicaulis*. *Scopulariopsis brevicaulis* consumes the starch found in the wallpaper paste while it converts the arsenate found in the paper to trimethylarsine oxide. Lastly, this oxide is further reduced into the fatal and death – causing trimethylarsine gas which is then released. Though this phenomenon was primarily linked only to *Scopulariopsis brevicaulis*, other molds present in the environment may also be able to discharge volatile arsenic compounds theoretically by using the same mechanism.

Several dematiaceous *Scopulariopsis* species are also clinically significant which include the *Scopulariopsis cinerea*, the anamorph of *Microascus cinereus*, which has been reported as the causative agent in human nail infection, in maxillary sinusitis co – existing with *Aspergillus repens*, cutaneous granulomata in a patient with chronic granulomatous disease, endocarditis of a prosthetic valve implanted following the staphylococcal endocarditis of a native valve, and a brain abscess in a bone marrow transplant recipient. The anamorph of *Microascus trigonosporus*, *Scopulariopsis trigonospora*, is an agent of fatal pneumonia in a bone marrow transplant patient. Additionally, the dematiaceous *Scopulariopsis* anamorph of *Microascus cirrosus* is an agent of onychomycosis and disseminated infection in a pediatric bone marrow transplant recipient.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Scopulariopsis mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

A dermatophytosis infection as proven by the presence of *Scopulariopsis* conidia in an infected nail mounted in 10% KOH.

Macroscopic Appearance

- Growth rate is moderately rapid and mature within five days and colonies are velvety to powdery in texture;
- The surface colony color is white initially becoming light brown or buff tan in maturation while reverse is tan with brownish center; and
- Some species may even form dark – colored colonies.

Microscopic Appearance

- Septate hyaline hyphae, conidiophores, annellides, conidia, and chlamydospores (occasionally), are present;

- Conidiophores [specialized hyphae upon which conidia develop] are dark, may be simple or branched, hyphae – like, and with annellides;
- Annellides [specialized conidiogenous cells producing conidia] may be solitary, appear in clusters, or may form a penicillus which are cylindrical and slightly swollen; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are hyaline or dark gray in color, unicellular, globose to pyriform with truncate bases, smooth or rough – walled, and appear in basipetal chains.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Limited data are available on the susceptibility activity of *Scopulariopsis* species. MICs of fluconazole, itraconazole, and the novel azole Syn - 2869 are high, showing that some azoles have no or very limited *in vitro* activity against isolated of *Scopulariopsis*. Flucytosine MICs are also high, while amphotericin B, ketoconazole and voriconazole MICs are variable. Terbinafine with azoles appears synergistic against *Scopulariopsis brevicaulis* isolates. For the determination of the entire extent of *in vitro* activity of various antifungal compounds against isolates of *Scopulariopsis* of various species large – scale studies are required.

Scytalidium Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Fungi Imperfecti
Genus: *Scytalidium*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of the *Scytalidium* anamorph

Ecology

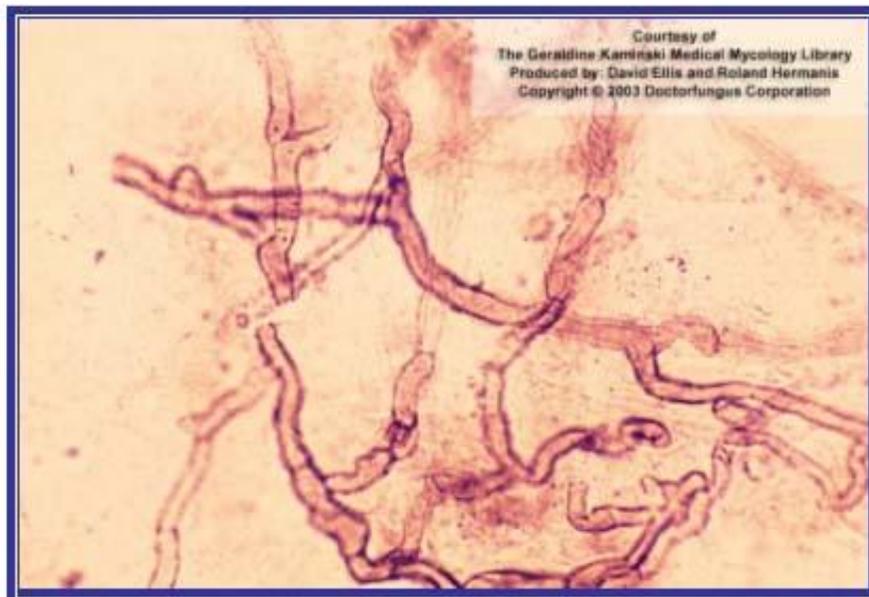
Scytalidium is a cosmopolitan, saprobic fungus [utilizes dead organic matter for food] which is at times associated with decaying wood or soil, and sometimes with woody plants diseases, particularly in tropical and sub – tropical regions.

Species

This genus lacks a known sexual state and is generally classified as a dark – walled dematiaceous fungus. There are five existing species under the *Scytalidium* genus namely, *Scytalidium dimidiatum*, *Scytalidium hyalinum*, *Scytalidium infestans*, *Scytalidium japonicum*, and *Scytalidium lignicola*.

Pathogenicity and Health Effects

Scytalidium species is an occasional agent of nail or skin infections. Some cases of subcutaneous or disseminated infection have also been noted. Additionally, *Scytalidium dimidiatum* and *Scytalidium hyalinum* are causative agents of onychomycosis [refers to non – dermatophyte nail infections or to any fungal nail infection caused by any fungus] and dermatomycosis [fungal infection of the skin, especially of moist parts covered by clothing].



(Image Courtesy of www.doctorfungus.org @ 2005)

Dermatophytosis infection as shown by the presence of brown pigmented hyphae of *Scytalidium dimidiatum* in an infected nail mounted in 10% KOH.

Macroscopic Appearance

- Growth rate is very rapid and colony texture is woolly; and

- Both surface and reverse colony color ranges from white to gray.

Microscopic Appearance

- Hyphae are septate, hyaline or pale gray in color; and
- Arthroconidia [thallic conidia released by either the splitting of a double septum or by the fragmentation or lysis of a disjunctive cell] are hyaline or pale brown in color, ellipsoidal - or oval - shaped, and unicellular or bicellular.

Table 1. Microscopic Feature Differences in *Scytalidium* arthroconidia.

<i>Scytalidium</i> species	Microscopic Features
<i>Scytalidium dimidiatum</i>	Brown – colored arthroconidia
<i>Scytalidium hyalinum</i>	Hyaline arthroconidia

Susceptibility

Scytalidium dimidiatum and *Scytalidium hyalinum* are usually inhibited by cycloheximide.

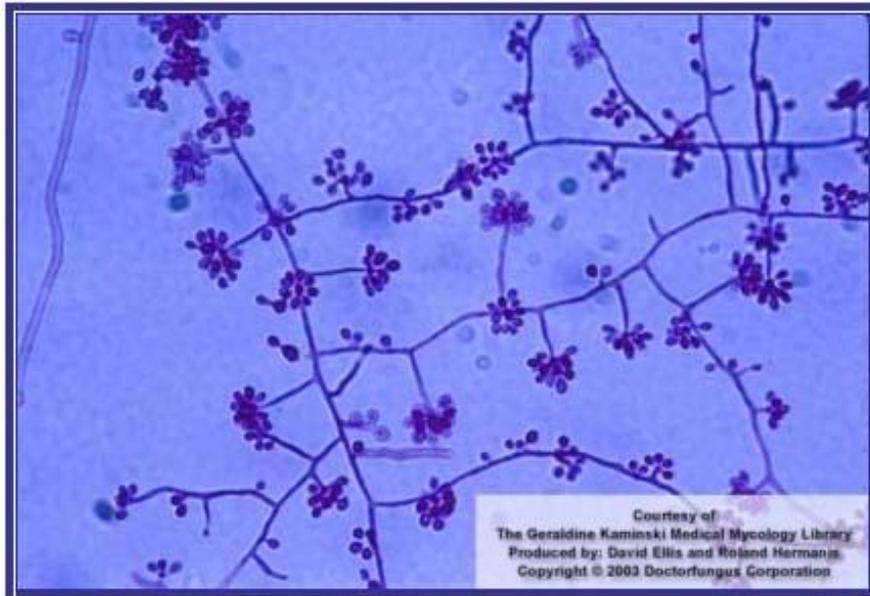
Remarks

Scytalidium, unlike *Geotrichum*, produces wooly colonies and brown – pigmented hyphae and arthroconidia.

Sporothrix schenckii

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Ophiostomatales
Family: Ophiostomataceae
Genus: *Sporothrix*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Sporothrix schenckii*

Ecology

Sporothrix is a cosmopolitan and thermally dimorphic fungus [may exist as a yeast form or a mold form, depending on the temperature at which they are growing] which is primarily isolated from decomposing plant material, from soil, and living plants particularly, peat moss. *Sporothrix schenckii* is an occasional agent of infections in humans. Despite its worldwide distribution,

infections due to *Sporothrix schenckii* are more frequently encountered at certain geographical areas, such as Peru which is known as an area of hyperendemicity for *Sporothrix schenckii* infections.

Species

Sporothrix schenckii is only active species under the genus *Sporothrix*.

Pathogenicity and Health Effects

Sporothrix schenckii is the causative agent of **sporotrichosis**, an infection which is most commonly chronic and subcutaneous, or progressive and lymphocutaneous and may affect otherwise healthy individuals. The infection is initiated following the entry of the pathogenic fungus through the skin via a minor trauma.

Infections such as pulmonary and osteoarticular infections, bursal infection, granulomatous tenosynovitis, carpal tunnel syndrome, endophthalmitis [term used by medical eye doctors (ophthalmologists) to describe an inflammation of tissues inside the eyes], invasive sinusitis, meningitis [inflammation of the meninges characterized by early flu – like symptoms and are followed by more serious symptoms which include confusion, fever, headache, loss of appetite, rash, stiff neck, vomiting, and coma; the onset is frequently rapid, and the disease can be fatal within a very short period of time, if untreated, as it can cause permanent damage to the brain and nervous system and is sometimes the cause of deafness], and disseminated sporotrichosis have been described. In immunocompetent individuals, the infection remains localized while in immunosuppressed patients, such as those with AIDS, fungemia and dissemination infection may be observed. Furthermore, patients with diabetes mellitus and alcoholism are prone to develop fatal fungemia. In alcoholic individuals, primary pneumonia without cutaneous disease may also develop.

An epidemic of **sporotrichosis**, interestingly, has been reported after sleeping in rust – stained camping tent and the tent was identified as the source of infection. *Sporothrix schenckii* – infected patients may be misdiagnosed as pyoderma gangrenosum due to the presence of large ulcerations observed during the course of infection.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Sporothrix mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



Lymphocutaneous sporotrichosis showing more advanced, ulcerating lesions developing along the lymph system of the forearm.

Macroscopic Appearance

Sporothrix schenckii is a thermally dimorphic fungus, thus its colony morphology varies depending on the temperature of growth.

At 25°C

- Growth rate is moderately rapid and colonies are moist, leathery to velvety in texture with a finely wrinkled surface; and
- Both surface and reverse colony color is initially white and becomes cream to black at maturation.

At 37°C

- Growth rate is moderately rapid and colonies are yeast – like and creamy in texture; and
- The colony color is cream to beige.

Microscopic Appearance

Similar to the macroscopic morphology of *Sporothrix schenckii*, the microscopic features also varies depending on the temperature of growth. It must be noted that the conversion of the mold – form to yeast – form is required for the precise identification of *Sporothrix schenckii*.

At 25°C

- Hyphae are septate and hyaline;
- Conidiophores are little differentiated from vegetative hyphae, sympodial, with inflated base, and arise from the vegetative hyphae at right angles;
- 1st type: Conidia are hyaline to brown, thin – walled, unicellular, arranged in rosettes at the tips of the conidiophores; and
- 2nd type: Conidia are brown in color, ovoid or sometimes triangular, thick – walled, attached directly to the sides of the hyphae, and are only observed in freshly isolated strains.

At 37°C

- Ovoid or elongated yeast cells are observed and single or multiple buds may be formed by a single yeast cell.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

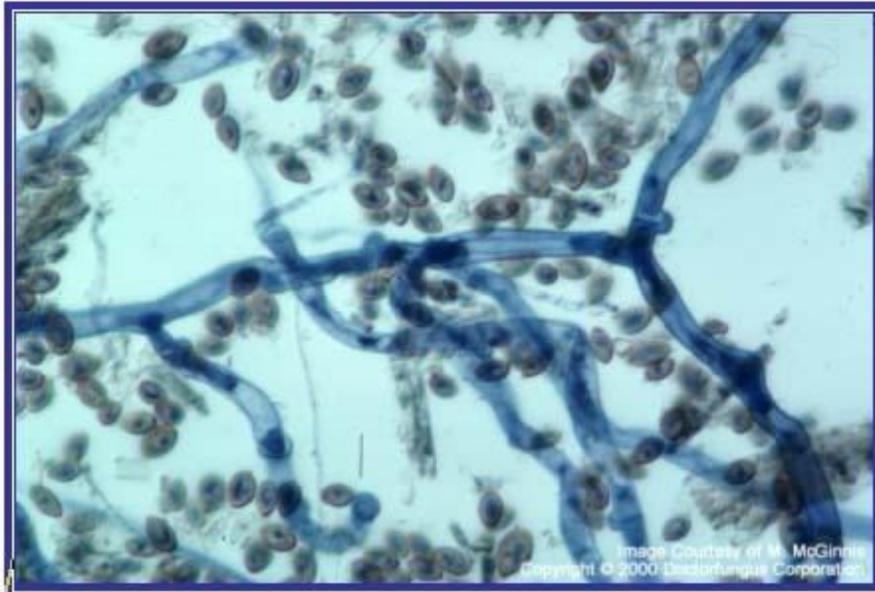
Amorolfine, naftifine, and terbinafine are active *in vitro* against *Sporothrix schenckii*. Fluconazole, ravuconazole, and voriconazole, however, yield high MICs for *Sporothrix schenckii* isolates.

One of the oldest therapeutic modalities used for sporotrichosis treatment is potassium iodide; however, amphotericin B, ketoconazole, and itraconazole are more commonly used as treatment for sporotrichosis infection. In addition, an initial amphotericin B treatment, followed by long – term maintenance therapy may be beneficial in cases with sporotrichosis and AIDS.

Sporotrichum Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Basidiomycota
Class: Hymenomycetes
Order: Stereales
Family: Corticiaceae
Genus: *Sporotrichum*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic Morphology of *Sporotrichum* species

Ecology

Sporotrichum is a cosmopolitan filamentous fungus primarily isolated from soil and decaying wood. *Sporotrichum* species are the anamorphs [asexual state] of basidiomycetous fungi which are important agents of wood decay.

Species

Sporotrichum pruinosum is the only active species under the genus *Sporotrichum*.

Pathogenicity and Health Effects

Sporotrichum are commonly considered non – pathogenic except for *Sporotrichum pruinosum* which has been isolated from the respiratory secretions of some patients which, therefore, is a suggestive of bronchopulmonary colonization by this fungus. Furthermore, *Sporotrichum pruinosum* was observed to produce giant, thick – walled chlamydospore – like structures in tissues, similar to the adiaspores of *Emmonsia parva*.

Macroscopic Appearance

- Growth rate is rapid to very rapid and colonies are velvety to powdery in texture; and
- Surface colony color is white at first and becomes rosy, beige, pinkish, yellow, or orange and the reverse is tannish.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate with clamp connections at the septa;
- Conidiophores [specialized hyphae upon which conidia develop] may be simple or branched, may appear in the form of long, branched stalks, and give rise to aleuriconidia;
- Aleuriconidia [thallic conidia released by lysis or fracture of the supporting cell] are unicellular, ellipsoidal to ovoid, measure 6 x 10 µm in diameter, truncate at the base, thick – walled, golden yellow in color, smooth or rough, are often terminal, numerous, appear in clusters, and may usually retain a portion of the conidiophore, called annular frill, after separation;

- Chlamydozooids are spherical, large measuring up to 60 μm in diameter, thick – walled, and are produced at 25°C as well as 37°C.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

No available published data.

Stachybotrys Species

Taxonomic Classifications

Kingdom: Fungi

Phylum: Deuteromycota (Fungi Imperfecti)

Genus: *Stachybotrys*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Stachybotrys chartarum*

Ecology

Stachybotrys is a cosmopolitan, filamentous fungus commonly isolated as contaminant from nature, such as from decaying plant material and soil, and from indoor environments.

“Prominent indoor reservoirs of Stachybotrys mold include water – damaged wallpapers and jute carpet backing along with their associated glues, plus moist debris in ducts and damp papers and books,” according to Guy St. Germain and R. Summerbell in their famous book entitled, Identifying Filamentous Fungi: A Clinical Laboratory Handbook.

The worldwide distribution of *Stachybotrys* is wide as it has been isolated from contaminated grains, insular foams, tobacco, indoor air, and water – damaged buildings. It is known that *Stachybotrys* has the feature of being a trichothecene [any of a group of mycotoxins found contaminating grain and other foods] mycotoxin – producer. Satratoxin, the specific name of the trichothecene mycotoxin produced by *Stachybotrys* may lead to pathological changes in animal and human tissues.

Species

Stachybotrys chartarum is only the single well – known species under the genus *Stachybotrys*.

Pathogenicity and Health Effects

The trichothecene – type of mycotoxin produced by *Stachybotrys*, specifically called as **satratoxin**, is a potent inhibitor of DNA, RNA, and protein synthesis. This toxin may be acquired by ingestion of fungus – contaminated food products and through direct inhalation of the spores.

In 1920, *Stachybotrys* – caused infections were first observed in cattle and horses in Russia which include conjunctivitis, rhinitis, pancytopenia, and neurological disorders due to consumption of *Stachybotrys* – contaminated hay. The syndrome was called **stachybotrytoxicosis**.

Stachybotrys is popular among health care workers due to its possible role in the development of sick – building syndrome wherein *Stachybotrys* is being one of the contaminants known to inhabit buildings with major indoor moisture problems. It must be noted, however, that *Stachybotrys* is not the only mold isolated from such buildings but *Aspergillus*, *Alternaria*, *Cladosporium*, and *Penicillium* molds as well have been found as inhabitants and are more frequently isolated under these settings. In addition, the definition and diagnosis of sick – building syndrome is vague. Also, sick – building syndrome may result from various chemical, physical, and biological factors which include molds. Therefore, these suggest the likelihood that *Stachybotrys* may play a role in development of sick – building syndrome, but most importantly combined with other hazardous factors.

Stachybotrys also has a possible role in development of acute idiopathic pulmonary hemorrhage and hemosiderosis in infants, who live in water – damaged houses, as there were several infant cases of acute idiopathic pulmonary hemorrhage and hemosiderosis in the years of 1993 to 1998. Furthermore, the fungus was isolated from bronchoalveolar lavage fluid of a child with pulmonary hemorrhage. Medical experts speculated that the rapidly growing lungs of the infants were probably more vulnerable to the hazardous effects of *Stachybotrys* toxins thus; infants were frequently reported to be infected with the fungus and not the adults.

However, later analysis showed that the presented data were uncertain despite all that was reported about the relation of *Stachybotrys* to the early death of infants. It was learned that there was no statistically – significant relation between *Stachybotrys* and acute idiopathic pulmonary hemorrhage.

Therefore, the health risks of environmental exposure to *Stachybotrys* are unclear due to contradicting, limited, and speculative information. The definite responsibility of *Stachybotrys* in the development of human diseases is poorly defined as yet.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Stachybotrys mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Learn all about the medical health effects of *Stachybotrys* and the medical treatment of *Stachybotrys* - caused health problems by reading the [Mold Health Guide](#).

Macroscopic Appearance

- Growth rate is moderately rapid and colonies are powdery in texture; and
- Surface colony color is white, pink, orange or black and reverse is pale, orange, pink or black.

Microscopic Appearance

- Hyphae [single filament of a fungus] are septate and hyaline;
- Conidiophores [specialized hyphae upon which conidia develop] are hyaline or pigmented, simple or branched, with smooth or rough walls, and bear phialides at their apices;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are hyaline or brown, ellipsoidal, appear in clusters of 3 to 10 at the apices of the conidiophores, have swollen upper portions; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are oval – shaped, hyaline or pigmented, one – celled, measure 4.5 x 9 µm in size, and appear in clusters.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

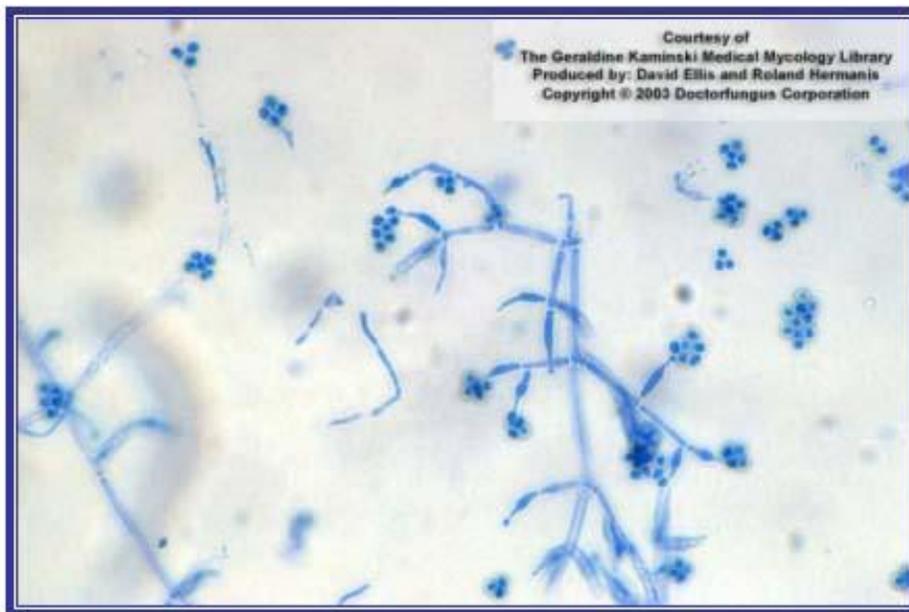
Susceptibility

No available data on the *in vitro* susceptibility profile of *Stachybotrys*.

Trichoderma Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eufungi
Order: Hypocreales
Family: Hypocreaceae
Genus: *Trichoderma*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichoderma harzianum*

Ecology

Trichoderma is a cosmopolitan, filamentous fungus that is commonly isolated from soil and from wood. *Hypocrea* species are the teleomorph [the sexual form or morphology of a fungus] of some *Trichoderma* species. *Trichoderma* may cause

infections in presence of certain influential factors, aside from commonly being considered as a contaminant.

Species

There are five species belonging to the genus *Trichoderma* namely, *Trichoderma harzianum*, *Trichoderma koningii*, *Trichoderma longibrachiatum*, *Trichoderma pseudokoningii*, and *Trichoderma viride*. Apart from these, there are two other species that have been proposed, *Trichoderma asperelum* and *Trichoderma citrinoviride*; however, their identity and clinical significance remain unreliable and unverified. In the differentiation of these species from one another, the morphological features of their conidia and phialides are of great importance.

Pathogenicity and Health Effects

Trichoderma species are usually considered as non – pathogenic, on the other hand, *Trichoderma viride* has been reported as a causative agent of pulmonary infection, peritonitis [an inflammation of the peritoneum tissue that lines the abdominal wall and covers most of the organs in the abdomen] in a dialysis patient, and perihepatic infection in a liver transplant patient. *Trichoderma* infections are opportunistic in nature and develop in immunocompromised patients, such as neutropenic cases and transplant patients, as well as those with chronic renal failure, chronic lung disease, or amyloidosis. Disseminated infections due to *Trichoderma* have also been reported.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Trichoderma mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."

Macroscopic Appearance

- Growth rate is rapid and colonies are woolly becoming compact in time; and
- The surface colony color is white and scattered greenish patches become visible as the conidia are formed and may form concentric rings at times while on the reverse, the color is pale, tan, or yellowish;

Microscopic Appearance

- Septate hyaline hyphae [single filament of a fungus], conidiophores, phialides, and conidia are present;
- *Trichoderma longibrachiatum* and *Trichoderma viride* may also produce chlamydospores ;
- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are hyaline, branched, flask – shaped, inflated at the base, solitary or may appear in clusters, and are attached to the conidiophores at right angles;
- Conidiophores [specialized hyphae upon which conidia develop] are hyaline, branched, and may occasionally demonstrate a pyramidal arrangement; and
- Conidia [asexual reproductive spores which function as organs of dissemination] are unicellular, round or ellipsoidal, green in color, smooth walled or rough, with an average diameter of 3 μm , and are grouped in sticky heads at the tips of the phialides, however, these clusters usually get disrupted during slide preparation procedure intended for microscopic examination.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

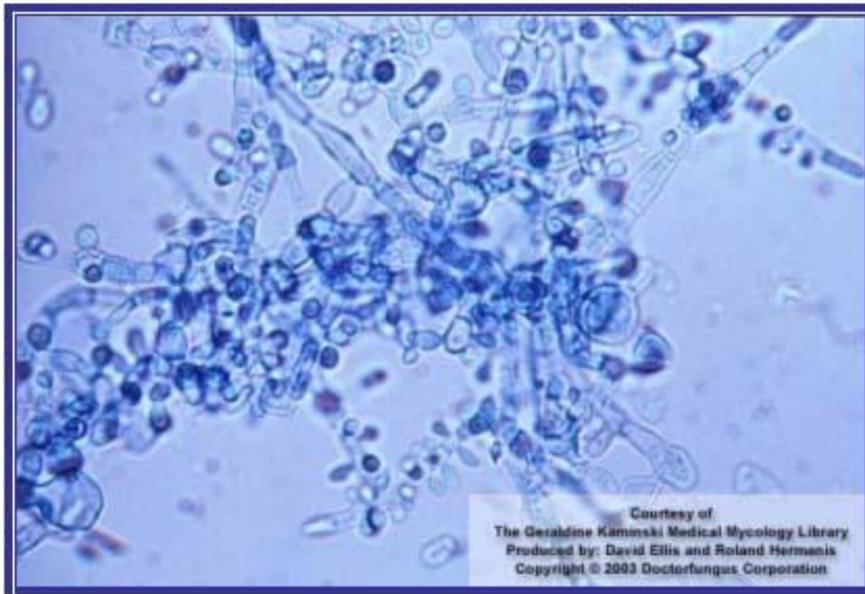
Susceptibility

Very limited data are available with regards to the susceptibility activity of *Trichoderma* species. MICs of amphotericin B and itraconazole may be elevated. Posaconazole, caspofungin, and anidulafungin show promising activity *in vitro* against *Trichoderma* isolates. To note, voriconazole exerts activity against *Trichoderma longibrachiatum* isolates.

Trichophyton Species

Taxonomic Classifications

Kingdom: Fungi
Phylum: Ascomycota
Class: Eueascomycetes
Order: Onygenales
Family: Arthrodermataceae
Genus: *Trichophyton*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of a *Trichophyton* species showing relatively broad hyphae, irregular and much branched with numerous septa.

Ecology

Trichophyton is a dermatophyte fungus [requires keratin for growth and can cause superficial infections of the skin, hair and nails] which is primarily isolated from the soil, humans, or animals. The genus includes anthropophilic [organisms which are attracted to humans especially, as a source of food], geophilic [species that is usually recovered from the soil], and zoophilic species

[organisms which prefer lower animals to humans as a source of food]. Certain *Trichophyton* species are cosmopolitan while others have a limited geographic distribution. *Trichophyton* species that is endemic at Central America, Pacific Islands and Southeast Asia is *T. concentricum*.

Species

There are twenty – two species under genus *Trichophyton*. Most common are *Trichophyton concentricum*, *Trichophyton mentagrophytes*, *Trichophyton rubrum*, *Trichophyton schoenleinii*, *Trichophyton tonsurans*, *Trichophyton verrucosum*, and *Trichophyton violaceum*. Out of the total number of species, eleven are commonly associated with tinea of the scalp, the nails, and the skin in humans while only four are often isolated from animals.

Table 1. Natural Habitats of *Trichophyton* Species

<i>Trichophyton</i> Species	Reservoir
<i>Trichophyton ajelloi</i>	geophilic
<i>Trichophyton concentricum</i>	anthropophilic
<i>Trichophyton equinum</i>	zoophilic (horse)
<i>Trichophyton erinacei</i>	zoophilic (hedgehog)
<i>Trichophyton flavescens</i>	geophilic (feathers)
<i>Trichophyton gloriae</i>	geophilic (feathers)
<i>Trichophyton interdigitale</i>	anthropophilic
<i>Trichophyton megnini</i>	anthropophilic
<i>Trichophyton mentagrophytes</i>	zoophilic (rodents, rabbit) / anthropophilic
<i>Trichophyton phaseoliforme</i>	geophilic
<i>Trichophyton rubrum</i>	anthropophilic
<i>Trichophyton schoenleinii</i>	anthropophilic
<i>Trichophyton simii</i>	zoophilic (monkey, fowl)
<i>Trichophyton soudanense</i>	anthropophilic
<i>Trichophyton terrestre</i>	geophilic
<i>Trichophyton tonsurans</i>	anthropophilic
<i>Trichophyton vanbreuseghemii</i>	geophilic
<i>Trichophyton verrucosum</i>	zoophilic (cattle, horse)
<i>Trichophyton violaceum</i>	anthropophilic
<i>Trichophyton yaoundei</i>	anthropophilic

Pathogenicity and Health Effects

Trichophyton is a keratinophilic filamentous fungus which has the ability to invade keratinized tissues thus; it is considered as one of the leading causes of hair, skin, and nail infections in humans. Possession of several enzymes, such as acid proteinases, elastase, keratinases, and other proteinases are the major virulence factors of *Trichophyton* species.

Out of the total number of species, eleven are commonly associated with tinea of the scalp, the nails, and the skin in humans while only four are often isolated from animals. Additionally, *Trichophyton* species may cause invasive infections in immunocompromised patients. *Trichophyton rubrum* is the commonest causative agent of dermatophytoses [are referred to as "tinea" infections; a characteristic feature is an inflammatory pattern at the edge of the skin lesion, noted by redness and scaling or occasionally, blister formation] worldwide.

Most of the *Trichophyton* species have teleomorphic forms and these teleomorphs are classified under genus *Arthroderma*.

According to the U.S Government's Occupational Safety and Health Administration [OSHA], "Trichophyton mold health effects include hypersensitivity pneumonitis, dermatitis, and it acts as an allergen and irritant."



(Image Courtesy of www.doctorfungus.org @ 2005)

Severe inflammatory kerion lesion of the scalp showing hair loss, scaling and exudate caused by *Trichophyton mentagrophytes kangaroo* variant.

Macroscopic Appearance

- Growth rate may range from being slow to moderately rapid, and colonies are waxy, glabrous, downy to cottony; and
- Surface colony color ranges from white to bright yellowish beige or red violet and the reverse may be pale, yellowish, brown, or red – brown.

Microscopic Appearance

- Hyaline, septate hyphae [single filament of a fungus], microconidia, macroconidia, and conidiophores, and arthroconidia are present, chlamydospores may also be produced;
- Conidiophores [specialized hyphae upon which conidia develop] are little differentiated from vegetative hyphae;
- Microconidia [smaller of two different types of conidia produced by a fungus in the same manner] are unicellular, round - to pyriform – shaped, numerous present, may be solitary or arranged in grape – like clusters;

- Macroconidia [larger of two different types of conidia produced by a fungus in the same manner] are multicellular (with two or more cells), may either be smooth -, thin -, or thick - walled, cylindrical, club - shaped, or cigar - shaped, and are often absent; and
- Several species are typically sterile; however, sporulation may be induced with the use of an appropriate media.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

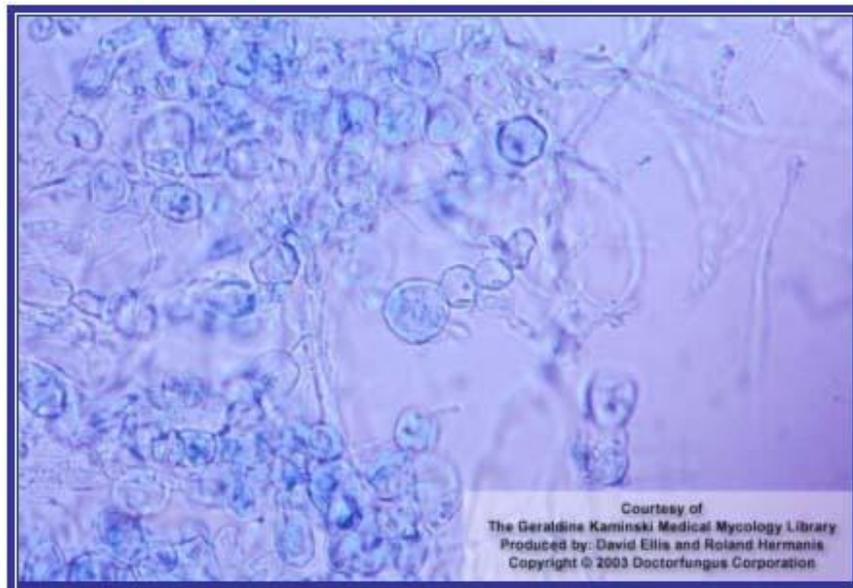
Susceptibility

Generally, amorolfine, clotrimazole, itraconazole, ketoconazole, naftifine, and terbinafine are general active *in vitro* against *Trichophyton* species. Terbinafine usually shows to be the most effective agent. Isolates of *Trichophyton rubrum* are more vulnerable to antifungal agents compared to *Trichophyton mentagrophytes*. Also active *in vitro* against *Trichophyton* species are the azole derivatives, Syn 2869, Syn2836, Syn2903, and Syn2921.

Terbinafine and itraconazole are commonly used now in treatment of infections caused by *Trichophyton* species compared to griseofulvin which is once the drug of choice for dermatophytosis treatment; however, due to the availability of more effective and less toxic drugs griseofulvin is now less commonly used. Oral therapy is usually preferred for treatment of tinea capitis and onychomycosis.

Specific Profiles of the Different *Trichophyton* Species

Trichophyton concentricum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton concentricum* showing broad, much-branched, irregular hyphae, which may have "antler" tips resembling *T. schoenleimii*.

Ecology

Trichophyton concentricum is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] which is primarily isolated from certain peoples from Central America, Oceania, South America, and Central America.

Pathogenicity and Health Effects

Trichophyton concentricum is a causative agent of dermatophytosis infection [referred to as "tinea" infections; a characteristic feature is an inflammatory pattern at the edge of the skin lesion, noted by redness and scaling or occasionally, blister formation] of the glabrous skin which is described by the formation of squamae in concentric and poly - cyclic rings that frequently cover the entire body.



(Image Courtesy of www.doctorfungus.org @ 2005)

Chronic non - inflammatory lesions in inhabitants of Papua New Guinea caused by *T. concentricum* showing characteristic concentrically arranged imbricated rings of scaling.

Macroscopic Appearance

- Rate growth is slow and colonies are glabrous, lightly downy at times; and
- The surface colony color is white becoming cream, amber or brown while the reverse ranges from white to pink or brown.

Microscopic Appearance

- Irregular, septate hyphae are present, appear in favic chandeliers at times;
and
- Both macroconidia and microconidia are absent.

Trichophyton equinum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton equinum* showing abundant microconidia.

Ecology

Trichophyton equinum is a zoophilic dermatophyte [found in association with animals and can cause marked inflammatory reactions in humans who have contact with infected cats, dogs, cattle, horses, birds, or other animals] which is primarily in association with the horse.

Trichophyton exists in two varieties namely, *Trichophyton equinum* var. *equinum* which is distributed worldwide, and *Trichophyton equinum* var. *autotrophicum* which can only be found in Australia and New Zealand.

Pathogenicity and Health Effects

Trichophyton equinum is a common cause of dermatophytosis infection [referred to as "tinea" infections; a characteristic feature is an inflammatory pattern at the

edge of the skin lesion, noted by redness and scaling or occasionally, blister formation] in the horse and it rarely infects humans.

Macroscopic Appearance

- Growth rate is moderately rapid and colonies have a downy texture; and
- Surface colony color is pale yellow while the reverse is deep yellow becoming reddish brown.

Microscopic Appearance

- Microconidia are pyriform – shaped, are formed along the hyphae, and may appear rarely in re – branching clusters; and
- Macroconidia are fusiform to club – shaped which are similar to those of *Trichophyton mentagrophytes*, and are only present rarely.

Trichophyton megninii

Ecology

Trichophyton megninii is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] which can be restrictedly found in parts of Europe, especially in Portugal and in Italy, and in certain regions of Africa.

Pathogenicity and Health Effects

Trichophyton megninii is a causative agent of tinea infection of the glabrous skin, the scalp and the beard. There are no cases of animal infection that have been reported.

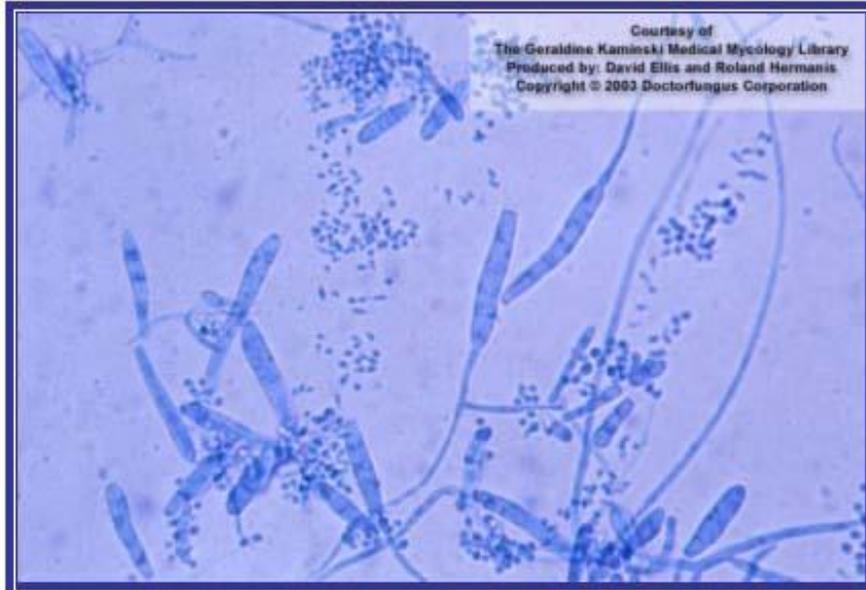
Macroscopic Appearance

- Growth rate is moderately rapid and colonies have a felty to downy texture; and
- Surface colony color is pink while the reverse is deep red.

Microscopic Appearance

- Microconidia are pyriform to club – shaped; and
- Macroconidia are rarely present, pencil – to cigar – shaped which are similar to those of *Trichophyton rubrum*.

Trichophyton mentagrophytes



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton mentagrophytes*

Ecology

Trichophyton mentagrophytes is a cosmopolitan fungus dermatophyte, that requires keratin for growth and can cause superficial infections of the skin, hair and nails, which may either be anthropophilic (attracted to humans especially, as a source of food) or zoophilic (prefer lower animals to humans as a source of food) in nature. The principal reservoirs of the zoophilic varieties in nature are certain small mammals, such as rodents, hedgehogs, and rabbits, however, many other animal species may also be infected.

Pathogenicity and Health Effects

Trichophyton mentagrophytes var. *interdigitale*, the anthropophilic type of isolates, are the frequent causative agents of chronic infection of the feet, the nails, and the groin. When infecting humans, the zoophilic isolates, such as *T. mentagrophytes*

var. *mentagrophytes*, are more frequently associated with inflammatory lesions of the scalp, the glabrous skin, the nails, and the bear region.



(Image Courtesy of www.doctorfungus.org @ 2005)

Large circular lesions with a raised erythematous advancing border on the stomach caused by *Trichophyton mentagrophytes* kangaroo variant.

Macroscopic Appearance

- Growth rate is moderately rapid and texture of anthropophilic isolates ranges from downy to powdery while colonies of zoophilic isolates are granular; and
- Surface colony color is white to pink while reverse is yellowish, brown or reddish brown.

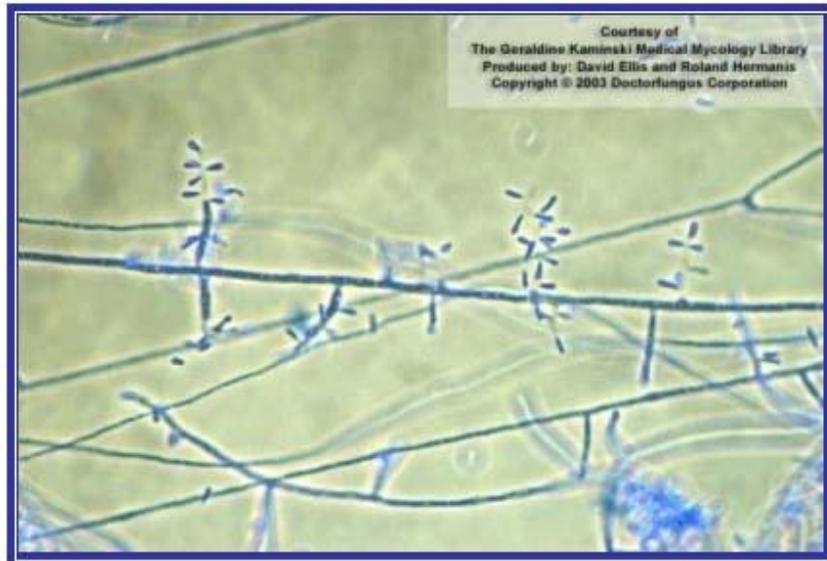
Microscopic Appearance

- Spiral hyphae are frequently present;
- Microconidia are round to pyriform in shape, unicellular, appear in closely re – branched clusters or along with otherwise undifferentiated

hyphae, frequently numerous, however at times, may be present rarely in anthropophilic isolates ; and

- Macroconidia are often absent, but if present, mostly are club – shaped, with thin, smooth walls, multi – septate, and solitary.

Trichophyton rubrum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton rubrum* showing the production of scanty to moderate numbers of slender clavate to pyriform microconidia.

Ecology

Trichophyton rubrum is the most widespread among the anthropophilic dermatophytes. Anthropophilic dermatophyte is a type of a dermatophyte that is found in association with humans.

Pathogenicity and Health Effects

Trichophyton rubrum is the most common agent of tinea infection of the feet, hands, nails, groin, and the glabrous skin, however, the scalp is rarely infected. Animals are very infrequently infected as well.



(Image Courtesy of www.doctorfungus.org @ 2005)

Skin lesion due to *Trichophyton rubrum*

Macroscopic Appearance

- Growth rate is slow to moderately rapid and texture of colonies ranges from downy to powdery; and
- Surface colony color is white to pale pink while reverse is usually wine red, however at times, the color ranges from red, brown, violet, yellow or even uncolored.

Microscopic Appearance

- Presence of microconidia is numerous to rare, club – shaped to pyriform, may be found solitary along the hyphae or sometimes in clusters, and are unicellular; and
- Microconidia are frequently absent; pencil – to cigar – shaped, and are multi - septate.

Trichophyton schoenleinii



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton schoenleinii*

Ecology

Trichophyton schoenleinii is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] which is primarily isolated in certain regions of Africa and Eurasia. *Trichophyton schoenleinii* has previously been detected in some minor endemic areas in the Americas, but has likely now been exterminated from most or all of them.

Pathogenicity and Health Effects

Trichophyton schoenleinii is the causative agent of favus (tinea favosa) of the scalp, a scalp infection which is characterized by the presence of scutula. Scatula is described as crusts which are composed of an accumulation of fungal hyphae and skin debris as shown in the illustration.

Animal infection is rare.



(Image Courtesy of www.doctorfungus.org @ 2005)

Tinea favosa of the scalp with possible occurrence of permanent hair loss and scarring.

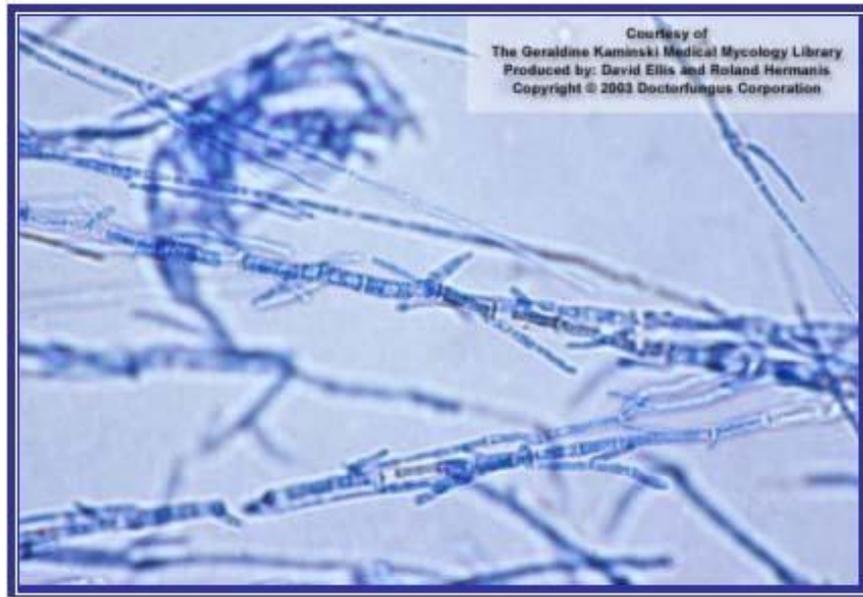
Macroscopic Appearance

- Growth rate is very slow and texture of colonies ranges from glabrous to waxy, but when on sub – culture, the texture is velvety; and
- Both surface and reverse colony color is cream.

Microscopic Appearance

- Hyphae are displayed in the form of “favic chandeliers”, or with “nail head” tips which are often present in the submerged mycelium; and
- Both microconidia and macroconidia are typically absent.

Trichophyton soudanense



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton soudanense*

Ecology

Trichophyton soudanense is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] with geographic distribution limited to certain areas of Africa.

Pathogenicity and Health Effects

Trichophyton soudanense is a frequent causative agent of inflammatory tinea of the scalp in Africa. Animal infection is very rare.

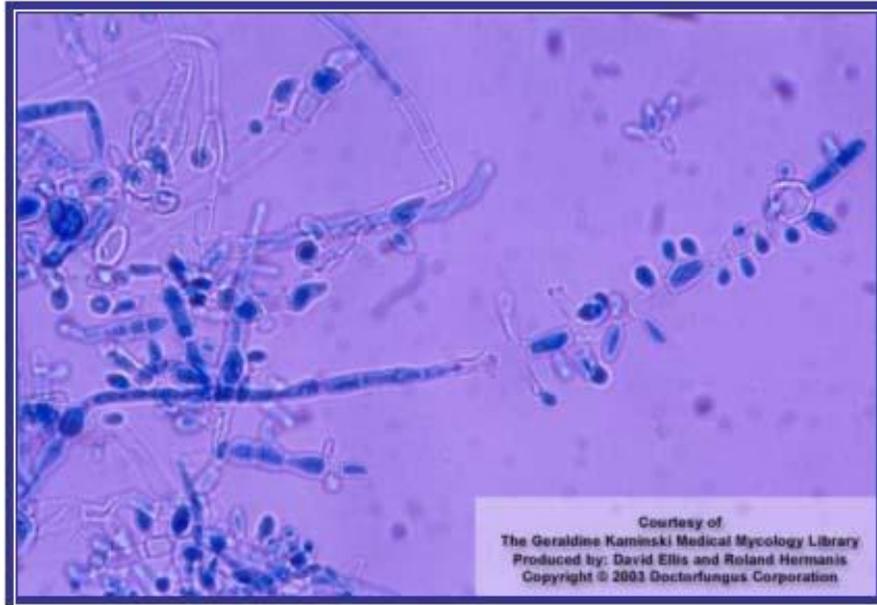
Macroscopic Appearance

- Growth rate is slow to moderately rapid and texture of colonies ranges from glabrous to felty, with a filamentous fridge which surrounds the colony; and
- Both surface and reverse colony color is pale yellow to rusty, red purple at times.

Microscopic Appearance

- Hyphae are observed with reflexive branching and are typically present;
- Microconidia are more or less present, pyriform to ovoid in shape, may appear solitary or in groups; and
- Macroconidia are typically absent.

Trichophyton tonsurans



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton tonsurans*

Ecology

Trichophyton tonsurans is a cosmopolitan and anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] which is commonly isolated in certain regions such as in Mexico, in other countries of Latin America and in large cities in the United States.

Pathogenicity and Health Effects

Trichophyton tonsurans is a causative agent of tinea infections of the scalp and of the glabrous skin or nails. Infection of animals is rare.



(Image Courtesy of www.doctorfungus.org @ 2005)

Circular, finely scaling lesion with distinct erythematous borders on the thigh of a seven year - old Aborigine due to *Trichophyton tonsurans*.

Macroscopic Appearance

- Growth rate is slow and texture of colonies ranges from suede – like, to powdery or velvety; and
- Surface colony color is white, beige, pale yellow, sulfur yellow, or brown while reverse is yellow to dark brown, or red brown.

Microscopic Appearance

- Microconidia are numerous present and with varying shapes and sizes from pyriform to club – shaped, or balloon – shaped; and
- Macroconidia are rarely present, with smooth, thin walls and are sinuous.

Trichophyton verrucosum



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Trichophyton verrucosum*

Ecology

Trichophyton verrucosum is a cosmopolitan zoophilic dermatophyte (a skin – eating fungus that infects animals) which is commonly isolated from cattle and horses.

Pathogenicity and Health Effects

Trichophyton verrucosum is a common causative agent of dermatophytosis infection of cattle and other farm animals. Humans, when contracted of *Trichophyton verrucosum* from an infected animal, may experience a strong inflammatory infection which may typically occur in the scalp, the beard region, or the glabrous skin.



(Image Courtesy of www.doctorfungus.org @ 2005)

Tinea manuum - severe infection of the hand due to *Trichophyton verrucosum*.

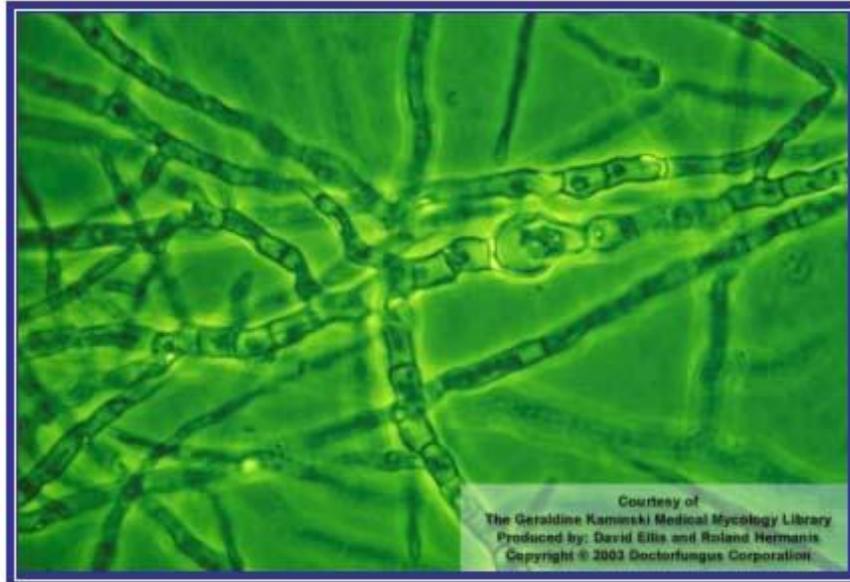
Macroscopic Appearance

- Growth rate is very slow, wherein at 37°C the growth is more rapid compared at 25°C;
- Texture of colonies is glabrous, lightly downy at times; and
- Surface colony color is white, yellow or grayish at times while reverse is without any characteristic pigment.

Microscopic Appearance

- Microconidia are often absent and are club - shaped; and
- Macroconidia are rarely present, and are rat tail – shaped; and
- Chlamydospores are typically present in chains.

Trichophyton violaceum



(Image Courtesy of www.doctorfungus.org @ 2005)

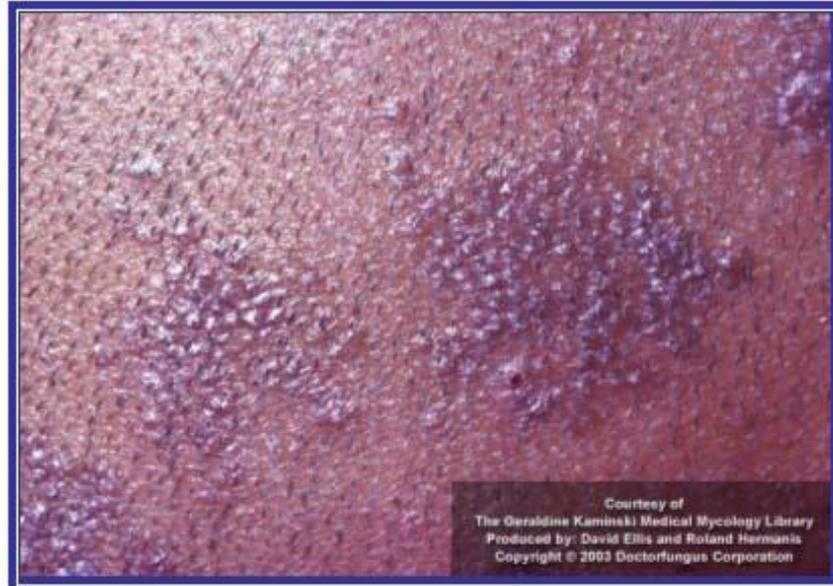
Microscopic morphology of *Trichophyton violaceum* showing broad, tortuous, much-branched, distorted hyphae and lack of conidia.

Ecology

Trichophyton violaceum is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] which is commonly isolated from North Africa and the Middle East, and also from certain parts of Europe. Some prevalent foci exist in South America and Mexico.

Pathogenicity and Health Effects

Trichophyton violaceum is isolated mainly from tinea of the scalp, although it is capable of infecting the glabrous skin, nails, and the soles of the feet. Animal infection is rare.



(Image Courtesy of www.doctorfungus.org @ 2005)

"Black dot" endothrix tinea capitis in an Australian Aborigine showing numerous broken - off infected hairs and pustular lesions of the scalp.

Macroscopic Appearance

- Growth rate is very slow and texture of colonies is glabrous; and
- Both surface and reverse colony color is deep red to violet.

Microscopic Appearance

- Hyphae with an irregular diameter are present;
- Microconidia are typically absent, however, may be present at times when cultured in an thiamine - enriched media; and
- Macroconidia are typically absent while chlamydospores are produced as the culture matures.

Trichophyton yaoundei

Ecology

Trichophyton yaoundei is an anthropophilic dermatophyte [found in association with humans and produces a mild, chronic inflammation] commonly endemic to equatorial Africa, particularly in Cameroons, Zaire, and Mozambique.

Pathogenicity and Health Effects

Trichophyton yaoundei is isolated mainly from tinea of the scalp, although it is capable of infecting the glabrous skin, nails, and the soles of the feet. Animal infection is rare.

Macroscopic Appearance

- Growth rate is very slow and texture of colonies is glabrous;
- Both surface and reverse colony color is cream in color becoming chocolate brown; and
- Brown diffusible pigment is observed within the medium in mature colonies.

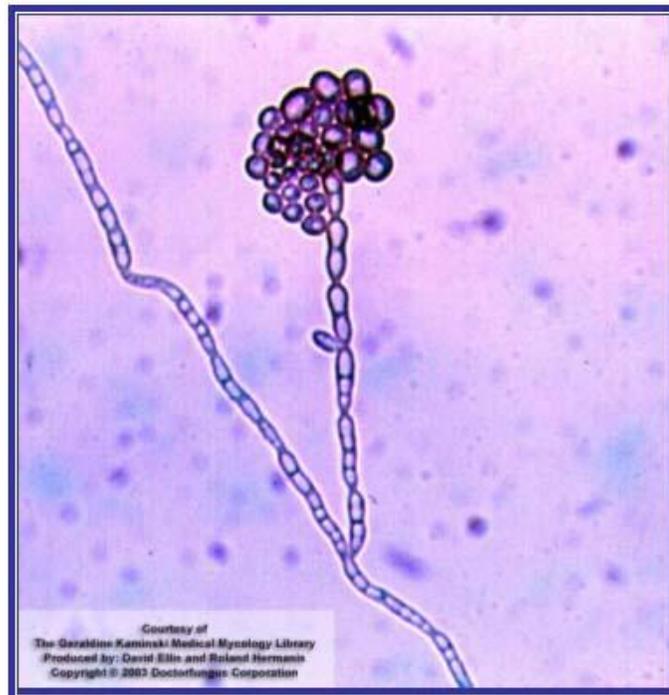
Microscopic Appearance

- Hyphae with an irregular diameter are present;
- Microconidia are rarely present and are pyriform - shaped; and
- Macroconidia are rarely present while chlamydospores are often present.

Wangiella Species

Taxonomic Classifications

Kingdom: Fungi
Order: Chaetothyriales
Genus: *Wangiella*



(Image Courtesy of www.doctorfungus.org @ 2005)

Microscopic morphology of *Wangiella dermatitidis* showing flask - shaped to cylindrical phialides without distinctive collarettes.

Ecology

Wangiella is a dematiaceous [type of fungus with melanin in the cell walls of its conidia, hyphae, or both resulting to its dark color], cosmopolitan saprobic fungus that inhabits the soil and plant material. *Wangiella* species is an occasional agent of various infections in humans.

Species

The only species classified under the genus *Wangiella* is *Wangiella dermatitidis*. However, the taxonomic position of this species is not totally consistent as some authorities would classify it in the genus *Wangiella* as *Wangiella dermatitidis*, others would prefer to classify it in the genus *Exophiala* as *Exophiala dermatitidis*.

Pathogenicity and Health Effects

Wangiella dermatitidis is considered as an occasional agent of subcutaneous phaeohyphomycosis [a mycotic infection of humans and lower animals caused by a number of dematiaceous fungi where the tissue morphology of the causative organism is mycelial] and of disseminated infection in the immunocompromised patient at times. The infection is usually subsequent to the traumatic implantation of the fungus into the dermis, and the fungus normally remains localized. *Wangiella dermatitidis* is a neurotropic fungus. Infections in the central nervous system and as well as cases of keratitis [wide variety of corneal infections, irritations and inflammations], otitis [an inflammation of the ear, which may be marked by pain, fever, hearing abnormalities, deafness, tinnitus and vertigo], pneumonia [an inflammation of one or both lungs with symptoms of chest pain, chills, cough with sputum production, fever, and shortness of breath], and endocarditis [an inflammation and infection of a heart valve or the lining of the heart's chambers] have been reported. In animals, *Wangiella dermatitidis* may cause bovine abortion and still birth.



(Image Courtesy of www.doctorfungus.org @ 2005)

Clinical slide of subcutaneous phaeohyphomycosis following a non - penetrating injury.

Macroscopic Appearance

- Growth rate is slow and colonies are initially moist, shiny, yeast – like becoming velvety around the periphery after incubation at 25°C;
- The surface colony color is black to olive black and as well as on the reverse;
- Aerial hyphae develop after three to four weeks of incubation; and
- *Wangiella dermatitidis* has the ability to grow at high temperatures, as high as 42°C and does not assimilate potassium nitrate.

Microscopic Appearance

- Septate brown hyphae, conidiophores, phialides, and yeast cells are present;
- Brown, budding, yeast – like cells are dominant in young culture when examined microscopically but as the culture gets older, hyphae and phialides are formed from these yeast – like cells;

- Phialides [specialized conidiogenous cells that produce conidia in basipetal succession without increasing in length] are brown, branched, flask – shaped to cylindrical, and without collarettes;
- Conidiophores [specialized hyphae upon which conidia develop] are commonly difficult to differentiate from vegetative hyphae;
- Conidia are unicellular, brown, round - to oval – shaped, with size ranging from 2 – 4 x 2.5 – 6 µm, and are found in clusters at the tips of the phialides and down the sides of the conidiophores; and
- The difference between *Exophiala* species and *Wangiella dermatitidis* is that the former produces annellides [specialized conidiogenous cells producing conidia] while the latter produces phialides. However, it must also be noted that annellide production has been observed in some isolates of *Wangiella dermatitidis*.

Laboratory Precautions

General laboratory precautions are required, no special safety measures needed.

Susceptibility

Very limited data are available with regards to the susceptibility activity of *Wangiella dermatitidis*. It is observed that amphotericin B, itraconazole, terbinafine, and voriconazole are active *in vitro* against *Wangiella dermatitidis* and voriconazole yields lower MICs compared to itraconazole.

Surgical excision appears as the preferred treatment in cases with subcutaneous infection. Amphotericin B alone or in combination with ketoconazole and rifampin has also been used. However, best medical treatment of *Wangiella* infections is not well – known.

Chapter 5

CONTROLLING MOLD MONSTERS

One of the most important issues we face today is our poor indoor air quality due to the presence of elevated levels of mold monsters that are found in our every environment, both indoors and outdoors, all year – round. Mold monsters release millions of killer spores and a number of them can even produce toxic agents known as mycotoxins. Killer spores and mycotoxins can pose negative effects on human health including allergic reactions, asthma, and other respiratory problems.

Mold monsters best thrive in places with moist and humid conditions. Mold infestations are encouraged by indoor moisture sources which include flooding, roof and plumbing leaks, damp basement and crawl spaces, or any moisture condensation on cold surfaces. This problem is often worse in modern, tighter homes with little ventilation.

According to the American Society of Home Inspectors, "About thirty – eight percent of homes have mold growth due to elevated moisture."

For mold monster colonies to grow, a favorable condition with elevated moisture, suitable temperature, and organic food materials is essential. These monsters can grow on cardboard, ceiling tiles, paper and wood products, paints, insulation materials, carpet, fabric, and dry wall. Molds love to grow in damp areas such as crawl spaces, bathrooms [especially shower stalls], basements, refrigerator drip trays, clothing closets, garbage pails, humidifiers, house plants, mattresses, upholstered furniture, and often in new houses due to evaporation of moisture from concrete and lumber.

Mold is only the symptom and moisture is the cause! The only effective way to control biological air contaminants like molds, fungi, dust mites, and bacteria is by tackling the cause. Below are easy – to – follow practical steps to control the unwanted mold monsters in your home:

- Improve ventilation by opening a window if possible to get rid of steam after a bath or shower and while cooking to avoid build – up of moisture;

- Wipe damp surfaces after showering and clean shower curtains and bathroom stalls frequently with effective mold killer such as Borax, a natural mold cleaner;
- Use anti – mold wallpaper adhesives when decorating and add mold – preventive agent to paint;
- Empty water pans below self-defrosting refrigerators frequently;
- Avoid using live Christmas trees and evergreen as decorations;
- Keep shrubs, vines, trees and leaves away from the outside of your home or residence;
- Stored clothes should be well – ventilated;
- Install and maintain an efficient air – conditioner filter ideally HEPA filters which is efficient in removing mold spores and other biological contaminants;
- Reduce indoor humidity level between thirty to forty percent by installing an efficient dehumidifier and check indoor humidity with a hygrometer which can be purchased from Home Depot or any other leading hardware stores;
- Do not use humidifiers and vaporizers as they will increase humidity in the room and create a favorable environment for mold growth;
- Clean all air filters, air conditioner filters and duct filters at an appropriate certain time interval;
- Look out for mold growth in foods stored in the refrigerator;
- Repair any plumbing leaks and other sources of water leakage in your home as soon as possible to reduce mold formation;
- Remove houseplants from your home as soil serves as a good habitat for molds; and
- Dispose garbage daily and clean garbage cans regularly as molds feed on decayed organic waste materials.

You would also be wise to mold test the indoor air of your entire home by using our [Do – It – Yourself Mold Test Kits](#), in contrast to your outdoor mold control test. Mold test the air in each room, kitchen, bathroom, basement, garage and the outgoing airflow of the heating and cooling duct registers to help you determine possible indication of mold cross – contamination within your entire home. You would also be wise to learn the [25 Steps for Safe and Effective Mold Remediation](#) to help you combat molds growing in your home.

Chapter 6

MANAGEMENT OF MOLD MONSTER EXPOSURE

The first step in the management of exposure to mold monster is for the doctor to establish an accurate diagnosis wherein a medical history of the chronology of symptoms and duration of exposure should be obtained. The doctor should ask open – ended question regarding the building’s water intrusion leaks, musty odor, and water stains and the presence of visible creeping mold monster on the walls, carpets, or clothes.

The doctor’s physical examination should deal on the evaluation of rhinitis, asthma, sinusitis, and hypersensitivity pneumonitis. When clinical symptoms suggest allergy, asthma, sinus infection, or hypersensitivity pneumonitis [an acute response to exposure to an organism], laboratory studies, such as radiographs, radioallergosorbent tests, cultures, pulmonary functions tests, and other specialized tests, may be indicated.

The most common mold exposure treatments involve the following:

- **Antihistamines** and avoidance of mold exposure for allergy management;
- **Beta – agonist** and **corticosteroid inhaler** against asthma;
- **Antifungal medications** for treatment of infections; and
- **Prolonged prednisone therapy** for patients with hypersensitivity pneumonitis, however, the patient may have significant disability due to pulmonary impairment.

Mold – related problems usually arise from a prolonged and cumulative breathing in of elevated levels of indoor airborne mold spores. **“Exposure to molds can trigger asthma episodes,” according to the U.S. Environmental Protection Agency.** To learn more on mold – related diseases and other health concerns, you would be wise to read the in – depth **Mold Health Guide**. Or you may read our **Seventy-one Health Home Remedies for Airborne Allergies** book which discusses about the potential airborne allergens as well as it gives practical easy – to – do ways on how to avoid getting exposed to airborne allergy triggers.

REFERENCES

Enlisted are helpful resources of the above information.

Online References:

Advanced Mold Inspections

http://www.lamold.com/pathogenic_mold.html

Answers.com

<http://www.answers.com>

Doctor Fungus.org

<http://www.doctorfungus.org>

Medicine.net

<http://www.medicine.net/>

Mold-Help.org

<http://www.mold-help.org>

Mold Inspector

<http://www.moldinspector.com/>

Paleos Fungi: Glossary

<http://www.palaeos.com/Fungi/Lists/Glossary/GlossaryA.html>

The Amazing Kingdom of Fungi

<http://waynesword.palomar.edu/ww0504.htm>

The Four Divisions of Fungi: A Basic Introduction

<http://www4.d25.k12.id.us/phs/biology/fungi.html>

The Fundamentals of Mold – related Illness

www.postgradmed.com/issues/2003/06_03/fung.htm

The Mold and Mildew Solution for Homeowners

<http://www.radonseal.com/molds-mildew.htm>

The Mycology.net

<http://www.mycology.net>

The University of Adelaide – Mycology Online

<http://www.mycology.adelaide.edu.au>

U.S. Occupational Safety and Health Organization

<http://www.osha.gov>

U.S. Professional Home Inspections

<http://www.usinspect.com/Mold/moldtypes.asp>

Book References:

Carlile, Michael J. et. al. *The Fungi*. 2nd edition. London, Great Britain: AcademicPress, 2001.

Deacon, J.W. *Modern Mycology*. 3rd edition. Oxford, United Kingdom: Alden Group, Oxford, 2001.

Prescott, Lansing M., J.P Harley, and D. A. Klein. *Microbiology*. 2nd edition. U.S.: Wm. C. Brown Publishers, 1993.

St. Germain, Guy and R. Summerbell. *A Clinical Laboratory Handbook: Identifying Filamentous Fungi*. California, U.S.A.: Star Publishing Company, 1996.