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I.B. Prasher

Wood-rotting non-gilled Agaricomycetes of Himalayas

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I.B. Prasher
Department of Botany
Panjab University
Chandigarh, India

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This monograph is dedicated to my parents Late Prof.(Mrs) P. D. Ulfat and Mr. B. K. Ulfat in gratitude and for their affection and support

and

to my Ph.D. supervisor Late Prof. Gurdeep Singh Rawla, ex Chairperson, Department of Botany, Panjab University, Chandigarh, for introducing me to the fascinating world of fungi.

I.B. Prasher

Abstract

The wood-rotting (non-gilled) Agaricomycetes of Himalayas is a part of outcome of fungal forays conducted by the author; collecting and photographing different groups of fungi; along with the faculty of the Department of Botany, Panjab University, Chandigarh, for the last three decades. Some of the photographs are 30 years old. Extensive collections of wood-rotting Agaricomycetes made for the last 10 years along with the Ph.D. students have resulted in the compilation of this book. This work comprising of 167 genera and 488 species (including 6 varieties) is the first comprehensive compilation of these fungi from Himalayas and Assam hills. The characteristic features of all the families included in this work are given before dealing with the taxonomic treatment. The generic and species concept is based on morphological details and the keys to the genera belonging to different families are provided. All the species described are provided with standard description and line diagrams, whereas illustrations are provided for the species which have been photographed by the author. The species described by other workers have been provided with the original herbarium numbers and name of herbarium. The species not collected by the authors have been studied from the specimens deposited by the previous workers in the herbarium of the Botany Department, Panjab University, Chandigarh (PAN). All the specimens collected by the author are deposited in PAN. Besides taxonomic treatment, a chapter pertains to ecology, distribution and interrelationships between Eastern and North-Western Himalayan elements of these fungi. An introductory account of the forest vegetation of Himalayas from where these fungi have been collected is also provided. Out of the total 488 fungi described, 6 taxa (2 species and 4 varieties) are proposed as new to science, 40 species are recorded for the first time from Himalayas, 15 species are recorded for the first time from North-Western Himalayas and 6 species are recorded for the first time from Eastern Himalayas. In the present work the genera are differentiated on the basis of morphological and anatomical characteristics. Till the time when majority of the genera or representative of a group of genera (in case of complex) are phylogenetically analyzed, a classification based on molecular characterization is not feasible. Since the basic aim of the work is to provide a workable text – to be used for the floristic analysis and identification of the fungi belonging to this group – differentiation of

genera has been made only on the basis of morphological and anatomical details. The genera have been placed in the families and orders in the text on the basis of their placement as given and followed in the mycobank, index fungorum and *Dictionary of the Fungi*. A list of the fungi included in the text is also provided at the end of the Chap. 1.

Chandigarh, India I.B. Prasher

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I.B. Prasher

Contents

Chapter 1
Introduction

Abstract A brief introduction of the group is provided regarding taxonomy and their ecology along with the resources and present status concerning the deposition of these fungi and their live cultures. A list of fungi included, is also provided.

This monograph is intended to provide a workable manual for the identification of wood-rotting non-gilled Agaricomycetes from the Himalayas. The Himalayas in this text includes the mountains which are in the territorial jurisdiction of India as well as Royal Kingdom of Bhutan and also includes the Assam Hills. The necessity of this text was felt in the view of the fact that no comprehensive illustrated manual on wood-rotting non-gilled Agaricomycetes of Himalayas with updated nomenclature is available. The works of Bakshi (1971), Rattan (1977), Roy and De (1996) and Sharma (1995, 2012) pertains to either specific/general groups of fungi and or needs revision from nomenclature point of view as well as due to the fact that large number of species have been discovered and reported from different regions of the area. The other compilations are either checklist (Sharma 2000) or checklists with few descriptions pertaining to a specific region (Prasher 1998, 1999, 2008, 2012), Dhingra et al. (2011), Prasher and Ashok (2013), Prasher and Lalita (2013), Ashok and Prasher (2014), Lalita and Prasher (2014).

In light of the above mentioned fact this monograph has been compiled. This work is based on extensive exploration made by the author and his students for more than a decade in the Himalayas as well as critical study of the specimens deposited in the Herbarium of the Botany Department Panjab University Chandigarh (PAN) by the earlier workers and other herbaria where ever required. It is worthwhile to mention that major portion of Himalayan collections are deposited in PAN. The authors endeavour in the present compilation has been to present the detailed information regarding each genus/species covering their taxonomy, morphology and ecology. The present compilation actually represents a small percentage of these fungi; which may be occurring in the Himalayas but can be considered as a foundation for future study; since large expanse of the Himalayas remain unexplored till-to-date and requires a massive and systematic floristic exploration by the mycologists. The taxonomic data concerning these fungi pertains to the collections made and described till end of 2012 only.

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1.1 About the Group

Wood-rotting non-gilled Agaricomycetes (referred to as "These fungi" now onwards in this volume) belong to class Agaricomycetes, sub-phyllum Agaricomycotina and phylum Basidiomycota. Agaricomycetes include fungi with hymenomycetous or gasteroid fructifications or basidiocarp and are characterized by perforate to imperforate parthenosomes and two to eight spored basidia (Hibbett et al. 2007; Kirk et al. 2008). The fungi with gasteroid type of fructifications have been placed in subclass Phallomycetidae (orders: Geastrales, Gomphales, Hysterangiales and Phallales) whereas those with hymenomycetous fructifications, belonging to orders Agaricales, Atheliales, Boletales have been assigned to subclass Agaricomycetidae. The fungi with hymenomycetous fructifications and belonging to orders Auriculariales, Cantharellales, Corticales, Gloeophyllales, Hymenochaetales, Polyporales, Russulales, Sebacinales, Thelephorales and Trechisporales have been placed in Agaricomycetes incertae sedis till the accumulation of sufficient data concerning molecular studies. Agaricomycetes as a group is equivalent to Homobasidiomycetes sensu Hibbett and Thorn (2001) plus Auriculariales and Sebacinales (Hibbett et al. 2007). These fungi have earlier been treated under Aphyllophorales by Patouillard (1900), Rea (1922), Bourdot and Galzin (1928), Donk (1964) and Talbot (1973) and other workers. Kirk et al. (2001) treated these fungi under subclass Agaricomycetidae. The classification of these fungi till the end of twentieth century by and large had been based on morphological and anatomical/histochemical parameters which have been followed in the major modern works on these fungi (Patouillard 1900; Rea 1922; Bourdot and Galzin 1928; Cunningham 1965; Donk 1960, 1962, 1964, 1974; Talbot 1973; Ryvarden and Johansen 1980; Gilbertson and Ryvarden 1987; Ryvarden 1990; Ryvarden and Gilbertson 1993, 1994; Núñez and Ryvarden 2001; Ryvarden et al. 2014). However, with the advent of the molecular fungal taxonomy started in 1990s with the analysis of PCR-amplified ribosomal RNA genes (White et al. 1990), a broad classification based on molecular fungal taxonomy has evolved with reassignment of the taxa (Hibbett and Thorn 2001). This has resulted in the intergeneric shifting of species, as well as reassignment of genera to different families, orders and classes. The fungi included in this work form fructifications (basidiocarps) on the wooden substratum, preceded by a vegetative phase in the form of mycelium inside the host as well as on the surface. These fructifications show varied forms and shapes. The simplest type is the radial growth of unlimited manner closely appressed to the host, on its under surface and bearing the hymenophore on the lower side. This type of fructification is termed as resupinate or effused e.g. *Poria*. The resupinate fructification may; after sometime in some cases; grow out of the substrate developing into characteristic forms like bract, shelf like or pileate (reflexed) fructifications or they may be of these types as such. The hymenium may line the walls of the cohering tubes or spread over smooth, teeth or corolloid, reticulate, meruloid and hydnoid surface. The presence of hymenium on the lower side towards the ground confers advantage with respect to spore dispersal as well as protection from environmental conditions.

Majority of these fungi grow on wood as saprophytes but some of these like *Aurificaria shoreae* and *Phellinus gilvus* (Schwein.) Pat., are also parasitic. These are capable of degrading both gymnospermous and angiospermous wood, the former termed as soft wood whereas the latter is termed as hard wood. The wood in the centre of the tree comprising of lignified xylem elements is called 'heart-wood' where as 'softwood' refers to the outer light-coloured region of the periphery of the wood. The heart-rot fungi continue to grow on the infected trees and do not kill the host whereas the soft-rot fungi growing on the sap-wood often kills the host caused by degradation of the sap-wood.

The lignin-degrading fungi cause white-rot which involves degradation of lignin and to a lesser extent the cellulose and hemicelluloses. This degradation reaction results in the formation of a bleached residue with greater percentage of cellulose. The brown-rot fungi utilize cellulose of the wood leaving a brown residue comprising of demethylated lignin (Jeffries 1987; Blanchette 1995) in the form of a powdery mass at later stages of degradation.

The degradation of lignocellulose of the tree as well as decayed wood by these fungi constitute one of the important events in the forest ecosystem, where by the carbon fixed by the green plants from the atmosphere is recycled back into the atmosphere. Most of the white as well as brown-rot fungi do not require lignin or cellulose for their growth in nature. Instead; for their survival and growth; they are dependent on simple plant polysaccharides which also provide them the energy (through oxidation) required for lignocellulolytic degradation. This physiological parameter of these fungi has been used beneficially in the biotechnological application like biopulping, employing fungi like *Phanerochaete chrysosporium & Ceriporiopsis subvermispora* (Akhtar et al. 1996; Wolfaardt et al. 1996), bio-bleaching, decolorization of industrial effluents, biodegradation of low molecular mass xenobiotic compounds, in the improvement of forage digestibility and in the production of many valuable chemicals like volatile organoleptic chemicals or their intermediate precursors and polynuclear aromatic hydrocarbon compounds- PAH's (Ralph and Catcheside 2002). The white-rot fungi have been found to be more effective than brown-rot fungi in all these applications (Bagley and Richter 2002). The major decay caused by brown-rot fungi is of coniferous trees in forest ecosystem, besides of wood in the buildings and other man-made infrastructure. The frequently occurring genera causing brown-rot of infrastructural wood are *Antrodia, Coniophora, Gloeophyllum, Neolentinus* and *Oligoporus*. Due to the degradation caused by brown-rot fungi, they have been used as test organisms world-wide by industries producing chemicals to check wood decay. Cultures of brown-rot fungi have been used world-wide for checking the efficacy of wood preservative chemicals before they are launched commercially in the market (Anonymous 1998). A lot of work has been done on bioconversion of biomass by these fungi (Kubicek et al. 2012). Extensive studies have been conducted on white-rot fungi than brown-rot fungi for their application in the industry and also the brown rot fungi are the little investigated ones as compared to white-rot fungi. Besides, due to their ability to degrade wood and their use in related biotechnological applications as discussed briefly above, they have been vigorously investigated for the production of bioactive metabolites for subsequent use in medicines.

1.2 Resources and Present Status

The major collections from the Himalayas have been deposited in the following herbaria in India by different workers:

(a) Herbarium Cryptogamae Indiae Orientalis (HCIO) IARI, New Delhi.
(b) Herbarium of Botany Department, Panjab University, Chandigarh, India (PAN).
(c) Herbarium of Botany Department, Punjabi University, Patiala (PUN).
(d) Mycological Herbarium of the Forest Research Institute, (FRI) Dehra Dun (D.D)
(e) Central National Herbarium, Botanical Survey of India, Calcutta (CAL).
(f) Herbarium of Botany Department, Calcutta University, Calcutta (CUH).
(g) Herbarium, Botanical Survey of India, Dehra Dun (BSD).
(h) Herbarium of Botany Department, Banaras Hindu University, Varanasi (BHUP).
(i) Herbarium National Botanical Research Institute, Lucknow (NBRI).
(j) Botany Group Plant Science Division, Agarkar Research Institute, Pune.
(k) Bose's Herbarium of Polyporaceae, Botany Department, R. G. Kar Medical College, Calcutta (CMS) now shifted to Presidency College Calcutta.

The collections in all these herbaria are well maintained. More than 80 % of the fungi (including type specimens) recorded from Himalayas and Assam hills are deposited in PAN. To the best of the knowledge of the author, major culture collections of these fungi is supported in the Indian Type Culture Collection (ITCC) at Indian Agricultural Research Institute (IARI), New Delhi; Agarkar Institute, Pune and in Microbial Type Culture Collection (MTCC) at Institute of Microbial Technology, Chandigarh (IMTech). The listing of culture at IMTech depicts 86 collections of wood-rotting Agaricomycetes. Majority of these resources are not obtained from the Himalayas but have been procured from the American Type Culture Collection (ATCC), Central bureau voor Schimmel cultures, Baarn (CBS), Deutsche Sammlung von Mikoorganismen and Zellkulturen Gmlott (DSMZ) & Imperial Mycological Institute Herbarium Culture Collection. The Indian collections deposited in MTCC are of A. Roy, D. S. Arora and A. Mitra, besides some cultures procured from Forest Research Institute (F.R.I) and ITCC. Around 150 collections of these fungi are being maintained in the Mycology and Plant Pathology Laboratory of the Botany Department, Panjab University, Chandigarh. However, this is a fraction of the vast resources available in Himalayas. This points out the state of affairs as far as maintenance/deposition of live cultures of wood-rotting Agaricomycetes in India is concerned. Not much attention has been paid towards culturing of these fungi from Himalayas and elsewhere in the country.

A total of 488 species of these fungi spreading over 167 genera are being recorded from the study area, where as 6 species and varieties are proposed as new to science. Forty species are recorded and described for the first time from Himalayas where as 15 and 6 species are recorded and described for the first time from North-Western and Eastern Himalayas respectively.

1.3 List of New Species & Varieties and New Records

1.3.1 New Species and Varieties

Leptosporomyces thindii Prasher & Lalita sp. nov.
Peniophorella microtsugae Prasher & Lalita sp. nov.
Leptosporomyces roseus Jülich, Willdenovia, Beih. 7: 208, 1972, var. *macrosporus* Prasher & Lalita var. nov.
Radulomyces confluens (Fr.) M.P. Christ., Dansk bot. Ark. 19(2): 230 (1960) (Fr.) M.P. Christ., var. *macrobasidiata* Prasher & Lalita var. nov.
Sidera lenis (P. Karst.) Miettinen, in Miettinen and Larsson, Mycol. Progr. 10(2): 136 (2011) var. *minutispora* Prasher & Lalita var nov.
Datronia stereoides (Fr.) Ryv., Blyttia 25: 168 (1967) var. *microspora* Prasher and Lalita var. nov.

1.3.2 New Records for Himalayas/India

Aleurodiscus lapponicus
Amyloathelia crassiucula
Anomoporia bombycina
Antrodia sinuosa
Boidinia lacticolor
Ceraceomyces cystidiatus
Coniophora arida
Coniophora fusispora
Coriolopsis caperata
Dendrothele seriata
Dichomitus leucoplacus
Dichostereum kenyense
Diplomitoporus crustulinus
Erythricium laetum
Fibulomyces mutabilis
Flaviporus hydrophilus
Fomes extensus
Fuscoporia ferrea
Galzinia incrustans
Ganoderma multiplicatum
Hyphoderma macedonicum
Hyphodontia abieticola
Hyphodontia alienate
Hyphodontia barbajovis
Inonotus albertinii
Inonotus tenuicarinus

Leptosporomyces galzinii
Microporellus obovatus
Microporellus obovatus
Paullicorticium delicatissimum
Phanerochaete velutina
Phlebia interjacenoides
Phlebiopsis flavidoalba
Postia ceriflua
Postia mappa
Postia undosa
Resnicium friabile
Scytinostroma alutum
Vararia minidichophysa
Vararia rugosispora

1.3.3 New Records for North-Western Himalayas

Crustoderma dryinum
Daedalea dochmia
Hyphoderma sikkimium
Hyphodontia caulicystidiata
Hyphodontia propinqua
Hypochnicium caucasicum
Lenzites eximia
Peniophorella rude
Phanerochaete galactites
Phanerochaete sordida
Phlebia interjacenoides
Phlebia rufa
Sarcodontia spumea
Tomentella clavigera
Vararia sphaericospora

1.3.4 New Records for Eastern Himalayas

Fuscoporia torulosa
Junghuhnia luteoalba
Polyporus grammocephalus
Postia guttulata
Postia mappa
Trametes incerta

1.4 Lists of the Orders, Families and Genera Included in This Text

Order- Agaricales

Family- Amylocorticiaceae

Genus- *Amyloathelia*

A. crassiucula

Genus- *Amylocorticium*

A. indicum

Genus- *Amyloxenasma*

A. allantosporum
A. grisellum

Genus- *Ceraceomyces*

C. bizonatus
C. borealis
C. cystidiatus
C. fibuliger
C. reidii
C. sublaevis
C. tessulatus

Family- Cyphellaceae

Genus- *Chondrostereum*

C. purpureum

Family- Physalacriaceae

Genus- *Cylindrobasidium*

C. evolvens

Family- Pterulaceae

Genus- *Aphanobasidium*

A. subnitens

Genus- *Radulomyces*

R. confluens var. *macrobasidiata*
R. molaris

Family- Stephanosporaceae

Genus- *Cristinia*

C. helvetica
C. mucida

Order- Atheliales

Family- Atheliaceae

Genus- *Amphinema*

A. byssoides

Genus- *Athelia*

A. decipiens
A. teutoburgensis

Genus- *Athelopsis*

A. parvispora
A. subinconspicua

Genus- *Fibulomyces*

F. cystoideus
F. mutabilis

Genus- *Hypochniciellum*

H. ovoideum

Genus- *Leptosporomyces*

L. adnatus
L. galzinii
L. globosus
L. roseus var. *macrosporus*
L. thindii

Order- Boletales

Family- Coniophoraceae

Genus- *Coniophora*

C. arida
C. cordensis
C. fusispora
C. olivacea
C. puteana

Family- Hygrophoropsidaceae

Genus- *Leucogyrophana*

L. mollusca
L. olivascens
L. thimphina

Family- Serpulaceae

Genus- *Serpula*

S. himantioides
S. lachrymans

Order- Cantharellales

Family- Botryobasidiaceae

Genus- *Botryobasidium*

B. asperulum
B. candicans
B. danicum
B. subbotryosum
B. subcoronatum
B. vagum

Genus- *Botryohypochnus*

B. isabellinus

Family- Ceratobasidiaceae

Genus- *Scotomyces*

S. subviolaceus

Family- Hydnaceae

Genus- *Paullicorticium*

P. delicatissimum
P. indicum

Genus- *Sistotrema*

S. angustispora
S. binucleosporum
S. brinkmannii
S. lachrymisporum
S. porulosum
S. sernanderi
S. subtrigonospermum

Order- Corticales

Family- Corticiaceae

Genus- *Corticium*

C. confine

Genus- *Dendrothele*

D. alliacea
D. incrustans
D. seriata

Genus- *Erythricium*

E. laetum

Genus- *Galzinia*

G. ellipsospora
G. incrustans

Genus- *Laeticorticium*

L. expallens

Genus- *Licrostroma*

L. subgiganteum

Order- Gloeophyllales

Family-Gloeophyllaceae

Genus- *Gloeophyllum*

G. abietinum
G. carbonarium
G. sepiarium
G. striatum
G. subferrugineum

Family- Hericiaceae

Genus- *Dentipellis*

D. leptodon

Genus- *Laxitextum*

L. bicolor

Order- Gomphales

Family- Lentariaceae

Genus- *Kavinia*

K. alboviridis

Family- Hymenochaetaceae

Genus- *Aurificaria*

A. indica

Genus- *Fomitiporia*

F. robusta

Genus- *Fuscoporia*

F. contigua
F. ferrea
F. ferruginosa
F.senex
F. torulosa

Genus- *Hymenochaete*

H. fuscobadia
H. leonina
H. luteobadia
H. mougeotii
H. rubiginosa
H. semistuposa

Genus- *Inonotus*

I. albertinii
I. cuticularis
I. dryadeus
I. tabacinus
I. tenuicarinis

Genus- *Onnia*

O. circinata
O. tomentosa

Genus- *Phellinus*

P. adamantinus
P. allardii
P. caryophylli
P. fastuosus
P. gilvus
P. grenadensis
P. igniarius
P. johnsonianus
P. linteus
P. merrillii

P. nilgheriensis
P. sanfordii
P. setulosus
P. xeranticus

Genus- *Phylloporia*

P. pectinata
P. ribis
P. spathulata

Genus- *Porodaedalea*

P. pini

Genus- *Tubulicrinis*

T. chaetophorus
T. glebulosus
T. hamatus
T. strangulates
T. subulatus

Family-Rickenellaceae

Genus- *Peniophorella*

P. microtsugae
P. pallida
P. praetermissa
P. pubera
P. rude

Genus- *Resinicium*

R. bicolor
R. friabile

Family- Repetobasidiaceae

Genus- *Sidera*

S. lenis var. *minutispora*
S. lunata

Family Schizoporaceae

Genus- *Alutaceodontia*

A. alutacea

Genus- *Basidioradulum*

B. tuberculatum

Genus- *Hyphodontia*

H. abieticola
H. alienata
H. altaica
H. alutaria
H. arguta
H. aspera
H. barbajovis
H. caulicystidiata
H. crustosa
H. efibulata
H. hastata
H. juniperi
H. nespori
H. pallidula
H. papilosa
H. propinqua
H. sambuci
H. spathulata
H. stipata

Genus- *Oxyporus*

O. cervinogilvus
O. corticola
O. populinus
O. ravidus

Genus- *Schizopora*

S. flavipora
S. paradoxa

Genus- *Xylodon*

X. pruni
X. rimosissima

O-Polyporales

Family- Cystostereaceae

Genus- *Cystostereum*

C. murrayi

Family- Fomitopsidaceae

Genus- *Antrodia*

A. albida

A. gossypium
A. serialis
A. sinuosa
A. xantha

Genus- *Anomoporia*

A. bombycina

Genus- *Daedalea*

D. dickinsii
D. dochmia
D. flavida
D. gollanii
D. imponens
D. quercina
D. sulcata

Genus- *Dacryobolus*

D. costratus
D. karstenii
D. sudans

Genus- *Fomitopsis*

F. palustris
F. pinicola
F. rosea
F. rubida
F. rufolaccata

Genus- *Laetiporus*

L. sulphureus

Genus- *Parmastomyces*

P. corticola

Genus- *Phaeolus*

P. schweinitzii

Genus- *Postia*

P. caesia
P. ceriflua
P. guttulata
P. leucomallella
P. mappa
P. sericeomollis

P. undosa

Family- Ganodermataceae

Genus- *Ganoderma*

G. applanatum
G. lucidum
G. multiplicatum
G. resinaceum
G. sessiliforme

Family- Hyphodermataceae

Genus- *Intextomyces*

I. contiguus

Family- Meripileaceae

Genus- *Physisporinus*

P. rivulosus

Genus- *Rigidoporus*

R. crocatus
R. lineatus
R. microporus
R. ulmarius
R. vinctus

Family- Meruliaceae

Genus- *Abortiporus*

A. biennis

Genus- *Bjerkandera*

B. adusta
B. fumosa

Genus- *Cabalodontia*

C. queletii
C. subcretacea

Genus- *Conohypha*

C. grandispora

Genus- *Crustoderma*

C. dryinum

Genus- *Flaviporus*

F. hydrophilus

Genus- *Flavodon*

F. flavus

Genus- *Gloeoporus*

G. dichorus
G. thelephoroides

Genus- *Gyrophanopsis*

G. polonensis

Genus- *Hyphoderma*

H. argillaceum
H. clarusproprietas
H. macedonicum
H. occidentale
H. parvisporum
H. setigerum
H. sibiricum
H. sikkimium
H. singularibasidium
H. sporulosum

Genus- *Hypochnicium*

H. caucasicum
H. cystidiatum
H. geogenium
H. longicystidiosum
H. lundellii
H. punctulatum
H. sphaerosporum

Genus- *Irpex*

I. consors
I. lacteus
I. vellereus

Genus- *Junghuhnia*

J. collabens
J. luteoalba
J. nitida
J. zonata

Genus- *Mycoacia*

M. fuscoatra
M. stenodon

Genus- *Phlebia*

P. crassisubiculata
P. interjacenoides
P. livida
P. microspora
P. radiata
P. rufa
P. segregata
P. singularisa
P. subserialis
P. subochracea
P. thindii

Genus- *Radulodon*

R. americanus
R. erikssonii

Genus- *Scopuloides*

S. hydnoides

Genus- *Sarcodontia*

S. delectans
S. pachyodon
S. spumea

Genus- *Steccherinum*

S. ciliolatum
S. fimbriatum
S. laeticolor
S. ochraceum

Family-Phanerochaetaceae

Genus- *Antrodiella*

A. semisupina
A. zonata

Genus- *Byssomerulius*

B. corium