

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).

Contents

Chapter 1	Overview.....	1
I.	Introduction.....	1
II.	What Are Mushrooms?	1
	A. Definition	2
	B. Characteristics of Mushrooms.....	3
	C. Categories of Mushrooms.....	4
	D. Poisonous Mushrooms.....	5
	1. <i>Amanita</i> -Type Poisoning.....	5
	2. Muscarine-Type Poisoning	5
	3. Psychotropic or Hallucinogenic Poisoning	6
	4. <i>Coprinus</i> Poisoning.....	6
	5. Poisoning from External Sources	6
III.	Magnitude of Mushroom Species	6
IV.	Ecological Importance of Mushrooms and Fungi in General	6
V.	Collection and Classification of Mushrooms.....	8
	A. Field Collection	9
	B. Preserving the Collection	9
	C. Precautions in the Use of Keys.....	9
VI.	Justification for the Term <i>Mushroom Biology</i>	10
VII.	Impact of Mushroom Biology on Human Welfare.....	11
VIII.	Mushroom Science	12
	A. Definition	12
	B. Contributing Fields	12
	1. Microbiology.....	12
	2. Fermentation	14
	3. Environmental Engineering	15
	C. Mushroom Cultivation Technology.....	17
	1. Concept	17
	2. Phases of Mushroom Technology	17
IX.	Development of Mushroom Science.....	21
X.	Mushroom Biotechnology	22
XI.	Nongreen Revolution.....	23
	References	24
Chapter 2	The Nutritional Attributes of Edible Mushrooms.....	27
I.	Introduction.....	27
II.	Nutritional Attributes.....	27
	A. Protein.....	28
	B. Essential Amino Acids.....	30
	C. Fat	31
	D. Vitamins.....	31
	E. Carbohydrate and Fiber.....	34
	F. Minerals	34

G. Nucleic Acids.....	34
H. General Considerations.....	35
References	36

Chapter 3 Medicinal Value.....39

I. Introduction.....	39
II. Medicinal Mushrooms.....	39
III. Effects of Medicinal Mushrooms.....	42
A. Hematological Effects	42
B. Antiviral Effects.....	43
C. Antitumor Effects	44
D. Antioxidant Activity	45
E. Cardiovascular and Renal Effects	45
F. Carcinogenicity of Mushrooms	46
G. Allergic Reaction to Spores.....	46
IV. General Considerations	46
References	47

Chapter 4 Overview of the Biology of Fungi.....53

I. Introduction.....	53
II. The Fungi	53
A. Distinguishing Characteristics	53
B. Habitats	54
C. Role in Nature	54
D. Classification.....	54
III. Vegetative Structure of Fungi.....	55
A. Hyphae	55
1. Coenocytic Hyphae.....	56
2. Septate Hyphae	56
B. Organelles	56
C. Septal Structures	57
D. Secondary Mycelium of Basidiomycetes.....	58
E. Cell Walls.....	59
F. Unicellular Fungi.....	60
IV. Growth	60
A. Growth Kinetics of Unicellular Fungi	60
B. Filamentous Fungi	60
1. Measurement of Growth.....	61
V. Specialized Vegetative Structures.....	62
VI. Specialized Reproductive Structures.....	62
A. Sexual.....	62
B. Nonsexual	64
VII. Requirements for Growth.....	64
A. Nutritional Requirements	64
1. Carbon.....	64
2. Nitrogen	65
3. Minerals	66
4. Vitamins	67

B.	Physical Requirements.....	68
1.	Temperature.....	68
2.	Light.....	68
3.	Moisture.....	69
4.	Aeration.....	69
5.	Gravity.....	69
C.	Transport and Translocation.....	70
1.	Barriers to Transport.....	70
2.	Passive and Active Transport.....	71
3.	Translocation.....	71
VIII.	Metabolism.....	73
A.	Carbon.....	73
1.	Respiration.....	73
B.	Nitrogen.....	77
C.	Lipids.....	78
IX.	Reproduction.....	78
A.	Introduction.....	78
B.	Sexual.....	79
1.	Homothallism.....	80
2.	Heterothallism.....	80
3.	Hormonal (Pheromonal) Control.....	82
C.	Nonsexual.....	83
1.	Types of Reproductive Units.....	84
D.	Spore Germination.....	86
1.	Factors Affecting Germination.....	86
2.	Measurement.....	87
X.	Relationship of Fungi with Other Organisms — Symbiosis.....	87
A.	Parasitism.....	88
B.	Mutualism.....	88
1.	Lichens.....	88
2.	Mycorrhiza.....	88
C.	Saprophytism.....	89
XI.	Chemical Composition of Fungi.....	89
A.	Proximate Composition of Fungal Cells.....	90
B.	Edible Mushrooms.....	91
	References.....	91

Chapter 5	Substrate and Mycelial Growth.....	93
I.	Introduction.....	93
II.	General Nutritional Requirements for Mushroom Growth.....	94
III.	Preparation of Substrate.....	95
A.	Composting.....	95
1.	Phase I Composting (Compost Preparation).....	96
2.	Phase II Composting (Compost Conditioning).....	97
B.	Microorganisms Involved during Composting.....	98
IV.	Breakdown of Substrates by Extracellular Enzymes of Mushroom Mycelium.....	99
V.	Genetic Improvement of Mushroom Culture in Regard to Substrate Utilization by Increased Production of Extracellular Enzymes.....	100
	References.....	101

Chapter 6	Sexuality and the Genetics of Basidiomycetes	105
I.	Discovery of Sexuality by Kniep and Bensaude	105
A.	Tetrapolarity	105
B.	Clamp Connection Formation	106
II.	Other Early Findings in Sexuality in Basidiomycetes	108
A.	Results of Tetrad Analysis	108
B.	Geographical Races	111
C.	Bipolarity	111
D.	Illegitimate Matings	111
E.	Buller Phenomenon (= Di-Mon Mating)	112
III.	Reactions Other Than Those Forming Dikaryons	112
IV.	Genetics of the Mating Type Loci and Sexual Morphogenesis in <i>Schizophyllum commune</i>	113
A.	<i>Schizophyllum commune</i>	113
B.	The A Locus of <i>Schizophyllum commune</i>	114
C.	The Two-Locus Mating Type Factor Occurs Elsewhere	116
D.	Findings from Molecular Genetic Studies	116
E.	Sexual Morphogenesis	116
V.	Genetics of Fungi	117
A.	Induction of Mutants	117
1.	Spontaneous Mutation Rates	118
2.	Mutagenic Treatment: X Rays	118
3.	Mutagenic Treatment: Ultraviolet	118
4.	Mutagenic Treatment: Chemical	119
B.	Isolation of Mutants	119
1.	Total Isolation	119
2.	Filtration Enrichment Method	120
3.	Starvation Selection Method	120
4.	Rescue Method	121
5.	Selective Elimination of Prototrophs by Use of Chemical Method	121
C.	Characterization of Mutants	121
1.	Auxotrophic Mutants	121
2.	Morphological Mutants	122
3.	Developmental Mutants	123
4.	Fruiting Mutants	123
D.	Utilization of Methods of Molecular Biology in Genetic Studies of Fungi	123
1.	Taxonomic Studies æ Distinguishing Species and Strains	123
2.	Demonstration of Genetic Variation in Natural Populations	124
3.	Demonstration of Genetic Variation in Germplasm Collections	125
4.	Linkage Studies	125
5.	Confirmation of Crosses	126
6.	Patent Labeling	126
References	126

Chapter 7	Mushroom Formation: Effects of Environmental, Nutritional, and Chemical Factors	129
I.	Introduction	129
II.	Development of Fruiting Bodies	129
A.	Role of Fruiting Bodies	129

B.	Variation in Fruiting Body Structure.....	130
1.	Mushroom with Cap, Gills, Stipe, and Volva	130
2.	Fruiting Bodies with No Stipe	131
3.	Spore-Bearing Layer (Hymenium) Not in Gills, But in Pores.....	131
4.	Funnel-Shaped Fruiting Body with Hymenial Layer in Folds on Underside of Body	131
C.	Primordium Formation	132
D.	Primordium Development.....	132
E.	Types of Hyphae in Fruiting Bodies	133
F.	Growth of <i>Agaricus</i>	133
III.	Environmental Factors and Fruiting	133
A.	Hydrogen Ion Concentration (pH)	134
B.	Temperature	134
C.	Aeration.....	135
D.	Light.....	136
E.	Gravity	137
IV.	Nutritional Factors and Fruiting.....	138
A.	Concentration of Nutrients	138
B.	Nature of Carbohydrate	139
C.	Nitrogen	139
D.	Mineral Nutrition	140
E.	Vitamins	140
V.	Chemical Factors and Fruiting	140
A.	Melanin Production and Perithecial Development in <i>Podospora</i>	141
B.	Morphogenesis in <i>Schizophyllum commune</i>	141
C.	Effect of Cyclic AMP.....	142
VI.	Summary	143
	References	143

Chapter 8 Mushroom Formation: Effects of Genetic Factors; Breeding.....145

I.	Introduction.....	145
II.	Genetic Factors for Fruiting Imposed on the Mating Type Requirements	145
A.	<i>Schizophyllum commune</i>	145
1.	Multigenic Fruiting Factors	146
2.	Morphological Fruiting Mutants	146
B.	<i>Lentinula</i>	147
1.	Various Stocks Display Fruiting Differences	147
III.	Genetics of Fruiting of <i>Polyporus ciliatus</i>	148
A.	No Subunits of Incompatibility Factors	148
B.	Genetic Control of Monokaryotic Fruiting	148
IV.	Monokaryotic Fruiting.....	149
A.	Species in Which Monokaryotic Fruiting Has Been Reported	149
B.	Induction	149
C.	Relationship with Dikaryotic Fruiting	150
D.	Potential in Mushroom Cultivation	150
V.	Breeding for Desired Mushroom Features	151
A.	Extension of Temperature Range	151
B.	Utilization of Substrates	152
1.	Use of Waste Substrates	152
2.	Increased Yield.....	152

C. Sporeless Fruiting Bodies.....	152
1. Why Desirable?.....	152
2. Methods Used to Obtain.....	153
D. General Techniques of Breeding for Strain Improvement.....	154
1. Establishment of Cultures.....	155
2. Maintenance of Cultures.....	155
3. Characterization of Monosporous Mycelia	155
4. Selection of Recombinants	156
References	156

Chapter 9 Mushroom Formation: Effect of Pests and Diseases in Mushroom Cultivation..... 159

I. Introduction.....	159
A. History of Mushroom Cultivation and Diseases.....	159
1. Outdoor Cultivation	159
2. Indoor Cultivation with Pure Culture Spawn.....	159
II. Viral Diseases	160
A. History.....	160
B. Symptoms	160
C. Diagnosis.....	161
D. Virus Morphology.....	162
E. Epidemiology.....	162
F. Patch Disease	163
III. Bacterial Diseases.....	164
A. Various Mushroom Diseases	164
1. Blotch Disease	164
2. Mummy Disease	164
3. Drippy Gill Disease	164
4. Brown Center Rot Disease of Shiitake	165
5. Mushroom Soft Rots.....	165
B. Management for Control of <i>Burkholderia gladioli</i> pv. <i>agaricola</i>	166
IV. Fungal Diseases	167
A. Introduction.....	167
B. Mycoparasites	167
1. Necrotrophic Parasitism.....	167
2. Economic Importance.....	168
C. Competitor Weed Fungi.....	169
1. False Truffle Disease Caused by <i>Diehliomyces microsporus</i>	169
2. Cobweb Disease Caused by <i>Dactylium</i>	170
3. Mushroom Green Mold	171
V. Nematode Diseases.....	177
A. Types of Nematodes	177
1. Saprophagous Nematodes.....	177
2. Mycophagous Nematodes.....	178
3. Entopathogenic Nematodes	178
VI. Insect Diseases.....	179
A. Introduction.....	179
B. Insects That Serve as Agents of Disease in Mushroom Houses	179
1. Family Phoridae	179

2. Family Sciaridae	180
3. Family Cecidomyiidae	184
VII. Activity of Mites in Mushroom Cultivation	184
A. Genera Found during Mushroom Cultivation	184
B. Economic Importance	185
References	185

Chapter 10 Culture Preservation 189

I. Introduction.....	189
II. Objectives	190
III. Methods	190
A. Short-Term Storage.....	190
1. Culture Practices	191
2. Substratum	191
3. Small Flat-Sided Culture Bottles.....	191
4. Temperature.....	193
B. Long-Term Storage.....	193
1. Starvation of Nutrients.....	193
2. Limitation of Oxygen	194
3. Lyophilization	194
4. Freezing.....	194
C. A Useful Technique in Genetic Studies.....	199
IV. Conclusions.....	199
References	201

Chapter 11 World Production of Edible Mushrooms 203

I. Introduction.....	203
II. Species Cultivated Commercially	205
A. <i>Agaricus bisporus</i>	205
B. <i>Lentinula edodes</i>	205
C. <i>Volvariella volvacea</i>	206
D. <i>Flammulina velutipes</i>	206
E. <i>Auricularia</i> spp.	206
F. <i>Pleurotus</i> spp.	206
G. <i>Pholiota nameko</i>	207
H. <i>Tremella fuciformis</i>	207
I. Mushroom Species Commercially Cultivated Recently	207
J. Mycorrhizal Fungi: <i>Tuber</i> , <i>Tricholoma</i>	207
K. <i>Termitomyces</i>	208
III. General Information for Mushroom Growers.....	209
IV. Trends	210
A. Production Methods Breaking the Barriers of Climate and Geography	210
1. <i>Agaricus</i>	210
2. <i>Lentinula</i>	211
B. World Production of Mushrooms.....	211
C. Utilization of Various Wastes as Substrates	216
V. Conclusion	218
References	218

Chapter 12	<i>Agaricus</i> — The Leader in Production and Technology	221
I.	Introduction	221
II.	Development in the Industry	223
	A. France	223
	B. Great Britain	223
	C. The Netherlands	224
	D. The United States	224
	E. Italy	224
	F. Ireland	225
	G. Taiwan	225
	H. South Korea	225
	I. China	225
	J. General Remarks	226
III.	Compost Materials and Composting	226
	A. Compost Materials	226
	B. Amount of Compost Material	228
	C. Composting	231
IV.	Spawn and Spawning	232
	A. Definition	232
	1. Natural Virgin Spawn	232
	2. Flake Spawn	232
	3. Brick Spawn	233
	4. Pure Culture Spawn	233
	5. Liquid Spawn	233
	B. Preparation of Spawn	233
	1. Pond Mud-Manure Spawn	233
	2. Straw-Manure Spawn	234
	3. Grain-Manure Spawn	234
	C. Spawning	234
V.	Casing	235
VI.	Harvesting	235
	References	235

Chapter 13	<i>Lentinula</i> — A Mushrooming Mushroom	237
I.	Introduction	237
II.	Early History of Cultivation	237
III.	Major Developmental Events of Cultivation	241
IV.	General Review of Production	243
V.	Cultivation in Wood Logs	246
	A. Preparation of Logs	246
	1. Felling of Logs	246
	2. Moisture Content	247
	B. Preparation of Spawn	248
	1. Stock	248
	2. Spawn	248
	C. Inoculation of Spawn into Logs	249
	1. Time of Spawning	249
	2. Method of Spawning	249
	D. Laying Logs for Mycelial Running	250

E.	Management of the Raising Yard for Fruiting	251
F.	Cropping	252
VI.	Cultivation in Polypropylene Bags (“Bag Log” Cultivation).....	253
A.	Materials	254
1.	Sifting the Materials	254
2.	Mixing the Materials	254
B.	Inoculation	254
C.	Incubation	255
1.	Mycelial Running Stage	255
2.	Established Mycelial Stage.....	255
D.	Fruiting.....	256
E.	Proper Care of the Bag Log.....	258
VII.	Special Cultivation Practices.....	259
A.	Taiwan.....	259
B.	China.....	259
1.	Seasonal Development.....	260
2.	General Formulas for Substrate.....	260
3.	Method for Filling the Bags	261
4.	Sterilization	261
5.	Inoculation	261
6.	Indoor Mycelial Running.....	261
7.	Shift to Outdoor Cultivation	262
8.	Formation of Mycelial Coats.....	263
9.	Stimulation of Fruiting by Temperature Fluctuation	263
10.	Management of Fruiting	264
11.	Reasons for Abnormal Mushrooms	265
12.	Case Studies: Qingyuan and Biyang	266
VIII.	Fruiting in Liquid Media.....	268
A.	Experiments with <i>Lentinula</i>	268
B.	Generalizations	271
IX.	Drying and Storage	273
	References	275

Chapter 14 *Volvariella* — A High-Temperature Cultivated Mushroom277

I.	Introduction.....	277
II.	Biological Characteristics.....	278
A.	Morphological Characteristics.....	278
1.	Mature Stage	279
2.	Elongation Stage	281
3.	Button and Egg Stages	282
4.	Pinhead Stage.....	283
5.	Germination and the Germling.....	283
6.	Vegetative Hyphae	284
7.	Chlamydo spores.....	285
B.	Requirements for Mycelial Growth.....	285
C.	Requirements for Fruiting Body Formation	285
III.	Cultivation Methods	286
A.	Production of Spawn	286
1.	Starting Cultures	286
2.	Culture Media	287

3.	Spawn Media	288
B.	Mushroom Production	289
1.	Without Pasteurization (Indoor Cultivation)	291
2.	Without Pasteurization (Outdoor Cultivation).....	291
3.	With Pasteurization	292
IV.	Harvesting and Processing	295
A.	Harvesting	295
B.	Processing	295
V.	Special Cultivation Practice	296
A.	Rural Spawn Station in Ping-Shan County, Hebei Province, China.....	296
1.	Substrate.....	296
2.	Bagging	296
3.	Sterilization	297
4.	Inoculation	297
5.	Incubation.....	297
6.	Comments on Management	297
7.	Implications of This Experimental Project	297
B.	Technique of Cultivation of Straw Mushrooms in Green Poplar Village, Ping-Shan County, Hebei Province, China	298
1.	Preparation of Compost	298
2.	Arrangement of Bed Blocks	298
3.	Harvesting of Mushrooms	299
4.	Spent Compost.....	299
5.	Conclusion	299
VI.	Some Special Methods and Their Rationale	299
A.	Phenomenon of Early Fruiting	299
B.	Insect Enemy of Straw Mushrooms — Nematodes	300
C.	<i>Coprinus</i> — Fungal Competitor of <i>Volvariella</i>	301
	References	302

Chapter 15 *Flammulina* and *Pholiota* — Low-Temperature Cultivated Mushrooms305

I.	Introduction.....	305
II.	Biological Characteristics of <i>Flammulina</i>	305
A.	Morphology.....	306
B.	Natural History	306
C.	Requirements for Mycelial Growth.....	307
D.	Requirements for Fruiting Body Formation	308
III.	Biological Characteristics of <i>Pholiota</i>	308
A.	Morphology.....	308
B.	Natural History	309
C.	Requirements for Mycelial Growth.....	310
D.	Requirements for Fruiting Body Formation	310
IV.	Cultivation Methods	311
A.	<i>Flammulina</i>	311
B.	<i>Pholiota</i>	312
	References	313

Chapter 16 *Pleurotus* — A Mushroom of Broad Adaptability.....315

I.	Introduction.....	315
----	-------------------	-----

II.	Biological Characteristics.....	316
A.	Morphology of Sporophores	316
B.	Sexuality	316
C.	Requirements for Mycelial Growth.....	317
D.	Requirements for Fruiting Body Formation	317
III.	Nutritional Values and Medicinal Properties	318
A.	Nutritional Values	318
B.	Medicinal Properties.....	318
IV.	Cultivation Methods	318
A.	Production of Spawn	318
1.	Grain Spawn.....	319
2.	Straw Spawn	319
B.	Production of Mushrooms	319
V.	Harvesting and Processing	320
VI.	Special Cultivation Practice	322
	References	324

Chapter 17 Tremella — Increased Production by a Mixed Culture Technique.....327

I.	Introduction.....	327
II.	Biological Characteristics.....	328
A.	Morphology.....	328
B.	Natural History	329
C.	Requirements for Mycelial Growth.....	330
D.	Requirements for Fruiting Body Formation	330
III.	Cultivation Methods	330
A.	Wood Log Culture	331
1.	Selection of Materials.....	331
2.	Spawn.....	331
3.	Inoculation	331
4.	Mycelial Running	331
5.	Management for Fruiting.....	331
B.	Plastic Bag Culture.....	332
1.	Substrate.....	332
2.	Spawn Production.....	332
3.	Inoculation	335
4.	Mycelial Running	335
5.	Management for Fruiting.....	335
IV.	Special Cultivation Practices.....	335
A.	Cultivation on Cottonseed Hulls in Gutian County, Fujian Province, China	335
1.	Formulas for Substrate.....	336
2.	Preparation of Substrate.....	336
3.	Filling the Bags.....	336
4.	Sterilization	337
5.	Inoculation	337
6.	Mycelial Running	337
7.	Management for Fruiting Body Formation	337
8.	Harvesting	337
9.	Processing	338
B.	Mixed Culture Cultivation of the Golden Ear Mushroom	339

V. Harvesting and Processing	340
References	340

Chapter 18 *Dictyophora* — Formerly for the Few.....343

I. Introduction.....	343
II. Biological Characteristics.....	344
A. Morphology.....	344
B. Natural History	346
C. Requirements for Mycelial Growth.....	346
D. Requirements for Fruiting Body Formation	347
III. Cultivation Methods	348
A. Cultivation in Forests.....	349
1. Selection of Place	349
2. Selection of Materials.....	349
3. Spawn.....	349
4. Inoculation	350
5. Covering the Substrate Materials	350
6. Management.....	351
7. Fruiting.....	352
B. Indoor Cultivation.....	352
1. The Mushroom House	352
2. Containers for Cultivation	353
3. Cultivation.....	353
4. Management.....	353
IV. Harvesting and Processing	353
A. Harvest Time and Method.....	353
B. Rapid Drying	354
C. Grading and Packaging.....	354
References	355

Chapter 19 *Ganoderma lucidum* — A Leader of Medicinal Mushrooms357

I. Introduction.....	357
II. Biological Characteristics.....	358
A. Taxonomic Characteristics.....	358
B. Morphological Characteristics.....	359
C. Growth Parameters	359
III. Cultivation of <i>Ganoderma lucidum</i>	360
IV. Traditional Uses.....	361
V. Biological Compounds	362
A. Triterpenes-Triterpenoids.....	362
1. Bitterness.....	362
2. Cytotoxicity.....	363
3. Platelet Aggregation Inhibition.....	363
4. Antihypertension	363
5. Hepatoprotective Activity	363
6. Anti-HIV	363
7. Hypoglycemic Effects.....	363
B. Polysaccharide	363
C. Fungal Immunomodulatory Protein	364

D. Steroids	365
VI. Contemporary Uses	365
VII. Products of <i>Ganoderma lucidum</i>	365
VIII. Market Value of <i>Ganoderma lucidum</i> Products	367
IX. A Protocol for Quality Mushroom Nutraceuticals	368
X. Conclusion	369
References	369

Chapter 20 *Agaricus blazei* and *Grifola frondosa* — Two Important Medicinal Mushrooms373

I. Introduction.....	373
II. Biological Characteristics of <i>Agaricus blazei</i>	373
A. History.....	373
B. Morphology.....	374
C. Requirements for Growth.....	374
III. Biological Characteristics of <i>Grifola frondosa</i>	375
A. History.....	375
B. Morphology.....	375
C. Requirements for Growth.....	376
IV. Cultivation Methods	377
A. <i>Agaricus blazei</i>	377
B. <i>Grifola frondosa</i>	377
V. Nutritional Content and Medicinal Properties.....	378
A. <i>Agaricus blazei</i>	378
B. <i>Grifola frondosa</i>	379
References	380

Chapter 21 Other Cultivated Mushrooms — Their Number Grows.....383

I. Introduction.....	383
II. <i>Auricularia</i>	384
III. <i>Hericium</i>	385
IV. Other Types of Interest.....	387
A. Mycorrhizal Mushrooms	387
B. Species with Regional Appeal.....	388
References	389

Chapter 22 Technology and Mushrooms391

I. Introduction.....	391
II. Microbial Biotechnology.....	392
A. What Is Biotechnology?.....	392
B. Lignocellulose Degradation and Utilization	392
1. Isolation of Actinomycete Strains	393
2. Selection of Suitable Species of White-Rot Fungi	393
3. Isolation of Hypercellulolytic Mutants.....	394
4. Cultivation of Mushrooms.....	394
5. A New Cloning Strategy for Filamentous Fungi.....	397
III. Biotechnology in the Mushroom Industry.....	397
A. General Review of Mushroom Production	397

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