

MUSHROOMS

Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact

SECOND EDITION



SHU-TING CHANG AND PHILIP G. MILES



CRC PRESS

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Shu-Ting Chang
Philip G. Miles

Preface

The mushroom is the fruiting body of the macrofungi. Approximately 14,000 described species of fungi produce fruiting bodies that are large enough to be considered mushrooms using our definition, which states that “the mushroom is a macrofungus with a distinctive fruiting body that can be either epigeous (aboveground) or hypogeous (underground) and large enough to be seen with the naked eye and to be picked by hand.” According to this definition, in contrast to other definitions, mushrooms can be Ascomycetes, grow underground, have a nonfleshy texture, and need not be edible. In nature, the role of the mushroom is to produce reproductive spores, to function in the protection of the tissues in which spores are formed, and to provide for spore dissemination. Current studies estimate that 1.5 million species of fungi may actually exist and that there may be 140,000 species that produce fruiting bodies of sufficient size and structure to be considered macrofungi, thus fulfilling our definition of a mushroom.

With a group of this dimension, it is to be expected that there will be great structural variation in mushrooms. Another important feature is that some species are poisonous, an aspect that is treated more extensively in this edition. The edibility of mushrooms has been known to humans since time immemorial, but the intentional cultivation of mushrooms had its beginning in China, around A.D. 600, when *Auricularia auricula* was first cultivated on logs. Today about 7000 species possess varying degrees of edibility, and more than 3000 species may be considered prime edible species, of which only 200 species have been experimentally grown, 100 economically cultivated, approximately 60 commercially cultivated, and about 10 species cultivated on an industrial scale. In addition, 2000 species have been suggested to possess medicinal properties. Such medicinal mushrooms produce substances that can improve biological functions and thus the health of the consumer. These products have been called by various names, including dietary supplements, functional foods, phytochemicals, nutraceuticals, and nutriceuticals. Industries providing these substances have expanded in the United States, where the supplement sales were valued at U.S. \$3.3 billion in 1990. These sales have increased steadily, and in 2000 there was an estimated value of U.S. \$14 billion.

The use of lignocellulosic materials, which provide a sustainable biomass resource for the growth of edible and medicinal mushrooms, is of great environmental importance by recycling organic waste, thereby playing a role in controlling problems of pollution.

As is true for revisions of most scientific books, the main motivations for the second edition of *Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact* are inclusion of material and references that have appeared since the publication of the preceding edition and consideration of the comments and suggestions of readers. The current edition includes much new material and a large number of new references. The format and organization are similar to those used in the earlier edition. Both editions provide a treatment of the following topics: overview of mushroom biology and mushroom science; nutritional attributes; medicinal values; overview of biology of fungi; substrate and mycelial growth; sexuality and the genetics of Basidiomycetes; mushroom formation (effects of environmental, nutritional, and chemical factors, as well as genetic factors and breeding); culture preservation; and world production of edible mushrooms. In addition, the chapters on specific edible mushrooms (*Agaricus*, *Lentinula*, *Volvariella*, *Flammulina*, *Pholiota*, *Pleurotus*, *Tremella*, *Dictyophora*, *Auricularia*, *Hericiium*) have been enlarged with the inclusion of more recent research findings. Chapters on the medicinal mushrooms *Ganoderma lucidum*, *Agaricus blazei*, and *Grifola frondosa* have been added, as well as a chapter on the effects of pests and diseases on mushroom cultivation. Finally, the chapter on technology

and mushrooms has been expanded to emphasize the environmental impact of mushrooms and mushroom cultivation.

Mushroom growing processes involve living organisms, and thus it is subject to the numerous interactions that living organisms have with their environment and with one another. Mushroom cultivation methods must be modified and appropriate strains developed for use in environmentally different situations. Thus, we have stressed that it is essential for a grower to have knowledge of the basic principles as well as practical cultivation techniques. A grower not only must know the “how” but also must understand the “why” of the individual steps of the complex events that constitute mushroom cultivation. The fact that there are mushroom species that can be grown in any populated area of the world on waste materials that are available in abundance in both urban and rural areas indicates the great potential for mushrooms to supplement, in a flavorful and nutritious manner, the protein-deficient diet of people everywhere, but especially in developing countries.

Much of the information concerning mushroom cultivation has come from China where the mushroom industry has advanced more rapidly than in any other country in the past two decades. It is hoped that the information and techniques described in this edition will be useful for other developing countries where a good source of protein is urgently needed. Emphasis has been placed on direct and simple methodologies that can be useful in developing countries, rather than on extensively mechanized cultivation procedures. Frequent interpretations have been made by the authors regarding the scientific rationale for the procedures developed.

The use of mushrooms for medicinal purposes continues to expand, and it is hoped that as technology advances for the production of medicinal products, there will be increased activity in medical research and clinical studies to examine the validity of many claims that have been made for various medicinal and tonic uses of these products. Anecdotal accounts are interesting and may be useful, but scientific experimentation is essential. This book is written for growers of edible and medicinal mushrooms and also for university students and researchers of the following specialties: environmentalists concerned with solid state fermentation for conversion of waste materials to food and concomitantly with the avoidance of pollution commonly associated with disposal of wastes; microbiologists interested in thermophilic organisms, as these are important in the composting process; geneticists concerned with strain improvement, especially the breeding of strains of species of edible and medicinal mushrooms that will be suitable for different environmental conditions; horticulturalists interested in the development of efficient cultivation practices; nutritionists involved in the assay and evaluation of mushroom nutrients; pathologists studying mushroom diseases; and medical doctors concerned with the nutritional value of mushrooms as well as with the compounds produced by certain mushrooms that have demonstrated potential in the treatment of various diseases.

The aspects emphasized in this book include cultivation, nutritional value, medicinal effects, and the environmental impact of mushrooms.

As with the preceding edition, this book is not intended to be an encyclopedic review; instead, it is presented with an emphasis on worldwide trends and developments in mushroom biology from an international perspective.

The Authors

Shu-Ting Chang, Ph.D., received the B.Sc. degree in 1953 from National Taiwan University, and he earned an M.S. degree in 1958 and a Ph.D. degree in 1960 from the University of Wisconsin. He was then appointed to the position of Assistant Lecturer in the Biology Department of The Chinese University of Hong Kong, became Lecturer in 1961, Senior Lecturer in 1970, Reader in 1974, Professor in 1978, and Emeritus Professor in 1995. Dr. Chang was Chairman of the Department of Biology from 1983 to 1994. He was Dean of the Faculty of Science from 1975 to 1977 and Director of Student Affairs from 1979 to 1981. Dr. Chang was a Visiting Postdoctoral Fellow at Harvard University in 1966, was a Visiting Fellow at Tokyo University in 1969, and a Visiting Fellow at Australia National University and the Commonwealth Scientific and Industrial Research Organization during 1972–1973 and 1978–1979.

Dr. Chang is a member of the American Association for the Advancement of Science and the Mycological Society of America. He served as Chairman of the Hong Kong Research Council in Biological Education from 1987 to 1989 and was President of the Hong Kong Society of Microbiology from 1982 to 1984. He was President of the International Mushroom Society for the Tropics from 1981 to 1995 and was also Editor-in-Chief of *The Mushroom Journal for the Tropics* during that period. He also was a member of the Editorial Board of *MIRCEN Journal of Applied Microbiology and Biotechnology*. Dr. Chang served as the Executive Secretary of the Headquarters of the UNESCO Regional Network of Microbiology in Southeast Asia from 1984 to 1987, and was a member of the Executive Board of International Union of Microbiological Societies from 1990 to 1994. He is Director of the Center for International Services to Mushroom Biotechnology under UNIDO and an editor of the *International Journal of Medicinal Mushrooms*. He has authored or co-authored six books, co-edited seven books, and authored or co-authored 180 articles in scientific journals.

Dr. Chang is a Fellow of the World Academy of Art and Science, the Institute of Biotechnology, and the World Academy of Productivity Science. He has also been named an Honorary Life Member of the British Mycological Society, and of the International Society for Mushroom Science, U.K. He received the International Cooperation Award for Light Industry in China in 1990 and the Science and Technology Corporation Award from The People's Government, Qingyuan, China in 1994. In 1994, he was named an Officer of the Most Excellent Order of the British Empire (OBE).

Dr. Chang's major research interests are in the areas of fungal genetics, mushroom germplasm conservation, the biology and cultivation of edible mushrooms, and medicinal mushrooms and mushroom nutraceuticals.

Philip G. Miles, Ph.D., received the B.A. degree in 1948 from Yale University with a major in botany. In 1953, he received the Ph.D. degree from Indiana University, with a major in mycology and minors in bacteriology and general botany. He then held appointments as a Research Associate at the University of Chicago and as a Research Fellow at Harvard University with Professor John R. Raper. In 1956, Dr. Miles joined the Biology Department of the University of Buffalo (now the University at Buffalo, State University of New York) as an Assistant Professor, becoming an Associate Professor in 1961, Professor in 1970, and Emeritus Professor in 2002. He served the Biology Department as Co-chairman (1968 to 1969), Chairman (1972 to 1974), and Director of the Division of Biology (1974 to 1976). Dr. Miles also held appointments as Assistant Professor at the Harvard University Summer School in 1958, 1960, and 1962. While on sabbatical leave, Dr. Miles held the following research and teaching appointments: 1963 to 1964, Fulbright Research

Scholar in Japan; 1970 to 1971, Long-Term Visiting Scientist at National Taiwan University and the Institute of Botany, Academia Sinica, under the National Science Foundation–National Science Council of China Cooperative Science Program; 1977 to 1978, Invited Scientist at the Tottori (Japan) Mycological Institute and Visiting Professor at National Taiwan University and The Chinese University of Hong Kong; 1985 to 1986, Exchange Scholar (SUNYAB–Beijing Municipal University Scholar Exchange Program) in Beijing, China, and Honorary Visiting Professor at The Chinese University of Hong Kong.

Dr. Miles is a member of numerous scientific societies including the American Association for the Advancement of Science, the Botanical Society of America, the Genetics Society of America, the Mycological Society of America, the World Society of Mushroom Biology and Mushroom Products, and the honorary society Sigma Xi. He has served on the editorial boards of numerous journals and was the first President of the World Society for Mushroom Biology and Mushroom Products. In 1998, Dr. Miles received an Excellence in Teaching Award from the Chancellor of the State University of New York.

Dr. Miles' research interests have been in the areas of genetics and physiology of sexual mechanisms and morphogenesis of Basidiomycetes, and for these studies he has been the recipient of grants from the National Science Foundation and the National Institutes of Health. Earlier studies were primarily with the experimental organism *Schizophyllum commune*; more recent publications are results of studies of edible mushrooms. He has directed the research of many undergraduate and graduate students, including nine for the Ph.D. degree. He is co-editor of *Genetics and Morphogenesis in the Basidiomycetes* (Academic Press, 1978), and *Genetics and Breeding of Edible Mushrooms* (Gordon & Breach Science Publishers, 1993). Dr. Miles is co-author of *Edible Mushrooms and Their Cultivation* (CRC Press, 1989), and *Mushroom Biology — Concise Basics and Current Developments* (World Scientific Press, 1997).

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