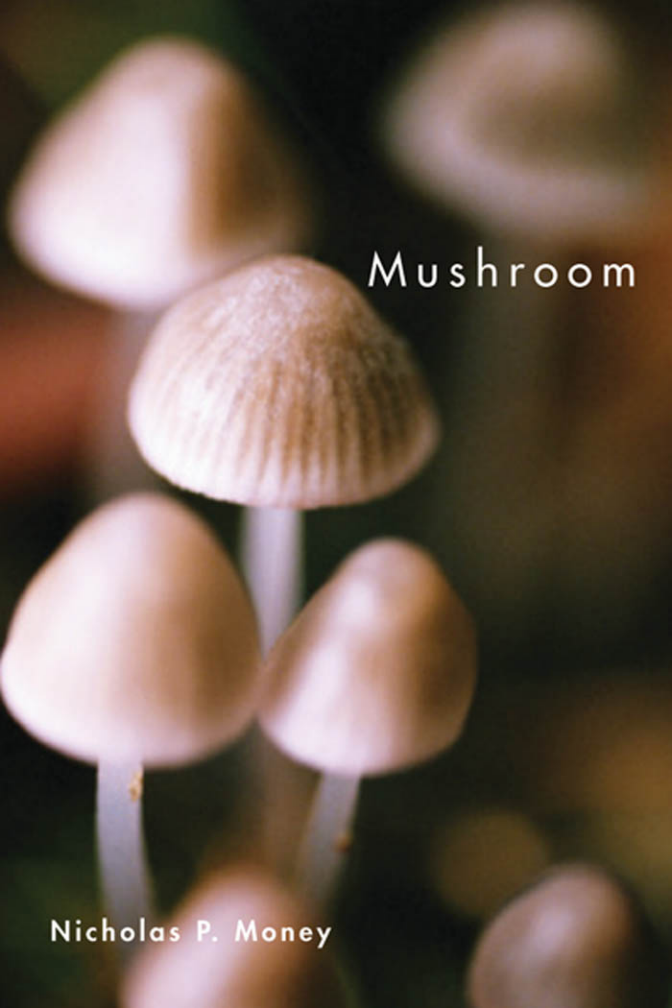
Mushroom
Nicholas P. Money

MUSHROOM

By the Same Author

The Triumph of the Fungi:
A Rotten History

Carpet Monsters and Killer Spores:
A Natural History of Toxic Mold

Mr. Bloomfield's Orchard:
The Mysterious World of Mushrooms, Molds, and Mycologists

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OXFORD
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Oxford New York
Auckland Cape Town Dar es Salaam Hong Kong Karachi
Kuala Lumpur Madrid Melbourne Mexico City Nairobi
New Delhi Shanghai Taipei Toronto

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Argentina Austria Brazil Chile Czech Republic France Greece
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Published by Oxford University Press, Inc.
198 Madison Avenue, New York, New York 10016
www.oup.com

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Library of Congress Cataloging-in-Publication Data
Money, Nicholas P.
Mushroom / Nicholas P. Money.
p. cm.
Includes bibliographical references and index.
ISBN 978–0–19–973256–2 (hardcover : alk. paper)
1. Mushrooms. I. Title.
QK617.M644 2011
579.6—dc22
2011009269

1 3 5 7 9 8 6 4 2

Printed in the United States of America
on acid-free paper

For Diana

Nature alone is antique, and the oldest art a mushroom.

—Thomas Carlyle (1795–1881, Scottish essayist)

Some day the delights of a mushroom hunt along lush pastures and rich woodlands will take the rank of the gentlest craft among those of hunting, and may perchance find its own Izaak Walton.

—Charles McIlvaine, *One Thousand American Fungi* (1900)

a sun struck stinkhorn
sticky with flies
thrusts up under
the skirt of an oak

—Tom Pickard, *Stinkhorn*, from *Hole in the Wall: New & Selected Poems* (Chicago: Flood Editions, 2002)

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PREFACE

As you will have gathered from the title, this is a book about mushrooms. Mushrooms are fungal sex organs and the most wondrous inventions of the last billion years of evolutionary history on earth. If you have missed out on these elemental facts of life, there's no reason for self-flagellation—the next 200 or so pages will soon bring you up to speed.

Mushrooms that appear overnight in a meadow or on a suburban lawn are a marvelous sight. Their growth process is pneumatic, with the inflation of millions of preformed cells from a button extending the stem, pushing earth aside, and unfolding a cap above the dewy grass. Once exposed, a mushroom's gills—arrayed on the underside of its cap—shed an astonishing 30,000 spores per second, delivering billions of microscopic particles into the air in a single day, cells that may be capable of spawning the largest organisms on the planet. Mushroom colonies, gargantuan or lilliputian, burrow through soil and rotting wood. They feed and spread wherever plants live and die. Roll over a rotten log or brush aside some damp leaves, and you'll find white bundles of fungal filaments; squeeze a handful of

forest topsoil and inhale its mushroomy fragrance—the rich perfume attending death and decay. The colonies of many mushrooms hook into the roots of forest trees and engage in mutually supportive symbioses; others are pathogens that decorate their food sources with hardened hooves and fleshy shelves. Among the staggering diversity of mushroom-forming species, we find strange apparitions, including gigantic puffballs, phallic eruptions with revolting aromas, and tiny "bird's nests" whose spore-filled eggs are splashed out by raindrops.

Yet, it is the poisonous effects of a handful of fungal metabolites, and the powerful hallucinogenic qualities of others, that account for the central place of mushrooms in mythology and their commonest associations in Western culture. In the twenty-first century, the latest generation of mushroom worshipers promotes the medicinal benefits of fungal extracts, and a global industry has evolved to market these elixirs for soothing every human ill. Mushrooms are also celebrated in modern cookery, and our appetite for wild and cultivated fruit bodies has enjoyed fantastic growth in the last decade. While the appearance of mushrooms in children's stories and the countercultural infatuation with "shrooms" has made everyone more aware of the fungi, this familiarity may also have handicapped their scientific study. Indeed, despite their primal role in supporting planetary health, fungi remain the least studied and most poorly understood kingdom of life.

Getting people to grasp the importance of other familiar groups of organisms can pose similar challenges for scientists. Consider insects. Everyone who has taken a biology class knows that there are millions of insect species and that they perform all manner of life-sustaining tasks, but the only arthropod of immediate concern is the cockroach waggling its antennae at you from the kitchen floor. Facts about all kinds of things can be explained to us—mind-boggling,

fascinating, consciousness-shattering conclusions about life and the universe—yet we spend much more time thinking about how much to spend on a bottle of wine on the way home from work, the eternity of nothingness after death, and other daily trivia. But if you have the shopping questions covered, fed the cat, and dealt with your e-mails, I hope you enjoy reading this book half as much as I have enjoyed researching and writing it.

The eight chapters that follow are interwoven and include some cross referencing, but they may be read as independent essays. They explain what mushrooms are (Chapter 1), how they work (Chapter 2), and what their underlying colonies do (Chapter 3); address the harvesting and conservation of wild mushrooms and the cultivation of domesticated species (Chapters 4 and 5); explore the science of poisonous and hallucinatory fungi (Chapters 6 and 7); and uncover deceptive claims about medicinal mushrooms (Chapter 8).

Nicholas P. Money
Oxford, Ohio
January 2011

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ACKNOWLEDGMENTS

This book would not have been possible without access to the incomparable collection of mycological books and journals housed in the Lloyd Library and Museum in Cincinnati. Many of the illustrations in the book were scanned from originals in the Lloyd's collection. My sincere thanks to Maggie Heran, director of the Lloyd, archivist Anna Heran, and other staff members for their help throughout this project. Mike Vincent (Miami University) and Mike Klabunde (College of Mount St. Joseph) provided indispensable assistance by translating Latin and Greek passages from original sources. Sushma Shrestha (Miami University) provided invaluable help by researching the medicinal mushroom literature that is discussed in the last chapter. Permission to reproduce Tom Pickard's poem *Stinkhorn* was provided generously by Flood Editions, Chicago. I also thank my editor, Tisse Takagi, for her unstinting support of my work, and my previous editor, Peter Prescott, who helped develop the concept for this book. My wife and scientific collaborator, Diana Davis, read every word of the manuscript, and so please refer any objections to her as the responsible party. I disown any of the book's errors and faults.

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MUSHROOM

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Chapter 1

Angels on the Lawn

HOW MUSHROOMS DEVELOP

A grown-up neighbor in the English village of my childhood told stories about angels that sat upon our shoulders and fairies that lived in her snapdragons. Like the other kids, I searched her flowers for a glimpse of the sprites, but agnosticism imbibed from my parents quickly overruled this innocent play. Yet, there *was* magic in my neighbor's garden, and I had seen real angels on her lawn: little stalked bells that poked from the dew-drenched grass on autumn mornings, evanescent beauties whose delicately balanced caps quivered to the touch. By afternoon they were gone, shriveled into the greenery. Does any living thing seem more supernatural to a child than a mushroom? Their prevalence in fairy-tale illustrations and fantasy movies suggests not. A reliable piece of scenery behind unicorns, providing forest shelters for elves, mushrooms are often the only things in these stories drawn from reality. Like no other species, the strangeness of fungi survives the loss of innocence about the limits of nature. They trump the supernatural, their magic intensifying as we learn more about them.

This celebration of the fungal fruit body begins, like every mushroom, in the air. On breezy days, the wind is full of invisible biology. Fungal spores—thousands or millions of them in a cubic meter of our life-sustaining gas—accompany pollen from flowers, crop plants, and cone-bearing trees, as well as countless bacteria and viruses. These spores come from innumerable species that blanket

the leaves and stems of plants, fungi that feed on animal dung and rot corpses, and the thousands of species of basidiomycete fungi that form mushrooms. We are bathed in a soup of these procreative morsels and inhale the biosphere with every breath. If that doesn't make you reach for nasal spray, consider that each mushroom that elbows itself from the ground sheds hundreds of millions, even trillions, of microscopic spores. As a source of airborne particulates, the mushroom is a masterpiece of natural engineering.

Mushroom spores can start forming a colony when they make landfall at that rarest of sites: moist soil that isn't crowded with other fungi and predatory bugs. This highlights a crucial point in understanding mushroom biology and in assessing the value of mushrooms in the restoration of damaged ecosystems—issues that will be addressed in later chapters. Vast numbers of spores are dispersed because most of them alight on hostile soil. Consider the blood-foot mushroom, a common species in North America. Also known as *Mycena haematopus*, this little orange mushroom weeps a bloody fluid when its stem, or "stipe," is severed (Plate 1). Able to grow on well-rotted, pulpy wood, it is abundant in rain-drenched forests with plenty of fallen timber. Thousands of spores sweep from the bottom of this mushroom's cap every second of its brief life. In perfectly still air, the spores descend at a speed of about one millimeter per second, which means that free fall from the bottom of the blood-foot gills is over in less than one minute. Yet, the slightest breeze can keep the particles aloft for hours. Experiments show that most spores fall quite close to the parent fruit body, many directly beneath the cap, where they are evident as a dusty drape; a few drift much farther through the trees and escape the canopy.[1] With all the wood in a forest, it would seem likely that a large number of spores settle on their preferred food sources. The actual number of successful landings is impossible to estimate with

any accuracy, but even among these winners, most perish. Exposed patches of wood aren't as inviting as they might seem. The spore may be eaten by a springtail, slug, or amoeba before it germinates; it may dry up in the withering ray of a sunbeam or get washed away by a raindrop. Its survival is not favored. The woody landing place of a spore may lack the nutrients that the fungus requires: perhaps its relatives have already digested the necessary foodstuffs of its finicky blood-foot diet. Starvation is a reliable reaper. Even when there is plenty of moist wood, malnutrition may be caused by competition from the germinating spores of one's siblings. Poisoning by other fungal species, whose domain the spore has entered, is another threat. There are so many other ways to die young, and the probability of longevity too slim to calculate. This computation, however, is precisely what the mushroom has done. Its output of spores has been fine tuned by natural selection to maximize survival and limit wastage.

Mushrooms illustrate the Malthusian "perpetual struggle for room and food" with greater force than any animal. On a global basis, the total fertility rate for our species is 2.3 births per woman; the births per giant puffball, *Calvatia gigantea*, soar into the trillions (Plate 2). This astonishingly prolific mushroom is also a common species, like the blood-foot, but it inhabits pastures rather than forests. Despite its sedentary condition, the puffball doesn't have any obvious problems casting spores over its habitat. The merest gust will spill its powdery offspring, and raindrops send a fog of them into the air. Those trillions of spores are necessary, not to find fresh grassland, but, once deposited, to survive the trials endured by every fungal spore: unpredictable climate, predation, and competition. This is why meadows are never filled with puffballs, but instead are decorated, here and there in their soggiest spots, with white globes that flag their subterranean colonies.

A raindrop is all that some species require for germination; others have more refined physical or chemical needs. Giant puffball spores are particularly resistant to germination in the lab, with only one per thousand agreeing to grow in a Petri dish.[2] Experiments suggest that more will germinate in the presence of yeasts (single-celled fungi), which offers a glimpse of the complexity of a spore's natural existence. This intertwining of life cycles, with mushrooms reliant on yeasts, or insects, or even birds, may explain why the spores of so many fungi have never been germinated in the laboratory. These diverse interactions may involve exposure to foreign secretions, cohabitation within the same food source for the purpose of cooperative digestion, or entail greater intimacy such as the passage through the partner animal's digestive system. Examples of mutually supportive relationships between insects and mushroom-forming fungi will be discussed in Chapter 3.

Germination occurs with the emergence of one or more slender filaments, or germ tubes, from the spore (Fig. 1.1). Some spores swell before they germinate, while others show no obvious signs of activity prior to the process. The germ tube extends for a while and then branches behind its tip, producing a second interconnected filament. Both filaments continue to extend until a second branch grows from the first axis, then more, and the branches form branches, and a network of filaments emerges within a few hours. This is the young mycelium, a colony whose multiple tips expand the fungus in an ever-enlarging circle from the original spore sitting at its hub. This rapid development of a series of perfectly cylindrical tunnels whose liquid contents pulse toward their extending tips is a beautiful thing to watch under a microscope. My introduction to the mycelium's shape was provided by my dad, who explained that Alexander Fleming discovered the antibiotic penicillin when he noticed that the sandwich he was about to shove in his mouth