# Fungal Movement: The Microscopic Circus

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## Overview of this research area

To anyone other than a mycologist, the concept of fungal mobility may seem absurd. After all, fungi are not renowned for their athleticism. A peregrine falcon can dive at speeds in excess of 200 m.p.h., fleas accelerate 20 times faster than the Space Shuttle, and the cosmopolitan sailfish can swim at almost 70 m.p.h., but fungi . . . fungi decompose leaf litter, cause bad smells in damp basements, and grow between our toes . . . aren't they the perfect embodiment of physical stagnation? Research in the Money lab addresses this misconception.

Fungi are the evolutionary champions of fast movement and use a variety of mechanisms to propel themselves into the air. Examples include the pressurized squirting of microscopic spores from cells called asci, the explosive eversion of an elastic membrane that launches the sporangia of the artillery fungus, and the intriguing surface-tension catapult that discharges the spores of mushroom-forming fungi and their relatives. Impressive cases of natural engineering are also involved in much slower fungal movements. The apical growth of invasive hyphae is a type of slow movement that is a defining characteristic of the fungi. Networks of these filamentous hyphae mine nutrients from all kinds of solid materials by exerting hydrostatic pressure and secreting enzymes to dissolve polymers. Mushroom emergence from hard-packed soil offers another dramatic illustration of a slow, but powerful movement.

Some fungal movements occur at very high speeds. For this reason, the most influential studies on fungal movements in the last century relied upon clever inferences rather than direct observation. In the last few years, technological advances in the area of high-speed video microscopy have provided the first unequivocal information on the operation of these processes. Students in the Money lab conduct experiments using this technology.

## Why study fungal movement?

There are many ways to address this question. Here is one argument: For more than 200 years, mycologists have catalogued the shapes and sizes of fungal spores. Entire books have been written about spore morphology within single groups of mushroom-forming fungi and ascomycetes. This morphological information has been used, in a few cases, to make sense of the relationships between different species, the argument being that related species are likely to possess similar spores. But beyond this, these data have revealed nothing about the biology of these organisms. The biomechanical perspective offered by the new research begins to make sense of subtle variations in spore shape, size, and surface ornamentation: these differences have profound effects upon the speeds with which spores are projected into the air and the distances that they travel. It follows, that a biomechanically-informed study of spore morphology may tell us a great deal about the evolutionary history of the fungi and about their contemporary ecology. At a time when American mycology is dominated by molecular phylogenetic studies, biomechanical research on fungal movement offers a novel, refreshing, and complementary approach to the study of biodiversity.

## Resources

For information on the different groups of fungi and their evolutionary relationships, the website www.tolweb.org is a fantastic source for up-to-date information.

The best book on fungal movement is C. T. Ingold's *Fungal Spores: Their Liberation and Dispersal* published in 1971 by Oxford University Press. Although dated, this volume offers a compelling introduction to the ways that fungi achieve dispersal.

Dr. Money has authored and coauthored a number of papers that address recent work on fungal movement. These include:

Money, N. P. 1998. More g's than the Space Shuttle: The mechanism of ballistospore discharge. *Mycologia* 90: 547-558.

Money, N. P., Davis, C. M., and Ravishankar, J. P. 2004. Biomechanical evidence for convergent evolution of the invasive growth process among fungi and oomycete water molds. *Fungal Genetics and Biology* 41: 872-876.

Money, N. P. 2004. The fungal dining habit: a biomechanical perspective. *Mycologist* 18: 71-76.

Fischer, M., Cox, J., Davis, D. J., Wagner, A., Taylor, R., Huerta, A. J., and Money, N. P. 2004. New information on the mechanism of forcible ascospore discharge from *Ascobolus immersus*. *Fungal Genetics and Biology* 41: 698-707.

Money, N. P., and Ravishankar, J. P. 2005. Biomechanics of stipe elongation in the basidiomycete *Coprinopsis cinerea*. *Mycological Research* 109: 628-635.

Pringle, A., Patek, S. N., Fischer, M., Stolze, J., and Money, N. P. 2005. The captured launch of a ballistospore. *Mycologia* 97: 866-871.

Besides the Money lab, few research groups specialize in this area of inquiry, but the following papers are important contributions to this field:

Trail, F., Gaffoor, I., and Vogel, S. 2005. Ejection mechanics and trajectory of the ascospores of *Gibberella zeae* (anamorph *Fuarium graminearum*). *Fungal Genetics and Biology* 42: 528-533.

Vogel, S. 2005. Living in a physical world. II. The bio-ballistics of small projectiles. *Journal of Biosciences* 30: 167-175.

Skotheim, J. M., and Mahadevan, L. 2005. Physical limits and design principles for plant and fungal movements. *Science* 308: 1308-1310.

For general information, students are referred to Dr. Money's books on fungal biology that were written for nonspecialist readers:

Money, N. P. 2002. *Mr. Bloomfield's Orchard. The Mysterious World of Mushrooms, Molds, and Mycologists.* Oxford University Press, New York.

Money, N. P. 2004. *Carpet Monsters and Killer Spores: A Natural History of Toxic Mold.* Oxford University Press, New York.

Money, N. P. 2007. *The Triumph of the Fungi: A Rotten History*. Oxford University Press, New York.

Students interested in graduate study in botany (MS or Ph.D.) at Miami University should consult the department website: www.cas.muohio.edu/botany/; Dr. Money welcomes e-mails to moneynp@muohio.edu