

Images in Allergy and Immunology

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An atlas of fungal spores

Fungi are a diverse group of eukaryotic organisms representing evolutionary lines that are distinct from those of plants or animals. More than 80,000 species of fungi have been described; however, most mycologists believe at least 1.5 million species of fungi exist. The majority of fungi reproduce by means of spores that are adapted for airborne dispersal. As a result, airborne fungal spores are an ever-present part of the environment and can be found both outdoors and indoors. The spores of many fungi are well-recognized allergens. In addition, some fungi are known to cause human infections, and some produce mycotoxins.

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FIG 1. Fall air sample from Tulsa, Oklahoma, shows components of the dry air spora that dominate the atmosphere during warm, dry, and windy weather. Spores of many fungi are included in this category; however, this image only shows conidia of *Cladosporium*, *Alternaria*, *Pithomyces*, and *Curvularia* species and smut teliospores. A ragweed pollen grain is also visible in the lower portion of the photo. All of the spores visible in this image are known allergens.

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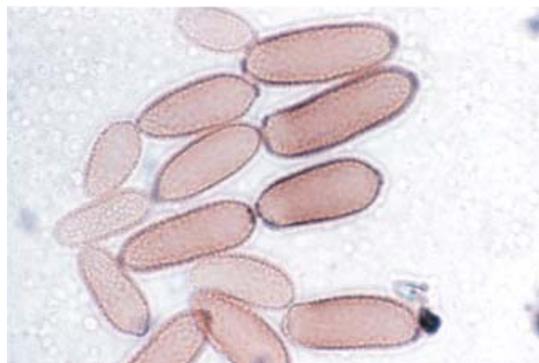


FIG 2. Conidia from *Cladosporium* species are the most abundant airborne spores in many parts of the world, occurring both indoors and outdoors. Hourly atmospheric concentrations of these spores in excess of 200,000 spores/m³ have been registered during high winds. Species of *Cladosporium* normally exist as saprobes or weak plant pathogens and are readily isolated from leaf surfaces. The spores are known to be allergenic, and there have been some reports of *Cladosporium* species infections in immune-compromised individuals. The lightly pigmented spores are produced in branching chains and show refractive attachment scars. The ornamented spores of *Cladosporium herbarum* in this air sample photo are all nonseptate (single celled); however, other *Cladosporium* spores can have 1 to 3 cells and smooth walls. In the older allergy literature, some species of *Cladosporium* were called *Hormodendrum*.



FIG 3. *Alternaria* species are characterized by large multicellular spores with both transverse and longitudinal septa (cross-walls) and a distinct beak. These deeply pigmented conidia are produced in chains, and at the tip of the beak, there is usually a refractive attachment scar. They are frequently the second most abundant spore type in the dry air spora. Species of *Alternaria* are pathogenic to a number of crop plants but also occur as saprobes on a variety of organic substrates, including indoor substrates. *Alternaria* conidia are allergenic and have been associated with severe asthma. Infections in immune-compromised patients have been reported.



FIG 4. Conidia from *Curvularia* species are often present in the outdoor air. The distinctive thick-walled spores are pigmented and normally have 3 or 4 transverse septa. The end cells are frequently lighter in color, and the spores are typically curved because of the asymmetric enlargement of the central cell. A protuberant basal attachment structure is visible on most spores. *Curvularia* species occur as saprobes and plant pathogens causing leaf-spot disease on various crops. Spores are allergenic and have been increasingly implicated in allergic fungal sinusitis.

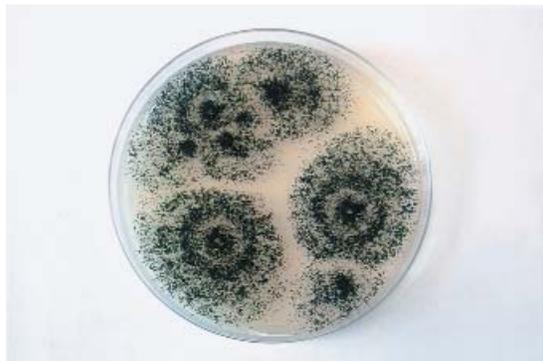


FIG 5. *Aspergillus niger* is one of the common species of *Aspergillus*, a genus characterized by globose heads of conidia. In nature this genus is widespread, typically occurring in the soil. Various *Aspergillus* species are a major cause of decay of agricultural crops in the field and in storage, and many species are also common in contaminated indoor environments. *Aspergillus* conidia are allergenic, and several species (especially *Aspergillus fumigatus*) cause aspergillosis in immune-compromised individuals. In addition, many species of *Aspergillus* are known to produce mycotoxins.

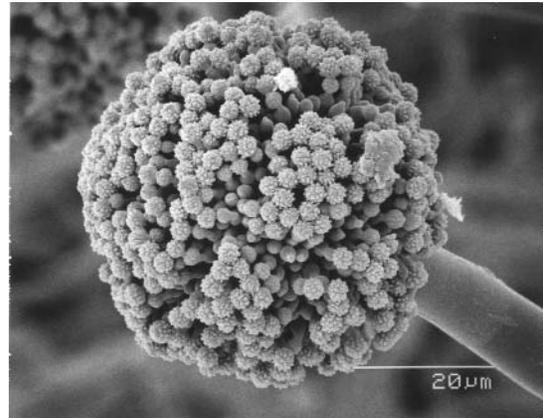


FIG 6. This scanning electron micrograph of a conidial head of *Aspergillus niger* shows developing conidia produced by phialides (visible beneath the spores). Individual conidia are approximately 3 to 4 μm in diameter and ornamented with irregular warts and ridges. Long chains of conidia are normally produced, but only short chains are visible in this young conidial head.



FIG 7. *Ganoderma applanatum* basidiocarps (fruiting bodies) growing from the base of a tree. Species of *Ganoderma* are wood-decay fungi attacking both living and dead hardwoods and conifers. This genus, which has a worldwide distribution, is easily distinguished from other bracket fungi by the unique spores (see Fig 8). A closely related species, *Ganoderma lucidum*, is widely used in Chinese herbal medicine to treat everything from cardiovascular disease to Alzheimer's disease to asthma.

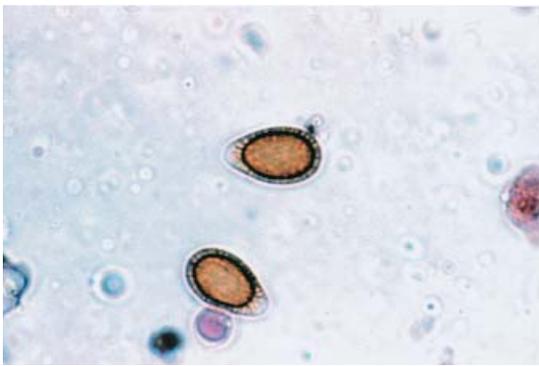


FIG 8. *Ganoderma* spores are the most distinctive basidiospores in the atmosphere, with a golden inner wall and a transparent, smooth outer wall. Interwall connections and a prominent germ pore with a truncated apex are also characteristic features. In some parts of the world, these basidiospores are the dominant component of the air spora for several months of each year. Allergenicity of *Ganoderma* species basidiospores along with basidiospores from other fungi have been reported in numerous clinical studies.

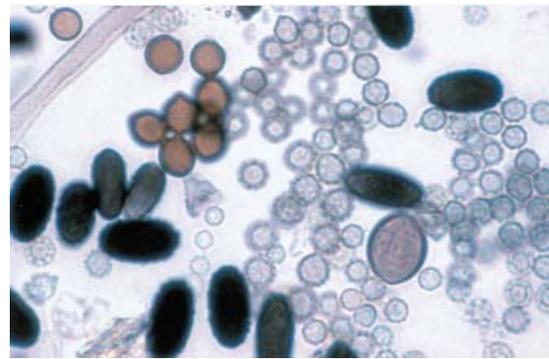


FIG 10. An air sample from a water-damaged home showed fungal spores at a concentration of more than 1 million spores per cubic meter. Visible in this figure are *Penicillium/Aspergillus*-type conidia (small, colorless, ornamented, globose spores), *Stachybotrys* conidia (black cylindrical spores), *Cladosporium sphaerospermum* conidia (pigmented subglobose spores at upper left), and a single *Chaetomium* species ascospore (lemon-shaped spore at lower right).

The author wishes to thank Richard Portman for his assistance with the scanning electron microscope.



FIG 9. Fungal contamination on ceiling tiles in a school bathroom resulted from a plumbing leak on the floor above. Samples from the tiles showed that the contamination was entirely *Stachybotrys chartarum*. This species is commonly found indoors on wet materials containing cellulose, such as wall-board, ceiling tiles, wicker, straw, cardboard, and paper. It has been shown to be allergenic, although little research has been done on the allergens. Also, some strains of *Stachybotrys* are well known to produce potent mycotoxins. There has been a great deal of recent controversy and concern about the possible health effects caused by this fungus.