

Fungi from Different Substrates

Fungi from Different Substrates

Editors

J.K. Misra

SLM Bharatiya Vidya Bhavan Girls Degree College
Vineet Khand, Gomti Nagar
Lucknow
India

J.P. Tewari

Department of Agricultural, Food, and Nutritional Science
University of Alberta
Alberta
Canada
and
Lung, Allergy, Sleep Centers of America
224 W. Exchange Street, Ste. 380
Akron, Ohio 44302
U.S.A.

S.K. Deshmukh

Piramal Enterprises Limited
Department of Natural Products
Goregaon (East), Mumbai
India

Csaba Vágvölgyi

Department of Microbiology
Faculty of Science and Informatics
University of Szeged
Szeged
Hungary



CRC Press

Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business
A SCIENCE PUBLISHERS BOOK

Cover illustrations reproduced by kind courtesy of Dr. Kim Fleming, Dr. Hoai Xuan Truong and Dr. Shubha Pandey

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2015 by Taylor & Francis Group, LLC
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper
Version Date: 20140707

International Standard Book Number-13: 978-1-4822-0960-0 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Visit the Taylor & Francis Web site at
<http://www.taylorandfrancis.com>

and the CRC Press Web site at
<http://www.crcpress.com>

CHAPTER 2

Wood-Inhabiting Fungi

Ivan V. Zmitrovich,^{1,} Solomon P. Wasser² and
Daniel Tura³*

ABSTRACT

The chapter summarizes the current developments on wood-inhabiting fungi. Taxonomically, wood-decomposers are represented by some groups of Basidiomycota, especially belonging to the order Polyporales (class Agaricomycetes). Composition of wood-inhabiting fungi established on generic and higher levels are given. Morphologically parallel series of sporogeneous structures of wood-inhabiting fungi are presented as a biomorphic system. Enzymatic systems of fungal wood-decomposers highlight white-rot and brown-rot fungi. It is emphasized that both groups are capable of oxidizing C-C components of wood polymers, but their targets are diverse. The mycogeographical aspects of wood-inhabiting fungi have been overviewed. The trophic aspects as well as substrate groupings of these fungi and their distributional patterns in the forest ecosystems of the Northern Hemisphere have also been discussed.

Introduction

Woody vegetation predominates in moist and cold climates, but is scarce in arid ones. This vegetation represents a main environment softening component of terrestrial ecosystems and shows maximum biodiversity of a zonal bioms. Such types of vegetation in terrestrial environments

¹ V.L. Komarov Botanical Institute, Russian Academy of Sciences 2, Professor Popov St., St Petersburg, 197376, Russia.

² Institute of Evolution and Department of Evolutionary & Environmental Biology, Faculty of Science & Science Education, University of Haifa, Mt Carmel, Haifa 31905, Israel.

³ Aloha Medicinals Inc., Carson City, Nevada 89706, USA.

* Corresponding author

are closely related to woody plant-fungal interactions, e.g., mycorrhizal symbiosis, wood decaying/decomposition and phyllophane fungal epi-endophytism.

The life history of a tree is connected, one way or the other, with diverse wood-inhabiting fungi. Fungal groups are connected spatially with wood at its various stages (from living trees to litter wood debris), and most of their representatives are capable of wood decomposition and utilization. However, some wood-inhabiting fungi are basically mycorrhiza-formers or mycoparasites.

Enzymatic systems of fungal wood-decomposers are adapted to the degradation of various components of wood, and the two main groups can be distinguished: the white-rot and brown-rot fungi. Both groups are capable of oxidizing C-C components of wood polymers. White-rot fungi target the lignin molecules, whereas the brown-rot fungi attack the celluloses and hemicelluloses.

The main diversity of wood-inhabiting fungi is represented by some groups of Ascomycota (with related anamorphic representatives), but the most adapted pool of wood decomposers is represented by some groups of Basidiomycota, especially belonging to the order Polyporales of class Agaricomycetes. All these fungi are characterized by having a wonderful parallel morphological adaptation for sporulation over various substrata such as small twigs, branches, trunks, stumps and fallen logs, and also amorphous wood-remnants within the forest litter.

It is hard to overestimate the role of wood-inhabiting fungi in forest ecosystems. In moist taiga environments these fungi are the key agents for enrichment of forest soil by humus-like compounds. The humic acids, released in the process of wood and litter decay in such forests, are powerful factors of relief formation in taiga landscapes. In mesophylic nemoral and moist tropical forests, the wood-inhabiting fungi are important agents for keeping the biomass balance, whereas in arid ecosystems their pathogenic role is important.

Pathogenic wood-inhabiting fungi produce heart-rots of many economically important trees; some species are connected with superficial necrosis or the colonization of total volume of the trunk. The control strategies of tree pathogens and timber fungi are, therefore, important issues of applied mycology.

Trophic and Topic aspects of Wood-Inhabiting Fungi

What are Wood-Inhabiting Fungi?

The term "wood-inhabiting fungi" is usually applied to the topic group, uniting those representatives of eumycetes (Ascomycota and Basidiomycota)

whose sporulations are associated with wood under various conditions. If the vegetative mycelium of a fungus is associated with wood, whereas fungal nutrition is connected to wood degradation, such a fungus may be called a "wood-destroying fungus".

In some cases, the mycelium of a fungus spreads through forest litter to the humus-soil horizon and is capable of forming ectomycorrhizae, whereas the fruitbodies are obligately or facultatively associated with woody substrates. These fungi coincide with the trophic grouping of wood-inhabiting fungi, but their trophic affiliations are diverse. The situation is similar to some obligate parasitic wood-destroying fungi that develop their spores/fruitlet bodies over woody substrates.

The lichenized Ascomycota (lichens), growing abundantly over wood of various types, are traditionally not considered as being part of wood-inhabiting fungi. However, lichenized Basidiomycota, whose dependence on algae is rather facultative and whose mycelium is capable of penetrating and destroying woody substrata, are traditionally considered as being representatives of wood-inhabiting fungi.

Biochemical Aspects of Wood Decay

Wood-decay is the most common mode of life of wood-inhabiting fungi. Historically, this mode descends to Devonian transformation of plant ecomorphs from plagiotropic to orthotropic ones through the processes of sprouts lignification as result of some transformations of plant secondary metabolism (Ragan and Chapman, 1978; Karatygin, 1993). According to Ragan and Chapman (1978), the close relatives of Devonian plants with associated symbiotic fungi did not exclude a horizontal plant-fungus gene transfer, particularly expressed by genes related to building and destroying of the lignin molecular composites.

A basic feature of wood organization, as shown in Fig. 2.1, is the presence of vessels with secondarily thickened walls. The fibrils of cellulose and hemicelluloses (Fig. 2.1a) compose a fibrillar core of this structure, whereas the lingo-cellulose complex composes their amorphous matrix (Fig. 2.1b, c).

Fungi are adapted to destroying and assimilating such a specific substrate; this process occurs in two ways: 1) the development of an enzymatic device system for polysaccharides biodegradation and 2) the development of an enzymatic system for lignin and polysaccharide oxidation.

The main polysaccharides of cell walls of woody plants and the corresponding hydrolytic enzymes that hydrolyze internal glycosidic bonds have been tabulated below (Table 2.1). The result of this hydrolysis process is the disruption of microfibrillar structure of the wood.

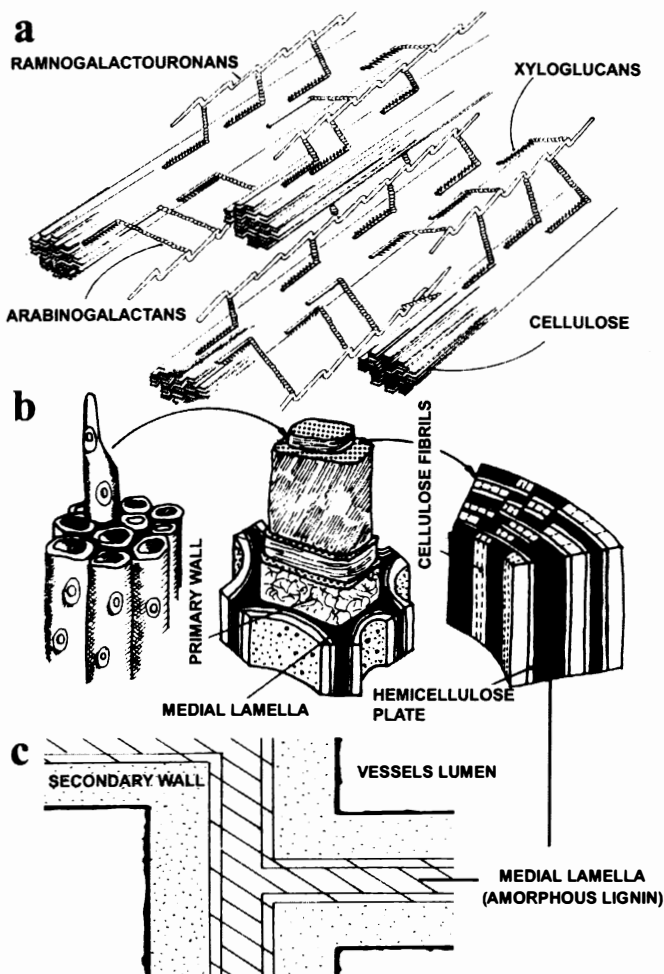


Figure 2.1. The structure and polymer composition of the xylem (according to Kirk 1983): (a) polysaccharide core, (b) the wall structure of xylem vessels; (c) schematic section crossing xylem tissue emphasizing secondary wall and medial lamella.

However, such a biodegradation of polysaccharide fibrillar core of the wood is rather rare. Particularly, this way of wood decomposition is a characteristic of cambial biotrophs that are associated with bark exfoliation. After exfoliation, sapwood can be attacked by highly specific hydrolizers produced by the so-called “bluestaining fungi”—ascmycetes for example, genera like *Ophiostoma* and *Ceratocystis*, whose xylanase and pectinase activities are the reasons for changes in wood surface spectral characteristics. The other pool of hydrolytically active fungi is associated with wood

Table 2.1. The hydrolytic biodegradation of the wood.

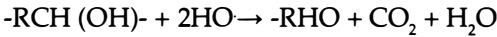
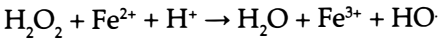
Fractions of polysaccharides of wood cell wall	Hydrolytic enzymes of wood-inhabiting fungi	Products of degradation	Example species, authors
Cellulose	1,4- β -D-glucan cellobiohydrolases	cellobiose, cellobioses, D-glucose	<i>Postia placenta</i> M.J. Larsen & Lombard, <i>Hypocrea jecorina</i> Berk. & Broome; <i>Phanerochaete chrysosporium</i> Burds. (Cowling, 1961; Aro et al., 2005)
Hemicelluloses	1,4- β -D-xylan xylohydrolase, β -xylosidase, acetyl xylan esterase; xylan- α -1,2-glucuronosidase; feruloyl esterase; α -L-arabinofuranosidase; endo-1,4- β -mannosidase; xyloglucan hydrolase	D-xylose; glucuronic acid; ferulic acid; L-arabinose; D-glucose; galactose	<i>Magnaporthe grisea</i> (T.T. Hebert) M.E. Barr (Polizeli et al., 2005; Gamauf et al., 2007)
Pectins	rhamnogalactouronan hydrolase, rhamnogalactouronan lyase; endo- β -1,6-galactanase, exogalactanase; L-arabinofuranosidase	D-galactouronic acid; D-galactose L-arabinose	<i>Ceratobasidium</i> spp. (González García et al., 2006); <i>Tremella aurantialba</i> Bandoni & M. Zang (Jing et al., 2007)

debris of forest litter, especially within pectin-rich remnants, such as fallen fruits and old herb stems. This group includes many members of the order Helotiales. But in most of the cases, the capacity of wood fungi to hydrolyze polysaccharides is combined with the capacity to oxidize C–C links both in polysaccharide and lignin-containing composites (= multicomponent substances: cellulose + lignin + pectines, etc.). Thus, depending on the targets of oxidation—polysaccharides or lignocelluloses, two types of wood decomposition are distinguishable: brown-rot and white-rot.

Brown-rot. The main targets of brown-rot wood-inhabiting fungi are cellulose and hemicelluloses; the lignin is subjected to slight modification via demethylation (Wright, 1985; Eriksson et al., 1980, 1990). The wood loses its fibrillar structure, and becomes fragile and cracks into a red-brownish mass due to lignin modification.

Koenigs (1972) demonstrated that such wood decomposers are capable of producing a huge amount of H_2O_2 . This substance is generated by extracellular enzymatic systems (peroxidases). The mechanism of attacking

the C-C-links of crystalline cellulose and similar composites is known as the Fenton reaction:



In order to avoid the destruction of hyphal wall and to act on lignified parts of the secondary cell wall, the OH-radicals should be produced at a distance from the hypha, and the fungal reductants should be stable enough to diffuse before they react to reduce Fe (III) and oxygen to Fe (II) and peroxide (Fig. 2.2). The production of OH-radicals takes place in several ways following different systems including secretion of hydroquinones, cellobiose dehydrogenases, low-molecular-weight glycopeptides and phenolate chelators (Gamauf et al., 2007).

The brown-rot fungi are adapted to rapid xylolysis, and are capable of causing heart-rots and decomposition of stumps and logs, presumably of conifers, which are characterized by highly resistant lignocellulose complexes. The wood cracks into polygons or chips, and this lignin-rich material is a predecessor of humus in forest soils (Fig. 2.3).

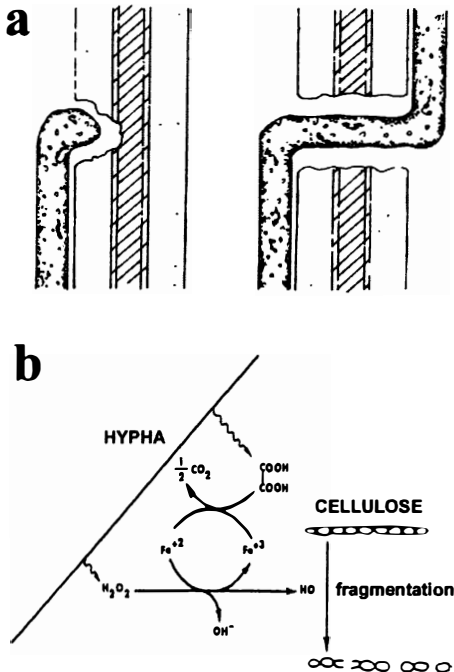


Figure 2.2. Scheme showing the vessel wall penetration by hypha of brown-rot fungus (a) and free radical production by such a hypha (b) according to Wright (1985).



Figure 2.3. A pine stump decomposed by brown-rot fungus *Neolentinus lepideus* (Fr.) Redhead & Ginns: on the foreground the large wood chip is appreciable whereas decomposed cubical material is converted into forest litter.

Under xerophylic conditions, in exposed fallen logs and decorticated stands, the brown-rot fungi demonstrate rather weak activity causing the so-called “dry-rot”. The typical dry-rot producers are representatives of the genera *Dacrymyces* and *Gloeophyllum*. However, when the process of water evaporation outside the wood is hampered by forest shade, by ground conditions or the abundance of fallen wet logs, the rot stays active, and in many cases is accompanied by self-moisturizing of wood due to metabolic water. Such an active—wet brown-rot is characteristic of *Serpula*, *Tapinella*, and many species of *Antrodia* and *Fomitopsis* (Fig. 2.4).

White-rot. The white-rot fungi are adapted to deep degradation of lignin and partial decomposition of polysaccharides. The lignin is a highly inert biopolymer with a high molecular weight, which is composed of many stacked polyphenol moieties. The simple type structure of this polymer is presented in Fig. 2.5.

White-rot fungi decompose this resistant biopolymer through many steps of the oxidative process, involving peroxidases and laccases (phenol oxidases), which act non-specifically by generating lignin free radicals and then undergo spontaneous cleavage reactions (Rabinovich et al., 2001; Gamauf et al., 2007).

The laccases, represented in wood-fungi by Lignin Peroxidases (LiPs), Manganese Peroxidases (MnPs), and Versatile Peroxidases (VP) have a high

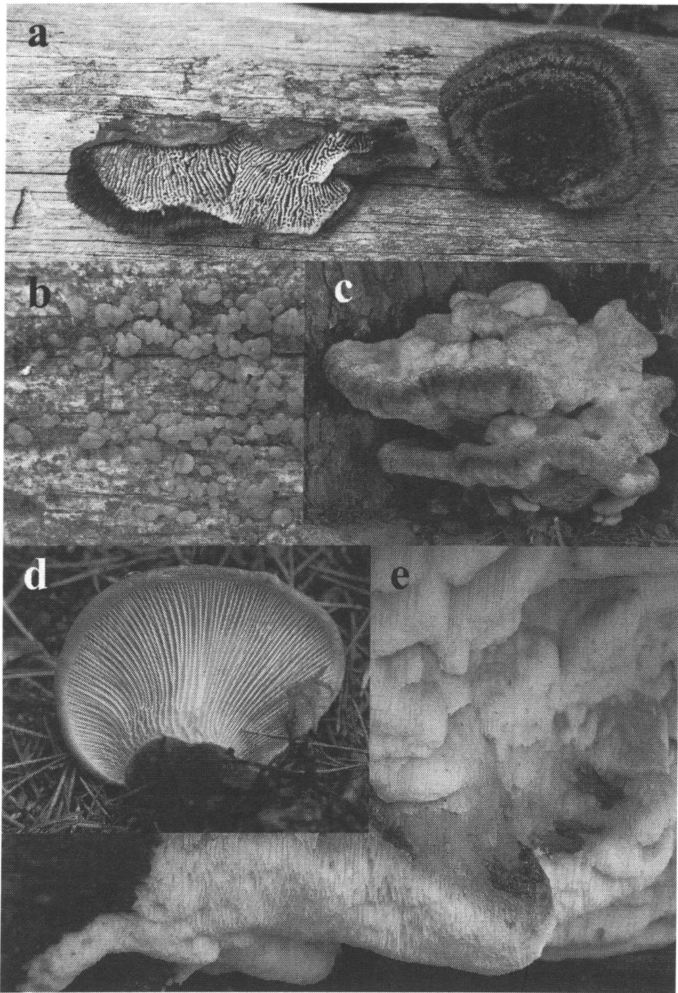


Figure 2.4. Key brown-rot fungi: (a) dry-rot producer *Gloeophyllum sepiarium* (Wulfen) P. Karst.; (b) superficial dry-rot producer *Dacrymyces punctiformis* Neuhoff; (c) heart dry-rot producer *Phaeolus schweinitzii* (Fr.) Pat.; (d) wet brown-rot producer *Tapinella atrotomentosa* (Batsch) Šutara; (e) mixed brown-rot producer *Antrodia crassa* (P. Karst.) Ryvarden.

level of redox potential and thus are capable of oxidizing polyphenolic and other polycyclic aromatic composites. The active center of laccases is presented by iron-containing gem structure (Fig. 2.6).

These peroxidases become highly oxidized when H_2O_2 is reduced to H_2O , and a two-electron reaction allows two activated substrate units to be in a resting state once again before their reduction by peroxidase. The scheme of basic pathways of lignin oxidation by this system is presented in Fig. 2.7.

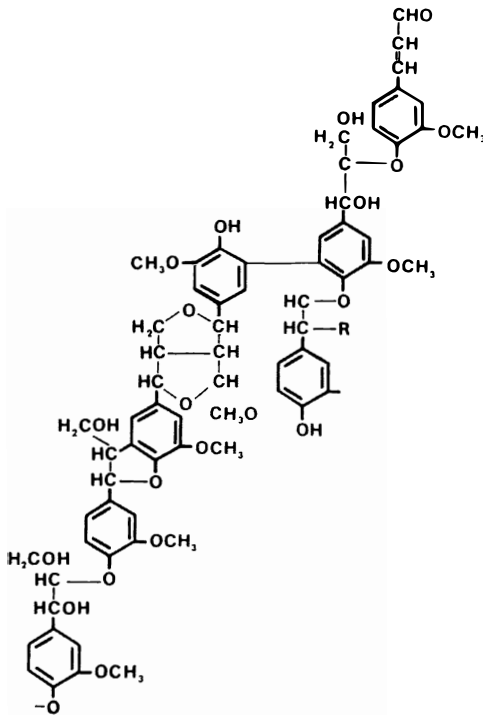


Figure 2.5. The type module of lignin molecular composite after Wright (1985).

There are two basic white-rot patterns:

- 1) Non-selective delignification attacks mainly hardwood and degrades cellulose, lignin, and hemicellulose simultaneously. The vessel walls are degraded progressively from the lumen towards the middle lamella. The wood remnants are represented by discolored lignin derivatives and breaking cellulose threads of white—stramineous colors. This pattern is characteristic to most white-rot producers, both for ascomycetes and basidiomycetes.
- 2) Selective delignification attacks hard and soft woods. In this case lignin and hemicelluloses are primarily attacked, and then cellulose. The wood remnants, in many cases, keep their regular crystalline structure or are penetrated by regular pockets. Discoloration occurs in many cases up to white or stramineous colors, but in some cases may be produced to an unusual red or green coloration due to polyphenol remnants. This pattern is a characteristic of some basidiomycetes only, e.g., *Pleurotus* spp., *Phanerochaete* spp., *Ceriporiopsis subvermispora* (Pilát) Gilb. & Ryvarden, and such white-rot fungi may be a good source for biotechnological applications (Schmidt, 2006).

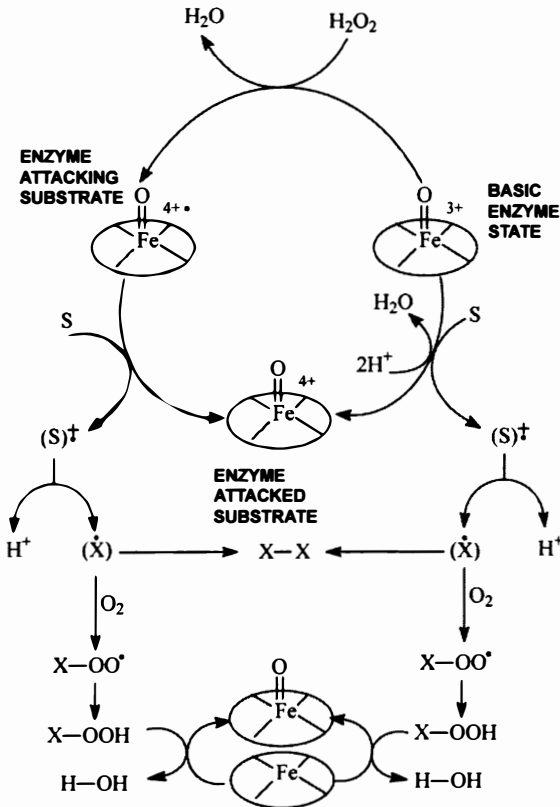


Figure 2.6. The principle structure of the active center of laccases and the mechanism of free-radical production and enzyme regeneration, according to Aisenstadt and Bogolytzin (2009).

White-rot fungi are represented by a huge pool of wood-decomposers, inhabiting a large range of ecological niches from living trees and shrubs to forest litter (Fig. 2.8).

According to Nobles (1958), white-rot fungi represent a derived and homogeneous group of xylotrophic fungi, which originated from brown-rotters via an elaborate system of oxidative enzymes. On the contrary, Gilbertson (1980) states that brown-rot fungi are phylogenetically younger than white-rotters and have multiple and independent origins. Indeed, remnants of gymnosperm predecessors (*Callyxylon* spp.) have characteristics similar to white-rot (Stubblefield et al., 1985). Gilbertson's view also supports this by revealing silent laccase genes in brown-rotters genome (D'Souza et al., 1996). The oxidative (not hydrolytic!) nature of cellulose degradation by brown-rotters may be interpreted as a secondary strategy of rapid colonization of wood substrates.

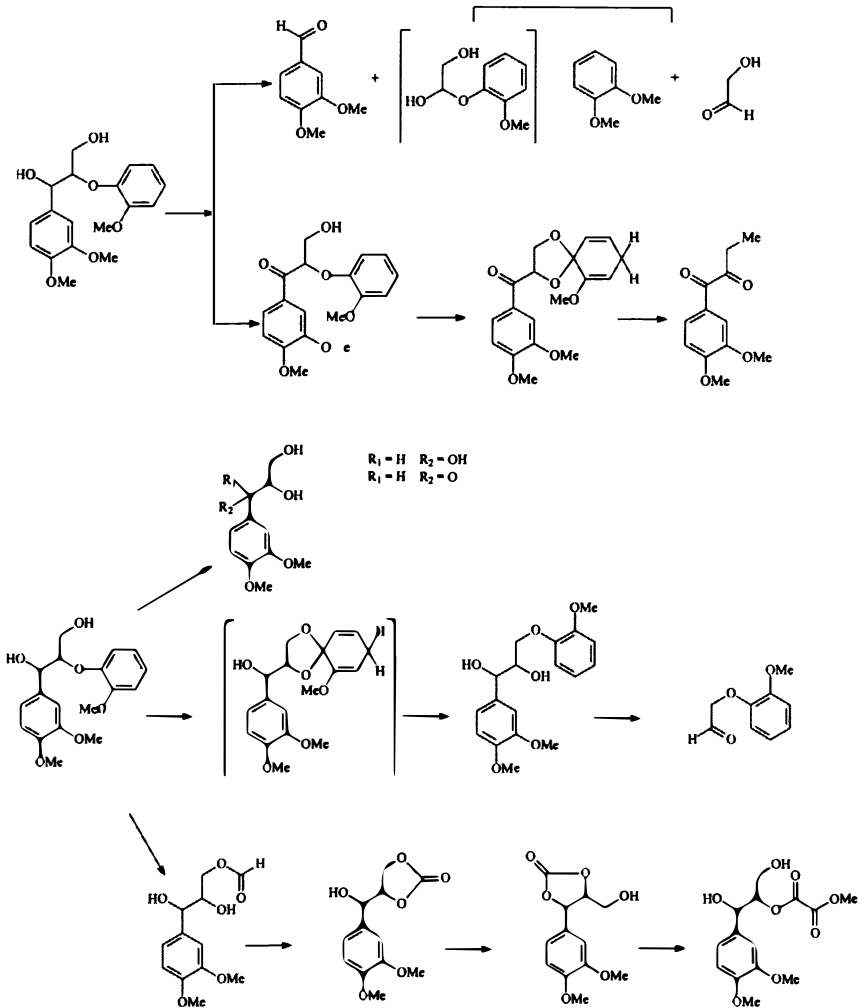


Figure 2.7. The basic ways of oxidation of lignin modules by laccase-generated radicals, as it is shown in Fig. 6 (according to Aisenstadt and Bogolytz in 2009).

C. Trophic Differentiation

According to a basic terminological revision of fungal modes of nutrition, presented by Cooke and Whipps (1980), there are five main modes of nutrition of plant-associated fungi (Fig. 2.9): facultative biotrophs, obligate biotrophs, facultative necrotrophs, obligate saprotrophs and obligate necrotrophs.

Biotrophs and necrotrophs cover an old uncertain category of “parasites”. The latter reflects a mode of life rather than a mode of nutrition; therefore, it should be excluded from the trophic category.

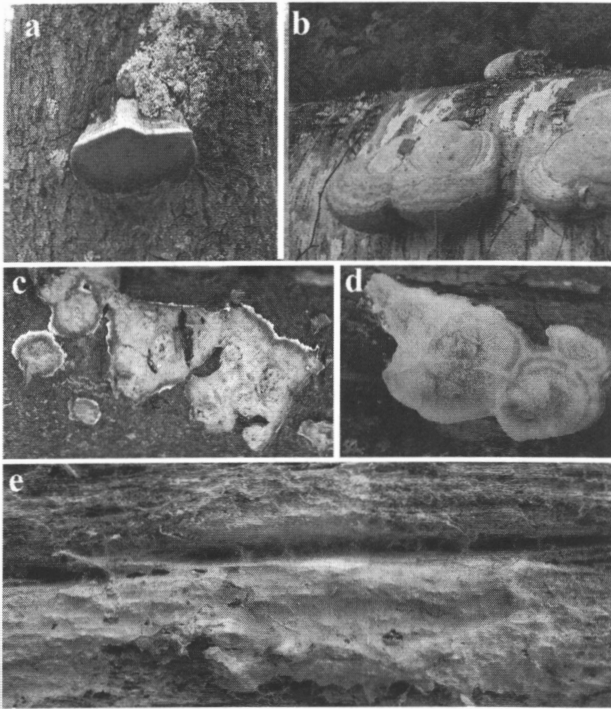


Figure 2.8. Key niches representatives of white-rot fungi: (a) *Phellinus tremulae* (Bondartsev) Bondartsev & P.N. Borisov on living aspen tree; (b) *Fomes fomentarius* (L.) J.J. Kickx on fallen birch tree; (c) *Peniophora rufomarginata* (Pers.) Litsch. in Keissler on fallen lime branch; (d) *Merulius tremellosus* Schrad. on debris of alder tree; (e) *Piloderma olivaceum* (Parmasto) Hjortstam on debris of pine tree and forest litter.

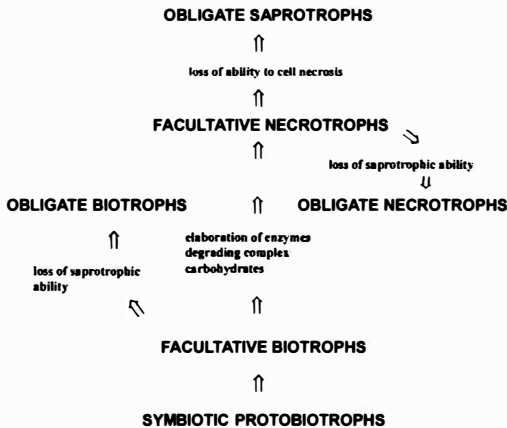


Figure 2.9. The evolution of nutritional modes of fungi according to Cooke and Whipps (1980). The wood-inhabiting fungi belong in their predominating mass to diapason from facultative necrotrophs to obligate necrotrophs and obligate saprotrophs.

True biotrophs are associated with grasses and leaves of woody plants. Their mycelium is adapted to weak exploitation of the host protoplast via elaboration of the so-called "interaction zone", appressoria and haustoria. Wood-inhabiting fungi, in most cases, are devoid of these specialized structures because wood cells are furnished with secondarily thickened walls and usually do not have a protoplast. However, within the Tremellales and some Pucciniomycetes, there are fungi combining xylosaprotrophic ability with a biotrophic (mycoparasitic) one. For example, the *Tremella* representatives are able to infest only cells of fungal hymenium (so-called "intrahymenial parasites"), or transform the whole host fructification (Fig. 2.10a) or occupy xylotroph-attacked wood and vegetative mycelium

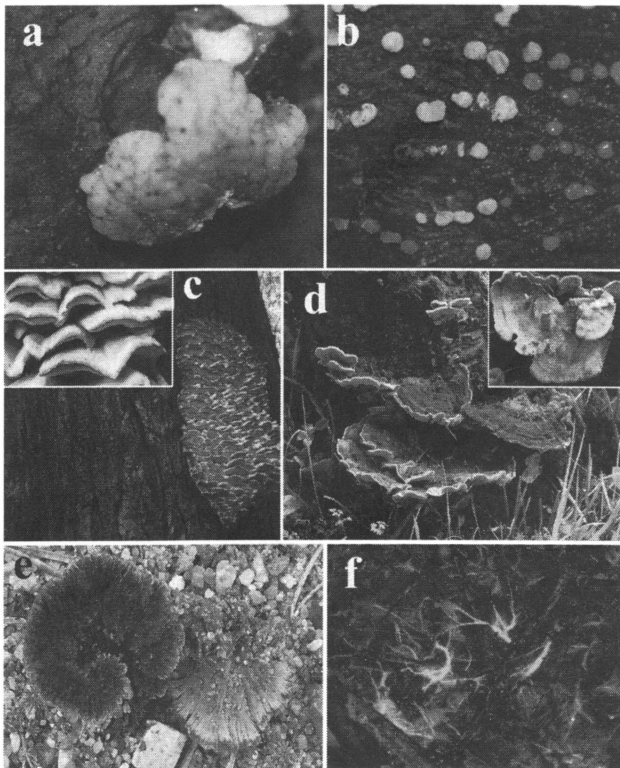


Figure 2.10. Representatives of main trophic groupings of wood-inhabiting fungi: (a) facultative biotrophs—mycoparasites [*Tremella encephala* Willd., transformed fruitbody of host xylotrophic fungus *Stereum sanguinolentum* (Alb. & Schwein.) Fr.]; (b) facultative necrotrophs [*Tubercularia vulgaris* Tode—anamorph of *Nectria cinnabarina* (Tode) Fr.]; (c) pathogenic saprotrophs [*Climacodon septentrionalis* (Fr.) P. Karst. on living maple tree]; (d) non-pathogenic saprotrophs [*Cerrena unicolor* (Bull.) Murrill on birch stump]; (e) facultative humus saprotrophs/mycorrhiziformers (*Thelephora terrestris* Ehrh.—with epiphytic pileate fruitbody); (f) *ibid.* [*Piloderma bicolor* (Peck) Jülich—with rhizomoid intramatrical to epiphytic fruitbody].

of xylosaprotrophs, penetrating them by haustoria or similar structures (Olive, 1946; Bandoni, 1961, 1987; Zugmaier et al., 1994; Torkelsen, 1997). In a similar way, some *Hypocreopsis* species (ascomycetes from Hypocreales order) protrude wood-destroying mycelium of basidiomycetes. Some wood-inhabiting fungi parasitize scale insects on bark, as *Septobasidium* (Pucciniomycetes) or *Myriangium* (Dothideomycetes). However, a predominant mass of wood-inhabiting fungi lie in diapason from facultative necrotrophs to obligate necrotrophs and obligate saprotrophs according to Cooke and Whipps' classification.

- 1. Facultative necrotrophs.** These fungi are localized in the cambial zone of trees and shrub shoots. Having an enzymatic complex, which influences plant cell walls, these fungi kill living cells and exhaust the products of protoplast degradation; however, being adapted to a certain degree of xylolysis (carbohydrate hydrolysis, rarely white-rot patterns), they continue to superficially decay wood. As a result, the bark exfoliates and sprouts die. Some species produce cancer spots. Taxonomically, facultative wood necrotrophs belong to Ascomycota (mostly to orders Diaporthales, Xylariales, Hypocreales and their anamorphs). The most important representatives are *Nectria* (and their *Tubercularia*-anamorphs; Fig. 2.10b), *Diaporthe*, *Diatrype*, *Biscogniauxia*, *Hypoxylon*, some *Valsa* and *Diplodia*-species.
- 2. Obligate necrotrophs.** Unlike facultative necrotrophs, these fungi are not capable of assimilating the necrotic tissues and are, therefore, adapted to destroy cells and protoplasts. Their wood-degrading capacity is weak. This group may be considered as a specialized derivative of the previous one. The activity of obligate necrotrophs results in the death of sprouts. As a rule, the target sprouts in a terminal phase. Taxonomically, obligate wood necrotrophs belong to the anamorphic genera of Ascomycota (*Phoma*, *Camarosporium*, *Phomopsis*, *Ottia*, *Cytospora*, and *Cucurbitaria*).
- 3. Obligate saprotrophs.** This type of fungi has the capacity of saprotrophic utilization of the cell wall skeleton of the wood substitute, and has the ability to interact with living plant cells. Probably, in some cases, some haustoria-like structures may be observed near living plant cells (as it was reported in cases of *Stereum* and *Chondrostereum* by Davydkina, 1980), but in general, the mycelium is adapted to colonization and a distant oxidation of wood biopolymers. The predominant part of wood-inhabiting fungi belongs to obligate saprotrophs. Both brown-rot and white-rot fungi belong to this group. Taxonomically, certain representatives of Ascomycota (Xylariales, Pezizales, and Helotiales) belong to this group, but the basic pool is composed of wood-inhabiting Basidiomycota belonging to the orders Polyporales, Agaricales,

Hymenochaetales, Cantharellales, Auriculariales, Dacrymycetales, Tremellales, and Platygloeales. Because wood-inhabiting saprotrophs have a wider range, a finer arrangement of this group is necessary.

- a. Pathogenic saprotrophs. These fungi colonize heart wood of living trees and shrubs or fresh decorticated branches, which are rich in water, mineral nutrients and oxygen. The nutrient source of fungi is carbohydrates or lignin of xylem vessels, together with a proper water level. After the tree dies, this type of fungi stop their activity (*Vuilleminia*, *Godronia*, *Chondrostereum*, *Climacodon*, *Oxyporus* spp., *Pholiota* spp., *Phellinus*, *Phaeolus*, *Laetiporus*, *Piptoporus*, *Fomes*, *Fomitopsis* spp., *Ganoderma* spp., *Inonotus* spp., *Lentinus* spp., and *Pleurotus* spp.; Fig. 2.10c). Some of these genera (e.g., *Phellinus* spp., *Inonotus* spp.), simultaneously die when their host tree dies, while some of them (e.g., *Chondrostereum*, *Ganoderma* spp., *Laetiporus*, *Piptoporus*, etc.) are capable of continuing their activity after the death of the host tree as non-pathogenic saprotrophs.
- b. Non-pathogenic saprotrophs. These fungi form a giant saprotroph pool. They colonize standing dead trees, fallen trees, branches, stumps and woody remnants of lost structures within forest litter. As a result, these fungi are associated with the wood at all stages of their decay. Certain species occupy spatially and temporarily localized niches. Initial stages and niches are associated with the same range of "terminal pathogenic saprotrophs" taxa. Fallen logs are found infested by many decorticators (such as *Ceriporiopsis*, *Junghuhnia*, *Oxyporus*, *Cylindrobasidium*, *Stereum*, etc.), superficial and per-volume wood decomposers (*Antrodia*, *Fomitopsis*, *Gloeophyllum*, *Skeletocutis*, *Tyromyces*, *Postia*, *Lentinus*, *Ossicaulis*, *Xylaria*, *Rosellinia*, etc.), followed by wood debris decomposers (*Anomoporia*, *Athelia*, *Botryobasidium*, *Serpulomyces*, *Peziza* spp., *Stropharia* spp., *Coprinus* spp., *Lycoperdon* spp., etc.). The stumps and fallen logs are infested by some characteristic ("leaders") species such as *Fomitopsis*, *Cerrena*, *Ganoderma*, *Fistulina*, *Lentinus*, *Tapinella*, *Clavicornia*, *Hypholoma*, etc. (Fig. 2.10d).
- c. Facultative humus saprotrophs/mycorrhiza-formers. The litter wood debris is connected to humus soil horizon by a continuous range of lignocellulose composites (Table 2.2).

The mycelium of some wood-inhabiting basidiomycetes penetrates these horizons throughout. In some cases, they form ectomycorrhizal covers. The capacity of ectomycorrhiza formation is known for such genera of litter-wood decomposers as *Coltricia*, *Thelephora*, *Tomentella*, *Tylospora*, *Piloderma*, *Amphinema*, and *Byssocorticium* (Erland and Taylor, 1999; Zmitrovich, 2008; Fig. 2.10e, f). According to studies by Chen et al.

Table 2.2. The quality and rates of litter decomposition in boreal-nemoral forests (after Heal and Dighton, 1985).

	Mosses	Herbaceous plants	Angiosperm leaves	Coniferous needles	Wood
Cellulose (%)	16–35	20–37	6–22	20–31	36–63
Lignin (%)	7–36	3–30	9–42	20–58	17–35
C : N ratio	13–50	29–160	21–71	63–327	294–327
Decay (% year ⁻¹)	20	30–70	40–60	3–50	1–90

(2001), the genes for lignolytic enzymes, normally associated with white-rot fungi, are widespread in a broad taxonomical range of ectomycorrhizal mushrooms (*Hydnullum*, *Bankera*, *Ramaria*, *Amanita*, *Cortinarius*, *Rozites*, *Tricholoma*, *Paxillus*, *Tylopilus*, *Xerocomus*, *Chroogomphus*, etc.). Of course, these ectomycorrhiza-formers are not part of the wood-inhabiting fungi group. According to Bon (1991), these fungi may be considered as facultative mycorrhiza-formers. However, their origin is connected to litter-inhabiting lignotrophic basidiomycetes in many phylogenetic lines (Hibbett and Donoghue, 1995; Binder and Hibbett, 2006; James et al., 2006).

D. Topic Groupings (Topic-Sic!)

Tropic (Sic!) groupings are important to be discussed here because of two main reasons: 1) some ectomycorrhizal mushrooms and mycoparasites are able to develop their fructification on wood and are, therefore, wood-inhabiting and, 2) the xylotrophic fungi are distributed over the wood showing some regularities.

Topic (Sic!) aspects of wood-inhabiting fungi have been discussed by Isikov and Konoplya (2004) and Arefiev (2010). According to Isikov and Konoplya (2004), the primary arrangement of topic (Sic!) groupings may be on the basis of topology of shoots (of I, II branching order, and stem). Arefiev (2010) highlighted the relationships of fungus with wood bark and distinguished transcortical vs. decortical species.

According to wood debris and its structural decomposition in time, the general topic groupings of wood-inhabiting fungi may be overviewed as follows:

- 1. Wood debris inhabiting fungi.** The grouping is associated with buried wood, rotten fallen branches incorporated into litter and rotten stumps. The fruit bodies of these fungi are, as a rule, stipitate or negatively geotropic. Several characteristic representatives are: *Peziza* spp., *Cudonia*, *Chlorociboria*, *Calocera*, *Macrotyphula*, *Stropharia*, *Hypholoma*, etc. (Fig. 2.11a).

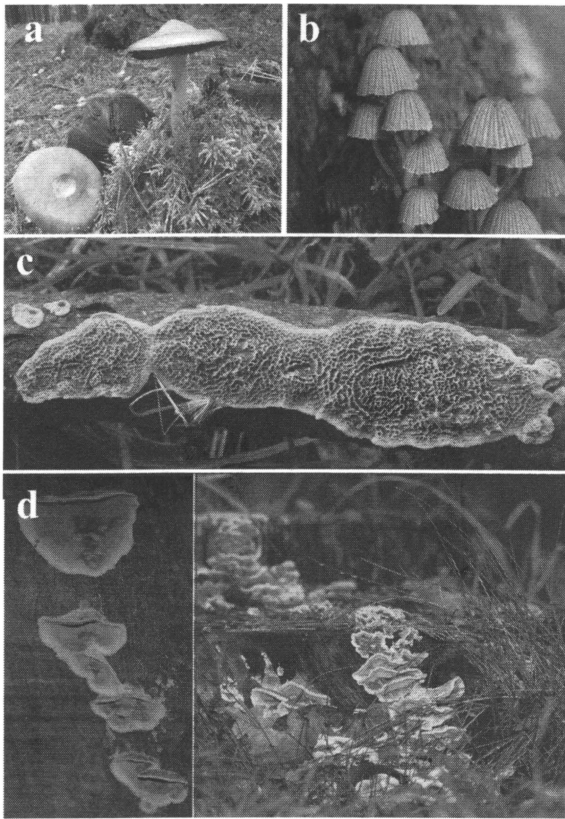


Figure 2.11. Main topic groupings of wood-inhabiting basidiomycetes: (a) wood debris inhabiting fungi [*Stropharia hornemannii* (Fr.) S. Lundell & Nannf. on stump debris]; (b) corticolous fungi [*Coprinellus disseminatus* (Pers.) J.E. Lange on bark lignose deposits]; (c) transcortical fungi [*Datronia mollis* (Sommerf.) Donk—the fruit bodies developing through small bark perforations]; (d) decortical fungi [*Bjerkandera adusta* (Willd.) P. Karst. on decorticated lime stump].

2. **Corticolous fungi.** The nutritional source of these fungi lies outside of cortex substratum. As a rule, they are connected to ectomycorrhiza—litter decomposition [*Paxillus involutus* (Batsch) Fr.; *Tylopilus felleus* (Bull.) P. Karst.], or to bark-surface lignocellulose deposits [*Coprinellus disseminatus*—Fig. 2.11b], or to the epiphytic algae/protonema of mosses (*Mycena pseudocorticola* Kühner). Some fungi are also parasites on scale insects (*Septobasidium*, *Myriangium*, *Podonectria*), but traditionally these groupings are not mentioned when wood-inhabiting fungi are discussed. Their fruiting bodies, as a rule, are negatively geotropic.
3. **Transcortical fungi.** These necrotrophic and xylosaprotrophic fungi are found infesting the shoots via natural bark perforations. Further mycelium development is connected to bark undergrowth, whereas

the sporulations develop mostly in the areas of penetration. Two main subgroupings can be distinguished here depending on shoot order association:

- a. Crown fungi (*Valsa*, *Mycosphaerella*, *Phoma*, *Dothistroma*, *Diaporthe*, etc.);
 - b. Stem fungi (*Oxyporus*, *Datronia*, *Basidioradulum*, *Hyphoderma*, *Cylindrobasidium*, *Radulomyces*, etc.; Fig. 2.11c).
4. **Decortical fungi.** This type of fungi attacks the wood after sufficient bark disruptions (frost cracks and keels and sores, insects or fungal exfoliation). The mycelium colonizes the general wood mass from alburnum to heart areas. In principle, all active tinder fungi belong to this group: *Fomitopsis*, *Antrodia*, *Gloeophyllum*, *Bjerkandera*, etc. (Fig. 2.11d), together with many corticioid fungal species and wood-inhabiting ascomycetes.

Biodiversity

A. Taxonomical Composition

Wood colonization by higher (multicellular) fungi are heterochronous and polyphyletic. As a result, all basic radiations of ascomycetes and basidiomycetes contain elements adapted to wood (Table 2.3). The worldwide these fungi are estimated to be 30,000 species.

Such a huge radiation of higher fungi, as was viewed by Hibbett et al. (2007), is predominated by wood-inhabiting genera and species. Within Ascomycota, such groups are represented by the orders: Helotiales (class Leotiomyces), Pezizales (class Pezizomycetes), Diaporthales and Xylariales (class Sordariomycetes). Within Basidiomycota, the dominant order of wood-inhabiting fungi is Polyporales (class Agaricomycetes), which is represented, almost exclusively, by xylotrophic taxa. The other gross taxa belong to Agaricales, Hymenochaetales and Russulales.

The groups with necrotrophic activities (mainly various Sordariomycetes from the old order "Sphaeriales") are characterized by the absence of biochemical mechanisms responsible for the oxidation of wood composites; however, as a rule all saprotrophic lineages of Ascomycota and Basidiomycota are characterized by peroxidase and laccase activities. The nodes of brown-rot producers within Basidiomycota are scarce and species-powered, and as a rule, they are well delimited taxonomically (order Dacrymycetales in Dacrymycetes, order Gloeophyllales and Boletales in Agaricomycetes, family Fomitopsidaceae in Polyporales). However, within Polyporaceae, the brown-rot taxa are distributed rather stochastically, and some genera (e.g., *Grifola*) may be heterogeneous on the basis of rot produced.

Table 2.3. The taxonomical composition of wood-inhabiting fungal groups (Zmitrovich et al., 2007, with addition).

Phyla, classes	Orders	Key genera of wood-inhabiting fungi
Ascomycota Caval.-Sm.		
Dothideomycetes O.E. Erikss. & Winka	Capnodiales Woron.	<i>*Mycosphaerella</i> Johans., <i>*Metacapnodium</i> Speg.
	Dothideales Lindau	<i>*Dothidea</i> Fr., <i>*Polwrightia</i> Sacc.
	Pleosporales Luttr. ex M.E. Barr	<i>*Astrosphaeriella</i> Sydow, <i>*Caryospora</i> de Not., <i>*Cucurbitaria</i> Gray, <i>*Fenestella</i> Tul., <i>*Herpotrichia</i> Fuckel, <i>*Karstenula</i> Speg., <i>*Massaria</i> de Not., <i>*Massarina</i> Sacc., <i>*Melanomma</i> Nitschke, <i>*Melomastia</i> Nitschke, <i>*Otthia</i> Nitschke, <i>*Pteridiospora</i> Penzig & Sacc., <i>*Teichospora</i> Fuckel, <i>*Thaxteria</i> Sacc., <i>*Thyridaria</i> Sacc., <i>*Trematosphaeria</i> Fuckel, <i>*Pleomassaria</i> Speg.
	Hysteriales Lindau	<i>Hysterium</i> DC. ex Mérat
Leotiomyces O.E. Erikss. & Winka	Cyttariales Luttr. ex Gamundí	<i>Cyttaria</i> Berk.
	Helotiales Nan nf.	<i>Arachnopeziza</i> Fuckel, <i>Ascocorticium</i> Bref., <i>Ascocorticium</i> Jülich & B. de Vries, <i>Ascocoryne</i> Groves & D.E. Wilson, <i>Ascotremella</i> Seaver, <i>Bisporella</i> Sacc., <i>Bulgaria</i> Fr., <i>Bulgariella</i> P. Karst., <i>Cenangium</i> Fr., <i>Chloencoelia</i> Dixon, <i>Chlorociboria</i> Seaver ex Ramamurthi, Korf & Batra, <i>Cistella</i> QuéL., <i>Claussenomyces</i> Kirschst., <i>Crocicreas</i> Fr., <i>Cudoniella</i> Sacc., <i>Dasyscyphella</i> Tranzschel, <i>Dematioscypha</i> Svrček, <i>Dencoeliopsis</i> Korf, <i>Discocainia</i> J. Reid & Funk, <i>Encoelia</i> (Fr.) P. Karst., <i>Eriopezia</i> (Sacc.) Rehm, <i>Godronia</i> Moug. & Lév., <i>Gorgoniceps</i> P. Karst., <i>Gremmeniella</i> M. Morelet, <i>Hamatocanthoscypha</i> Svrček, <i>Holwaya</i> Sacc., <i>Hyaloscypha</i> Boud., <i>Hymenoscyphus</i> Gray, <i>Incrupila</i> Raitv., <i>Ionomidotis</i> E.J. Durand, <i>Lachmellula</i> P. Karst., <i>Lachnum</i> Retz., <i>Lasiobelonium</i> Ellis & Everh., <i>Mollisia</i> (Fr.) P. Karst., <i>Neobulgaria</i> Petr., <i>Neodasyscypha</i> Spooner, <i>Patinellaria</i> P. Karst., <i>Perrotia</i> Boud., <i>Phaeohelotium</i> Kanouse, <i>Proliferodiscus</i> J.H. Haines & Dumont, <i>Tympanis</i> Tode, <i>Velutarina</i> Korf, <i>Rutstroemia</i> P. Karst., <i>Unguicularia</i> Höhn.
	Rhytismatales M.E. Barr ex Minter	<i>Propolis</i> (Fr.) Corda
Orbiliomycetes O.E. Erikss. & Winka	Orbiliales Baral et al.	<i>Hyalinia</i> Boud., <i>Orbilina</i> Fr.

Table 2.3. contd....

Table 2.3. contd.

Phyla, classes	Orders	Key genera of wood-inhabiting fungi
Pezizomycetes O.E. Erikss. & Winka	Pezizales J. Schröt.	<i>Balsamia</i> Vittad., <i>Cheilymenia</i> Boud., <i>Discina</i> (Fr.) Fr., <i>Gyromitra</i> Fr., <i>Helvella</i> L., <i>Humaria</i> Fuckel, <i>Karstenella</i> Harmaja, <i>Microstoma</i> (Fr.) Kanouse, <i>Peziza</i> Fr., <i>Pithya</i> Fuckel, <i>Plectania</i> Fuckel, <i>Rhizina</i> Fr., <i>Scutellinia</i> (Cooke) Lambotte, <i>Urnula</i> Fr.
Sordariomycetes O.E. Erikss. & Winka	Coronophorales Nannf.	* <i>Calyculosphaeria</i> Fitzp., * <i>Coronophora</i> Fuckel, * <i>Bertia</i> de Not., * <i>Nitschkia</i> Otth, * <i>Tympanopsis</i> Stärb.
	Hypocreales Lindau	<i>Arachnocrea</i> Z. Moravec, <i>Calonectria</i> de Not., <i>Gibberella</i> Sacc., <i>Hypocreopsis</i> P. Karst., <i>Nectria</i> (Fr.) Fr., <i>Podostroma</i> P. Karst.
	Boliniales P.F. Cannon	* <i>Camarops</i> P. Karst., * <i>Bolinia</i> (Nitschke) Sacc.
	Calosphaeriales M.E. Barr	* <i>Calosphaeria</i> Tul. & C. Tul.
	Chaetosphaeriales Huhndorf, A. N. Mill. & F.A. Fernández	* <i>Chaetosphaeria</i> Tul. & C. Tul., <i>Zignoëlla</i> Sacc.
	Coniochaetales Huhndorf, A. N. Mill. & F.A. Fernández	* <i>Coniochaeta</i> (Sacc.) Massee
	Diaporthales Nannf.	<i>Apioportha</i> Höhn., <i>Diaportha</i> Nitschke, <i>Calosporella</i> J. Schröt., <i>Caudospora</i> Starb., <i>Cryptodiaportha</i> Petrak, <i>Cryptospora</i> Tul. & C. Tul., <i>Cryptosporella</i> Sacc., <i>Endothia</i> Fr., <i>Hercospora</i> Fr., <i>Melanconiella</i> Sacc., <i>Prosthecium</i> Fr., <i>Pseudovalsa</i> Ces. & de Not., <i>Sillia</i> P. Karst., <i>Valsa</i> Fr.
	Ophiostomatales Benny & Kimbr.	* <i>Ceratocystis</i> Ellis & Halst., * <i>Ophiostoma</i> Syd. & P. Syd.
	Sordariales Chadef. ex D. Hawksw. & O. E. Erikss.	* <i>Bombardia</i> Fr., * <i>Camarops</i> P. Karst., <i>Chaetomium</i> Kunze ex Fr., * <i>Lasiosphaeria</i> Ces. & de Not.

	Xylariales Nannf.	<i>Biscogniauxia</i> Kuntze, <i>Daldinia</i> Ces. & de Not., <i>Diatrype</i> Fr., <i>Diatrypella</i> (Ces. & de Not.) Cooke, <i>Entoleuca</i> Syd., <i>Entonaema</i> Möller, <i>Eutypa</i> Tul. & C. Tul., <i>Eutypella</i> (Nitschke) Sacc., <i>Hypoxylon</i> Bull., <i>Lopadostoma</i> (Nitschke) Traverso, <i>Nemania</i> Gray, <i>Rosellinia</i> de Not., <i>Ustulina</i> Tul., <i>Xylaria</i> Hill ex Schrank
	Trichosphaerales M.E. Barr	* <i>Trichosphaeria</i> Fuckel
	Triblidiales O.E. Erikss.	<i>Pseudographis</i> Nyl., <i>Triblidium</i> Rebentisch & Pers.
Basidiomycota R.T. Moore		
Pucciniomycetes Bauer et al.	Platyglloeales R.T. Moore	* <i>Eocronartium</i> G.F. Atk., <i>Platyglloea</i> J. Schröt.
Tremellomycetes Dowled	Tremellales Fr.	<i>Tremella</i> Pers.
Dacrymycetes Dowled	Dacrymycetales Henn.	<i>Calocera</i> (Fr.) Fr., <i>Cerinomyces</i> G.W. Martin, <i>Dacrymyces</i> Nees, <i>Ditiola</i> Fr., <i>Femsjonina</i> Fr.
Agaricomycetes Dowled	Agaricales Underw.	<i>Armillaria</i> (Vahl) P. Kumm., <i>Arrhenia</i> Fr., <i>Calyptella</i> Quél., <i>Campanella</i> Henn., <i>Caripia</i> Kuntze, <i>Cellypha</i> W.B. Cooke, <i>Chaetocalathus</i> Singer, <i>Cheimonophyllum</i> Singer, <i>Chondrostereum</i> Pouzar, <i>Chromocyphella</i> De Toni & Levi, <i>Claudopus</i> Gillet, <i>Clitopilus</i> (Fr. ex Rabenh.) P. Kumm., <i>Collybia</i> (Fr.) Staude, <i>Coprinus</i> Pers., <i>Coronicium</i> J. Erikss. & Ryvardeen, <i>Cotylidia</i> P. Karst., <i>Crepidotus</i> (Fr.) Staude, <i>Crinipellis</i> Pat., <i>Cylindrobasidium</i> Jülich, <i>Deflexula</i> Corner, <i>Episphaeria</i> Donk, <i>Favolaschia</i> (Pat.) Pat., <i>Filoboletus</i> Henn., <i>Fistulina</i> Bull., <i>Flagelloscypha</i> Donk, <i>Flammulina</i> P. Karst., <i>Gymnopilus</i> P. Karst., <i>Hemipholiota</i> (Singer) Bon, <i>Henningsomyces</i> Kuntze, <i>Hohenbuehelia</i> Schulzer, <i>Hypholoma</i> (Fr.) P. Kumm., <i>Hypsizygos</i> Singer, <i>Kuehneromyces</i> Singer & A.H. Sm., <i>Lachnella</i> Fr., <i>Lampteromyces</i> Singer, <i>Lentinula</i> Earle, <i>Lycoperdon</i> P. Micheli, <i>Merismodes</i> Earle, <i>Mucronella</i> Fr., <i>Mycena</i> (Pers.) Roussel, <i>Nothopanus</i> Singer, <i>Omphalina</i> Quél., <i>Ossicaulis</i> Redhead & Ginns, <i>Panellus</i> P. Karst., <i>Pellidiscus</i> Donk, <i>Phaeosolenia</i> Speg., <i>Pholiota</i> (Fr.) P. Kumm., <i>Pleurocybella</i> Singer, <i>Pleurotus</i> (Fr.) P. Kumm., <i>Pluteus</i> Fr., <i>Podoscypha</i> Pat., <i>Porothelium</i> Fr., <i>Radulomyces</i> M.P. Christ., <i>Rectipilus</i> Agerer, <i>Resupinatus</i> Nees ex Gray, <i>Rhodotus</i> Maire, <i>Rimbachia</i> Pat., <i>Schizophyllum</i> Fr., <i>Stigmatolemma</i> Kalchbr., <i>Strobilurus</i> Singer, <i>Stromatocyphella</i> W.B. Cooke, <i>Stropharia</i> (Fr.) Quél., <i>Tricholomopsis</i> Singer, <i>Trogia</i> Fr., <i>Typhula</i> (Pers.) Fr., <i>Volvariella</i> (Fr.) P. Kumm.

Table 2.3. contd....

Phyla, classes	Orders	Key genera of wood-inhabiting fungi
	Atheliales Jülich	<i>Amylocorticium</i> Pouzar, <i>Amylocorticium</i> Spirin & Zmitr., <i>Athelia</i> Pers., <i>Ceraceomyces</i> Jülich, <i>Piloderma</i> Jülich, <i>Serpulomyces</i> (Zmitr.) Zmitr., <i>Tylospora</i> Donk
	Auriculariales J. Schröt.	<i>Auricularia</i> Bull. ex Juss., <i>Basidioidendron</i> Rick, <i>Bourdotia</i> (Bres.) Bres. & Torrend, <i>Craterocola</i> Bref., <i>Ductifera</i> Lloyd, <i>Eichleriella</i> Bres., <i>Exidia</i> Fr., <i>Exidiopsis</i> (Bref.) Möller., <i>Heterochaete</i> Pat., <i>Pseudohydnum</i> P. Karst., <i>Stypella</i> Möller, <i>Tremellostereum</i> Ryvar den
	Boletales E.-J. Gilbert	<i>Bondarcevomyces</i> Parmasto, <i>Coniophora</i> DC., <i>Gyrodontium</i> Pat., <i>Jaapia</i> Bres., <i>Leucogyrophana</i> Pouzar, <i>Meiorganum</i> R. Heim, <i>Paxillus</i> Fr., <i>Serpula</i> (Pers.) Gray, <i>Tapinella</i> E.-J. Gilbert, <i>Tylophilus</i> P. Karst.
	Cantharellales Gäum.	<i>Botryobasidium</i> Donk, <i>Ceratobasidium</i> D.P. Rogers, <i>Clavulicium</i> Boidin, <i>Oliveonia</i> Donk, <i>Scotomyces</i> Jülich, <i>Suillosporium</i> Pouzar, <i>*Thanatephorus</i> Donk, <i>Tulasnella</i> J. Schröt.
	Corticiales K.H. Larss.	<i>Corticium</i> Pers., <i>Cytidia</i> Qué l., <i>Punctularia</i> Pat., <i>Vuilleminia</i> Maire
	Gloeophyllales Thorn	<i>Boreostereum</i> Parmasto, <i>Donkioporia</i> Kotl. & Pouzar, <i>Gloeophyllum</i> P. Karst., <i>Neolentinus</i> Redhead & Ginns, <i>Veluticeps</i> Cooke
	Gomphales Jülich	<i>Hydnocristella</i> R.H. Petersen, <i>Kavinia</i> Pilát, <i>Lentaria</i> Corner, <i>Ramaricium</i> J. Erikss.
	Hymenochaetales Oberw.	<i>Asterodon</i> Pat., <i>Basidioradulum</i> Nobles, <i>Cyclomyces</i> Kunze ex Fr., <i>Fibricium</i> J. Erikss., <i>Hydnochaete</i> Bres., <i>Hymenochaete</i> Lé v., <i>Hyphodontia</i> J. Erikss., <i>Inonotopsis</i> Parmasto, <i>Inonotus</i> P. Karst., <i>Leucophellinus</i> Bondartsev & Singer, <i>Oxyporus</i> (Bourdot & Galzin) Donk, <i>Phellinidium</i> (Kotl.) Fiasson & Niemelä, <i>Phellinus</i> Qué l., <i>Phylloporia</i> Murrill, <i>Pyrrhoderma</i> Imazeki, <i>Repetobasidium</i> J. Erikss., <i>Resinicium</i> Parmasto, <i>Schizopora</i> Velen., <i>Sidera</i> MiETTinen & K. H. Larss., <i>Stipitochaete</i> Ryvar den, <i>Subulicium</i> Hjortstam & Ryvar den, <i>Trichaptum</i> Murrill, <i>Tubulicrinis</i> Donk
	Polyporales Gäum.	<i>Abortiporus</i> Murrill, <i>Amauroderma</i> Murrill, <i>Amylocystis</i> Bondartsev & Singer, <i>Anomoporia</i> Pouzar, <i>Antrodia</i> P. Karst., <i>Antrodiella</i> Ryvar den & I. Johans., <i>Aurantiporus</i> Murrill, <i>Auriculariopsis</i> Maire, <i>Auriporia</i> Ryvar den, <i>Bjerkandera</i> P. Karst., <i>Bulbillomyces</i> Jülich, <i>Byssomerulius</i> Parmasto, <i>Ceriporia</i> Donk, <i>Cerrena</i> Gray, <i>Climacocystis</i> Kotl. & Pouzar, <i>Climacodon</i> P. Karst., <i>Cryptoporus</i> (Peck) Shear, <i>Dacryobolus</i> Fr., <i>Daedalea</i> Pers., <i>Daedaleopsis</i> J. Schröt., <i>Datronia</i> Donk, <i>Dichomitus</i> D.A. Reid, <i>Flaviporus</i> Murrill, <i>Fomes</i> (Fr.) Fr., <i>Fomitopsis</i> P. Karst., <i>Ganoderma</i> P. Karst., <i>Gloeoporus</i> Mont., <i>Grammothele</i> Berk. & M.A. Curtis, <i>Grifola</i> Gray, <i>Haddowia</i> Steyaert, <i>Hapalopilus</i> P. Karst., <i>Haploporus</i> Bondartsev & Singer, <i>Hexagonia</i> Fr., <i>Humphreya</i> Steyaert, <i>Hydnophlebia</i> Parmasto, <i>Hymenogramme</i>

	<p>Mont. & Berk., <i>Hyphoderma</i> Wallr., <i>Hyphodermella</i> J. Erikss. & Ryvarde n, <i>Hypochnicium</i> J. Erikss., <i>Intextomyces</i> J. Erikss. & Ryvarde n, <i>Ischnoderma</i> P. Karst., <i>Irpex</i> Fr., <i>Jahnoporus</i> Nuss, <i>Junghuhnia</i> Corda, <u><i>Laetiporus</i></u> Murrill, <i>Lentinus</i> Fr., <u><i>Leptoporus</i></u> Qué l., <i>Lopharia</i> Kalchbr. & MacOwan, <i>Loweomyces</i> (Kotl. & Pouzar) Jülich, <i>Megasporoporia</i> Ryvarde n & J.E. Wright, <i>Meripilus</i> P. Karst., <i>Microporus</i> P. Beauv., <i>Mycorrhaphium</i> Maas Geest., <i>Nigroporus</i> Murrill, <u><i>Oligoporus</i></u> Bref., <i>Pachykytospora</i> Kotl. & Pouzar, <i>Panus</i> Fr., <u><i>Parmastomyces</i></u> Kotl. & Pouzar, <i>Perenniporia</i> Murrill, <i>Phaeolus</i> Pat., <i>Phanerochaete</i> P. Karst., <i>Phlebia</i> Fr., <i>Phlebiella</i> P. Karst., <i>Phlebiopsis</i> Jülich, <u><i>Piptoporus</i></u> P. Karst., <i>Polyporus</i> P. Micheli, <i>Porogramme</i> (Pat.) Pat., <i>Postia</i> Fr., <i>Pycnoporellus</i> Murrill, <i>Pyrofomes</i> Kotl. & Pouzar, <i>Scopuloides</i> (Massee) Höhn. & Litsch, <i>Skeletocutis</i> Kotl. & Pouzar, <i>Sparassis</i> Fr., <i>Spongipellis</i> Pat., <i>Steccherinum</i> Gray, <i>Trametes</i> Fr., <i>Theleporus</i> Fr., <i>Tyromyces</i> P. Karst., <i>Wolfiporia</i> Ryvarde n & Gilb., <i>Xenasma</i> Donk</p>
Russulales Kreisel ex Kirk et al.	<p><i>Acanthobasidium</i> Oberw., <i>Acanthophysellum</i> Parmasto, <i>Aleurodiscus</i> Rabenh. ex J. Schröt., <i>Amylonotus</i> Ryvarde n, <i>Amylosporomyces</i> S.S. Rattan, <i>Asterostroma</i> Massee, <i>Auriscalpium</i> Gray, <i>Boidinia</i> Stalpers & Hjortstam, <i>Bondarzewia</i> Singer, <i>Clavicornia</i> Doty, <i>Conferticium</i> Halle nb., <i>Dentipellis</i> Donk, <i>Dentipratulum</i> Domański, <i>Dichopleuropus</i> D.A. Reid, <i>Dichostereum</i> Pilát, <i>Echinodontium</i> Ellis & Everh., <i>Gloeocystidiellum</i> Donk, <i>Gloeodontia</i> Boidin, <i>Gloiodon</i> P. Karst., <i>Gloiothete</i> Bres., <i>Hericium</i> Pers., <i>Heterobasidion</i> Bref., <i>Laurilia</i> Pouzar, <i>Laxitextum</i> Lentz, <i>Lentinellus</i> P. Karst., <i>Megalocystidium</i> Jülich, <i>Pseudoxenasma</i> K.H. Larss. & Hjortstam, <i>Scytinostroma</i> Donk, <i>Scytinostromella</i> Parmasto, <i>Stecchericium</i> D.A. Reid, <i>Stereofomes</i> Rick, <i>Stereum</i> Hill ex Pers., <i>Vararia</i> P. Karst., <i>Wrightoporia</i> Pouzar, <i>Xylobolus</i> P. Karst.</p>
Sebacinales M. Weiß et al.	* <i>Sebacina</i> Tul.
Thelephorales Corner ex Oberw.	<i>Amaurodon</i> J. Schröt., <i>Pseudotomentella</i> Svrček, <i>Thelephora</i> Ehrh. ex Willd., <i>Tomentella</i> Pers. ex Pat., <i>Tomentellopsis</i> Hjortstam, <i>Tomentellago</i> Hjortstam & Ryvarde n
Trechisporales K.H. Larss.	<i>Litschauerella</i> Oberw., <i>Subulicystidium</i> Parmasto, <i>Trechispora</i> P. Karst.

Note. The genera, devoid of oxidative enzymes, are marked by an asterisk, the genera, associated with a brown-rot are underlined, and the rest of the genera are associated with white-rot.

It is obvious that colonization of wood, wood remnants and wood surfaces was realized on several levels of organization of ascomycetes and basidiomycetes, and these adaptations as well as certain convergence and unifications were overbuilt on various organization types and biochemical pathways. The most dramatic changes occur in the external mycelial structures—the stromata and fruiting bodies.

Biomorphic Diversity

The aerial mycelia of wood-inhabiting fungi develop in a rather limited range of parameters such as the presence or absence of bark, lacunes on wood material, wood remnants exposure and forest insolation regimes. Most fungal wood-inhabiting fructifications are mechanically layed out above ground; therefore, their main morphogenetic tendency is to develop a positive geotropism and prostrate growth form.

As a result of adaptation to wood overgrowth, the sporulation structures of ascomycetes and basidiomycetes have a convergent similarity (Bondartseva, 2001), producing a wide biomorphic diversity. The overview of their biomorphic diversity is given below.

- α. Ascomycetous cycle of forms (hyphae with one to multinucleate segments; septum with a central pore without doliolum; meiospores formed endogenously in a stichal mode; meiotangia—asci; the arrangement of aerial mycelium mostly cladonian, with axial and pleuridial differentiation, organized as [a] stromata with many carpocenters, [b] single ascocarps, and [c] clustered ascocarps).
 1. Ascolocular series (obligate stromatic; conceptacles originating as locules into the stroma; in some cases the interlocular stromatic context disintegrates and conceptacles transform into pseudothecia; sporulation passive).
 - a. Elsinoid group (stroma pulvinate with stochastically dispersed locules—the so-called “myriotheceum”)
 - Elsinoid biomorph (stroma immersed into host tissue):
Myriangium and some others.
 - b. Dothideoid group (stroma globose to pulvinate, with singular or multiplicate pseudothecia; mostly subepidermal):
 - Dothideoid biomorph—*Dothidea*, *Mycosphaerella*, *Cucurbitaria* and some others.
 - c. Hysterioid group (stroma elongated—with fusoid or cylindrical outline, revealed by linear fissure; subepidermal):
 - Hysterioid biomorph—*Hysterium* and some others.
 2. Pyrenocarpous series (conceptacles differentiated as individuals—perithecia—surrounded by a wall of stromatic origin: pitcher-like,

pear-like or subglobose, in some cases with developed excretory channel; integrated by common stroma or disintegrated; sporulation active).

- A. Hypocreoid infraserie (stromatic wall not carbonized, of *textura globulosa*—*epidermoidea*, light or bright-colored; stromata fleshy or subceraceous).
- Hypocreoid group (stroma pulvinate to prostrate)
- Creopoid biomorph (stroma gelatinous, pulvinate): *Creopus* and some others.
 - Hypocreoid biomorph (stroma non-gelatinized, pulvinate to prostrate, persisting): *Hypocrea*, *Hypocreopsis*, *Hypomyces*, *Gibberella* and some others.
 - Nectrioid (stroma non-gelatinized, pulvinate, transforming into perithecia clusters).
- B. Xylarioid infraserie (stromatic wall carbonized, of *textura angularis*—*porrecta*, blackish-colored; stromata of hard consistency).
- a. Xylarioid group (perithecia submerged into stroma).
- Hypoxyloid biomorph (perithecia copious, stroma superficial, globose or pulvinate): *Hypoxylon*, *Daldinia* and some others.
 - Ustulinoid (perithecia copious, stroma superficial, crustose): *Ustulina*, *Hypoxylon* pr. p.
 - Xylospheroid biomorph (perithecia copious, stroma superficial, erect—clavate or staghorn-like): *Xylospheera*, *Thammomyces* and some others.
 - Nummularioid biomorph (stroma submerged; ectostroma prostrate, with singular or copious perithecia).
 - Nummularioid (strict) biomorph (perithecia copious): *Biscogniauxia* and some others
 - Rosellinioid biomorph (stroma monoperithecial): *Rosellinia*, *Phyllachora* and some others.
- b. Diatrypoid group (perithecia deeply immersed, with long necks).
- Diatrypoid biomorph (ectostroma enlarged, perithecial necks not clustered): *Diatrype*, *Diaporthe*, *Glomerella*, *Eutypa*, *Cryptospora*, *Endothia* and some others.
 - Valsoid biomorph (ectostroma local, perithecial necks clustered): *Valsa*, **Cytospora* and some others.
- C. Sphaerioid infraserie (perithecia disintegrated—singular or grouped over common subiculum).
- a. Sordarioid group (perithecia pear-like, mazaedium present or absent).

- Sordarioid biomorph (perithecia without hyphal appendages and mazaedium): *Sordaria*, *Nectria* and some others.
 - Chaetomioid biomorph (perithecia with hyphal appendages; apical apparatus transformed into mazaedium): *Chaetomium*, **Chaetomella* and some others.
- b. Sphaerioid group (perithecia subglobose, mazaedium as a rule present).
- Sphaerioid biomorph (perithecium without neck): *Lasiosphaeria*, *Podospora*, **Rabenhorstia* and some others.
 - Ophiostomoid biomorph (perithecium having an elongated neck): *Ophiostoma*, *Ceratocystis*, **Ceratopycnis* and some others.
3. Discomycete series (ascocarp open, differentiated into hymenium and excipulum (so-called apothecium): cupulate, discoid, pulvinate with prominent or reduced stipe; sporulation active).
- a. Pezizoid group (apothecia more than 1.5 cm across, fleshy-ceraceous, with reduced stipe, symmetrically or asymmetrically cupulate to discoid).
- Pezizoid biomorph (apothecia symmetrical, cupulate, sometimes lobate): *Peziza* and some others.
 - Discinoid biomorph (apothecia symmetrical, prostrate plate-like to turned out plate-like): *Discina*, *Rhizina*, *Plicaria* and some others....
 - Gyromitroid biomorph (apothecia asymmetrical, cerebriform, with irregularly-folded hymenial surface and increscent margin): *Gyromitra*.
 - Helvelloid biomorph (apothecia asymmetrical, irregularly-lobed, even or folded, with free margin): *Helvella* and some others.
 - Humarioid biomorph (apothecia cupulate, sessile or substipitate, excipulum/margin pubescent): *Humaria*, *Trichophaea*, *Rutstroemia* pr. P and some others.
 - Scutellinioid biomorph (apothecia discoid-cupulate, sessile, excipulum and margin prominently ciliate): *Scutellinia* and some others.
- b. Sclerotinioid group (ascocarp less than 1.5 cm across, ceraceous, stipitate, cupulate to discoid).
- Ciborioid biomorph (sclerotium absent, excipulum even): *Ciboria*, *Rutstroemia*, *Chlorociboria*, *Hymenoscyphus*, *Cudoniella*, *Cyathicula* and some others.
 - Dasyscyphoid biomorph (sclerotium absent, excipulum pubescent): *Dasyscyphus*, *Lachmellula* and some others.

- c. Geoglossoid group (ascocarps medium-sized to small, waxy to subgelatinous, differentiated into stipe and fertile head).
- Cudonioid biomorph (fertile head pileate with inrolled margin, cerebriform): *Leotia lubrica*, *Cudonia* and some others.
- d. Helotioid group (apotheciun less than 1.5 cm across, waxy to subgelatinous, discoid, substipitate).
- Helotioid biomorph (apothecium waxy, excipulum even): *Helotium*, *Pezicula*, *Bisporella*, *Pezizella*, *Mollisia*, *Calycellina*, *Phialina*, *Pithya*, **Jaczewskiella* and some others.
 - Hyaloscyphoid biomorph (apothecium waxy, excipulum pubescent): *Hyaloscypha*, *Hyalopeziza*, *Patellariopsis*, *Tapezia*, *Cenangium*, **Pseudocenangium* and some others.
 - Ascocoryneoid biomorph (apothecium subgelatinous, excipulum even): *Ascocoryne* and some others.
- e. Bulgarioid group (apothecia 1–12 cm across, gelatinous, turbinate to barrel-shaped):
- Bulgarioid biomorph—*Bulgaria*.
- f. Ascotremelloid group (apothecia 0.5–1.5 cm across, in brain-like to lobed clusters):
- Ascotremelloid biomorph—*Ascotremella*, **Coryne* and some others.
- g. Scleroderrioid group (apothecia less than 1.5 cm across, bowl-shaped, with villous excipulum, of corneous consistency, clusterized):
- Scleroderrioid biomorph—*Godronia*, *Tympanis* and some others.
- h. Cyttarioid group (apothecia less than 1.5 across, bowl-shaped, immersed into fleshy-gelatinous globose to trametoid stroma):
- Cyttarioid biomorph—*Cyttaria*.
- i. Cryptodiscoid group (apothecia less than 1.5 cm across, pitcher-like, immersed into substratum):
- Cryptodiscoid biomorph—*Cryptodiscus*, *Pyrenopeziza*, *Stictis* and some others.
- j. Clitrioid group (apothecia small, lanceolate, with prominent excipulum, immersed into substrate):
- Clitrioid biomorph—*Propolis*, *Colpoma*, *Lophodermium* and some others.
- k. Ascocorticoid group (excipulum reduced, hypothecium prostrate):
- Ascocorticoid biomorph—*Ascocorticium*, *Ascocorticium*.
- β. Basidiomycetous cycle of forms (hyphae of secondary mycelium dikaryotic to multicellular, mostly doliporous; meiospores exogeneous; meiotangia as basidia—auricularioid, tremelloid, dacrymycetoid,

tulasnelloid heterobasidia or homobasidia; structure presumable hemicladome without prominent pleuridia; cladothalle as basidiocarps of various structure).

1. Clavarioid series (basidiocarps erect, without pileus differentiation).
 - a. Clavarioid group (basidiocarps unbranched, non-gelatinous).
 - Clavariadelphoid biomorph (basidiocarps large, hollow, clavate): *Macrotiophula* and some others.
 - Typhuloid biomorph (basidiocarps small, monolith).
 - Strict typhuloid biomorph (emerging from sclerotium): *Typhula*.
 - Pistillarioid (without sclerotium): *Pistillaria*, *Mucronella* and some others.
 - b. Caloceroid group (basidiocarps erect, unbranched or with apical branching, gelatinous or viscous):
 - Caloceroid biomorph—*Calocera*.
 - c. Ramarioid group (basidiocarps erect, more or less sympodially branching, non-gelatinous):
 - Ramarioid biomorph—*Ramaria*, *Lentaria*.
 - d. Clavicornoid group (basidiocarp erect, branched via scyphoid proliferation, non-gelatinose):
 - Clavicornoid biomorph—*Clavicornia*.
2. Cantharelloid series (basidiocarps erect, funnel-shaped, pileus plectologically not differentiated from the stipe).
 - a. Grifoloid group (basidiocarps erect, multipileate, with even or poroid hymenophore).
 - Amylarioid biomorph (hymenophore even): *Amylaria*, *Sparassis*.
 - Grifoloid biomorph (hymenophore poroid): *Grifola*, *Meripilus*.
 - b. Polyporoid group (basidiocarps erect to laterally-attached, unipileate, funnel-shaped to tongued, with central to lateral stipe and cellar to poroid hymenophore):
 - Polyporoid biomorph—*Polyporus*, *Microporus*, *Coltricia*, *Coltriciella*, *Ganoderma* pr. p., *Ischnoderma* pr. p.
 - c. Hericioid group (basidiocarps erect, ramose, with spinose hymenophore):
 - Hericioid—*Hericum*.
3. Corticioid series (basidiocarps positively geotropic to ageotropic with radial tendency to expansion of hyphal masses).
 - a. Merulioid group (basidiocarps prostrate with free margin or in lateral forms semipileate; double-layered with loose pubescent

- abhymental stratum and gelatinized hymenophoral stratum; hymenophore even, wrinkled or tubulose, cornescent).
- Meruloid biomorph (basidiocarps prostrate of pileate, with wrinkled hymenophore): *Merulius*, *Serpula* and some others.
 - Phleboid biomorph (basidiocarp prostrate with concentrically folded to even hymenophore): *Phlebia*, *Punctularia* and some others.
 - Chondrostereoid biomorph (basidiocarp prostrate to pileate with even hymenophore): *Chondrostereum*, *Auriculariopsis*, *Auricularia mesenterica*, *Gloeostereum*.
 - Gloeoporoid biomorph (basidiocarps prostrate to pileate, with poroid hymenophore): *Gloeoporus*, *Skeletocutis*, *Gelatoporia* and some others.
- b. Poroid group (basidiocarps prostrate, annual—perennial, with non-gelatinized poroid hymenophore).
- Fuscoporioid biomorph (hymenophore multilayered, of tough consistency): *Phellinus* pr. p., *Fuscoporia*, *Phellinidium*, *Rigidoporus crocatus* and some others.
 - Fibroporioid biomorph (hymenophore as a single layer, of fibrous consistency): *Antrodia* pr. p., *Fibroporia*, *Trametes*, *Antrodiella* pr. p., *Kneiffiella* pr. p., *Diplomitoporus* and some others.
 - Ceriporioid biomorph (hymenophore as a single layer, of soft-ceraceous consistency): *Ceriporiopsis*, *Ceriporia*, *Oligoporus*, *Postia* pr. p., *Parmastomyces*, *Protomerulius* and some others.
 - Cristelloid biomorph (hymenophore as a single layer, not condensed, of softfilm consistency): *Trechispora* pr. p., *Sistotrema* pr. p., *Porpomyces mucidus* and some others.
- c. Stereoid group (basidiocarps of hard consistency, homogeneous, pileate to resupinate, with or without stipe: hymenophore basically even, often irregularly sculptured, one-layered to multilayered).
- Stereoid biomorph (basidiocarps prostrate, with a smooth hymenophore): *Stereum*, *Amylostereum*, *Hymenochaete*, *Lopharia*, *Boreostereum*, *Cystostereum* and some others.
 - Sterelloid biomorph (basidiocarps prostrate with border-like margin and even—papillose hymenophore): *Cylindrobasidium*, *Peniophora* pr. p., *Xylobolus*, *Aleurodiscus* and some others.
 - Podoscyphoid biomorph (basidiocarps with sublateral to central stipe, hymenophore one-layered, even): *Podoscypha*, *Cotylidia*, *Cyphellostereum* and some others.

- Arrhenioid biomorph (basidiocarps with lateral, sometimes rudimentary, stripe and venose-sublamellate hymenophore sculpture): *Arrhenia*, *Caripia* and some others.
- d. Raduloid group (basidiocarps prostrate, with dull-toothed? to radulose hymenophore):
 - Raduloid biomorph—*Radulomyces*, *Basidioradulum*, *Sistotrema* pr. p., *Dentocorticium* and some others.
- e. Corticioid group (basidiocarps prostrate, loose to dense consistency, with even or papillose hymenophore).
 - Peniophoroid biomorph (basidiocarps of hard consistency, with multilayered hymenophore): *Peniophora*, *Dendrophora*, *Duportella* and some others.
 - Corticioid biomorph (basidiocarps of hard consistency, with single-layered even hymenophore): *Corticium*, *Exidiopsis*, *Acanthophysellum*, *Dendrothele* and some others.
 - Hyphodermoid biomorph (basidiocarps homogeneous, of ceraceous consistency, with even or sculptured hymenophore): *Hyphoderma*, *Gloeocystidiellum*, *Metulodontia*, *Phanerochaete* and some others.
 - Athelioid biomorph (basidiocarps two-layered—with loose subiculum and pellicular even hymenium): *Athelia*, *Byssocorticium*, *Piloderma* pr. p., *Coniophora*, *Leptochaete* and some others.
- f. Odontoid group (basidiocarps prostrate to semipileate, with toothed hymenophore).
 - Grandinioid biomorph (basidiocarps prostrate, teeth small, as farinaceous tinge): *Grandinia*, *Kneiffiella*, *Resinicium*, *Trechispora* pr. p., *Steccherinum* pr. p., *Lyomyces* and some others.
 - Sarcodontoid biomorph (basidiocarps prostrate or semipileate, teeth long, cylindrical): *Sarcodontia*, *Mycoacia*, *Dentipellis*, *Kavinia*.
 - Irpicoid biomorph (basidiocarps semipileate to resupinate with teeth and disrupted pores): *Irpex*, *Steccherinum*, *Trichaptum* and some others.
- 4. Hypochnoid series (basidiocarps ageotropic, the growth mostly prostrate, mucedinous):
 - Hypochnoid biomorph—*Amaurodon*, *Amauromyces*, *Botryobasidium*, *Botryohypochnus*, *Byssocorticium* pr. p., *Ceratobasidium*, *Coniophora olivacea*, *Epithele*, *Hypochnella*, *Pseudotomentella*, *Sistotrema* pr. p., *Subulicystidium*, *Suillosporium*, *Thanatephorus* s. l., *Tomentella* pr. p., *Tomentella* s. l., *Tomentellopsis*, *Tylospora* and some others.

5. Tremelloid series (basidiocarps ageotropic, strongly gelatinized, with more or less radial growth, prostrate, cushion-like, hemispheric and often lobate).
 - a. Tremelloid group (basidiocarps strongly lobate):
 - Tremelloid biomorph—*Tremella*, *Tremiscus* and some others.
 - b. Exidioid group (basidiocarps wrinkled, but not strongly lobate—prostrate, cushion-like, turbinate, ear-shaped):
 - Exidioid biomorph—*Exidia*, *Auricularia* pr. p., *Craterocola*, *Tremella encephala* and some others.
 - c. Platygloeoid group (basidiocarps prostrate, even, often incrusting the substrate):
 - Platygloeoid biomorph—*Platygloea*, *Galzinia* and some others.
 - d. Dacrymycetoid group (basidiocarps somewhat reduced—hemispheric or discoid with non-differentiated excipulum):
 - Dacrymycetoid—*Dacryomyces*, *Femsjonia*, **Linodochium* and some others.
6. Tyromycetoid series (basidiocarps parageotropic—sessile, pileate; annual, soaked; hymenophore one layered, tubular, rarely toothed).
 - a. Pseudohydroid group (basidiocarps strongly gelatinized, with toothed hymenophore):
 - Pseudohydroid biomorph—*Pseudohydnum* and some others....
 - b. Tyromycetoid group (basidiocarps not gelatinized).
 - Climacodontoid biomorph (basidiocarps tongue-shaped, in clusters, hymenophore spinose): *Climacodon*.
 - Fistulinoid biomorph (basidiocarps tongue-shaped, singular, hymenophore polycyphelloid): *Fistulina*.
 - Phaeoloid biomorph (basidiocarps large, fan-shaped to plate-like, with pseudostipe, clustered): *Laetiporus*, *Phaeolus*, *Bondarzewia*.
 - Tyromycetoid biomorph (basidiocarps small or medium-sized, semicircular, spathulate or kidney-shaped, singular or in small clusters; laterally attached or with prostrate base): *Tyromyces*, *Postia*, *Leptoporus*, *Hapalopilus*, *Bjerkandera*, *Piptoporus* and some others.
 - c. Trametoid group (basidiocarps persisting, sessile, of tough consistency, with tubular or derivative hymenophore).
 - Trametoid biomorph (hymenophore poroid, context thicker than hymenophoral layer): *Trametes*, *Antrodia*, *Ischnoderma* and some others.

- Coriolid biomorph (hymenophore poroid, context more or less equal in thickness to hymenophoral layer): *Antrodiella*, *Pycnoporus*, *Diplomitoporus* and some others.
- Scenidioid biomorph (hymenophore poroid, cellar, or irpicoid, context thinner than hymenophore layer): *Datronia*, *Earliella*, *Hexagonia*, *Trichaptum* and some others.
- Daedaleoid biomorph (hymenophore labyrinthine to lamellate): *Daedalea*, *Daedaleopsis*, *Gloeophyllum*, *Lenzites*, *Cerrena* pr. p.
- d. Fomitoid group (basidiocarps perennial, sessile, of hard consistency, with multilayered poroid hymenophore):
 - Fomitoid biomorph—*Fomes*, *Fomitopsis*, *Ganoderma* pr. p., *Phellinus* pr. p., *Oxyporus* pr. p., *Rigidoporus* pr. p.
- 7. Agaricoid series (basidiocarps negatively geotropic, pileate, stipe differentiated from pileus; hymenophore mostly lamellate).
 - a. Pluteoid group (pileus expanding, lamellae free):
 - Pluteoid biomorph—*Pluteus* and some others.
 - b. Mycenoid group (pileus conical, stipe thin and elongated; lamellae of various attachments; ring and other velum derivatives none):
 - Mycenoid biomorph—*Mycena*, *Conocybe* pr. p., *Bolbitius* pr. p., *Entoloma* pr. p.
 - c. Armillarioid group (pileus expanding, lamellae slightly decurrent, with ring and other velum derivatives):
 - Armillarioid biomorph—*Armillaria*, *Tubaria*, *Kuehneromyces* and some others.
 - d. Coprinoid group (pileus expanding from semiclosed to conical; lamellae autolytic, narrowly attached; ring persistent in many representatives):
 - Coprinoid biomorph—*Coprinus*, *Coprinopsis* and some others.
 - e. Pleurotoid group (stipe excentric to short; pileus sublateral, expanding; lamellae decurrent; ring and derivatives absent in most of representatives).
 - Lentinoid biomorph (stipe prominent; basidiocarps tough, surface hispid or squamulose, lamellae sinuose or not, ring absent in most of representatives): *Lentinus*.
 - Panelloid biomorph (stipe prominent, basidiocarps fleshy, surface matt, lamellae sinuose or not, without ring): *Panellus*, *Lentinellus* pr. p., *Panus* pr. p.
 - Pleurotoid biomorph (stipe prominent or not, basidiocarp fleshy, surface naked—cuticulate, sometimes gelatinized, without ring): *Sarcomyxa*, *Hypsizygus*, *Ossicaulis*, *Rhodotus*, *Pleurotus* pr. p., *Hohenbuehelia* pr. p.

- Crepidotoid biomorph (stipe short, basidiocarp fleshy, surface matt to cuticulate, without ring): *Crepidotus*, *Resupinatus*, *Lentinellus* pr. p.
 - Schizophylloid biomorph (without stipe, lamellae repeatedly splitting; basidiocarps coriaceous, surface hispid to matt, no ring): *Schizophyllum*.
8. Cyphelloid series (basidiocarps positively-, negatively, or parageotropic—as cupulate or tubular bodies—singular or united by a common subiculum).
- a. Cyphelloid group (subiculum absent—basidiocarps solitary or clustered).
- Cyphelloid biomorph (basidiocarp cupulate, with prominent stipe).
 - Strictly cyphelloid (abhymenial surface naked): *Cyphella*, *Chromocyphella*, *Cellypha* and some others.
 - Lachnelloid (abhymenial surface villose): *Lachnella*, *Merismodes* and some others.
 - Calatelloid biomorph (basidiocarp cupulate with short stipe): *Calathella*, *Campanella*, *Woldmaria* and some others.
 - Solenioid biomorph (basidiocarps tubular with prominent or short stipe): *Phaeosolenia*, *Henningsomyces* and some others.
- b. Porotheleoid group (cyphelloid basidiocarps are united by a common subiculum).
- Porotheleoid biomorph (basidiocarps initially hemispheric, then tubular): *Porotheleum*.
 - Stigmatolemmoid biomorph (basidiocarps cupulate on minute stipes): *Stigmatolemma* and some others.

C. Chorionomical Notes

Many wood-inhabiting species have a circumglobal distribution (approx. 5,000 species). Other species (approx. 15,000 species) are connected to zonal biomes (boreal or nemoral forests, arid zones and rainy tropical forests). For detailed chorionomical reconstructions, mycogeography generally compels the student to integrate vascular plants into more complex associations, for example, the host-associate connections (Pirozynski, 1983; Rajchenberg, 1989; Zmitrovich et al., 2003). Other dimensions of mycotas specificity are connected to isolation processes in the Southern Hemisphere, where specific segments contain roughly 5,000 species of wood-inhabiting fungi.

On the whole, the following gross units may be distinguished in the wood-inhabiting mycota.

Cosmopolitan species. These species are distributed worldwide in warm climates. In order to recognize such species, at least three “control points” are needed: circumboreal, pantropical, and New Zealand. Within wood-inhabiting fungi, at least 5,000 species both from Ascomycota and Basidiomycota are listed. The New Zealand control point is well represented in the check-list of Buchanan and Ryvar den (2000) which is highly informative because the list includes all groups of wood-inhabiting fungi together with their biogeographical descriptions.

Examples of cosmopolitan species:

Bjerkandera adusta (Willd.) P. Karst.

Schizophora paradoxa (Schrad.) Donk

Trametes versicolor (L.) Lloyd

Gloeophyllum trabeum (Pers.) Murrill

Byssomerulius corium (Pers.) Parmasto

Annulohyphoxylon multiforme (Fr.) Y.M. Ju et al.

Nectria cinnabarina (Tode) Fr.

Holarctic species. It is assumed that the comprising Ascomycota and Basidiomycota is the richest in species diversity. These fungi, distributed over large parts of Eurasian and North American land massifs and many other areas, are associated with humid climates, and are adapted to active wood decay. The exact number of species is currently controversial and is a challenge for future research (Ginns, 1998). As of now we may refer to basic modern “large-scale Mycotas”, only:

Bondartsev (1971)—polypores: East Europe and Caucasia;

Bondartseva (1998)—polypores: East Europe, Urals, Siberia, Far East Russia;

Dennis (1978)—Ascomycota: West Europe;

Jülich and Stalpers (1980)—corticoid fungi: Europe, North America;

Gilbertson and Ryvar den (1986, 1987)—polypores: North America;

Ryvar den and Gilbertson (1993, 1994)—polypores: Europe;

Teng (1996)—all groups: non-tropical Central and East Asia;

Nordic macromycetes. Vol. 3 (1997)—former Aphyllophorales: North Europe;

Nordic macromycetes. Vol. 1 (2000)—discomycetous and stromatic Ascomycota (including wood-inhabiting fungi): North Europe;

Funga Nordica (2008)—agaricoid fungi (including wood-inhabiting fungi): North Europe;

Ghobad-Nejhad (2011)—former Aphyllophorales: Caucasia.

Examples of Holarctic species:

Phellinus lundellii Niemelä

Ph. nigricans (Fr.) P. Karst.

Lentinus suavissimus Fr.
Trametes suaveolens (L.) Fr.
Phlebia centrifuga P. Karst.
Tylospora fibrillosa (Burt) Donk
Piloderma croceum J. Erikss. & Hjortstam

Palaearctic species. These fungi are known only from the Eurasian segment of the Holarctic. The history of migration of species comprising this union is explained by Vasilyeva and Stephenson (2010).

Examples of Palaearctic species:
Heterobasidium abietinum Niemelä & Korhonen
Pachykytospora wasseri Zmitr., V. Malysheva & Spirin
Ganoderma carnosum Pat.
Lentinus martianoffianus Kalchbr.
Loweomyces sibiricus (Penzina & Ryvarden) Spirin
Peniophora laeta (Fr.) Donk
Biscogniauxia maritima L.N. Vasilyeva

American radiating species. Species are distributed from temperate areas of North America to American arids and tropics. Certain biogeographical notes on these species are given by Gilbertson and Ryvarden (1986) and Vasilyeva and Stephenson (2010).

Examples of American radiating species:
Corioloopsis byrsina (Mont.) Ryvarden
C. hostmannii (Berk.) Ryvarden
Hexagonia variegata Berk.
Trametes ectypa (Berk. & M.A. Curtis) Gilb. & Ryvarden
T. pavonia (Hook.) Ryvarden
T. supermodesta Ryvarden & Iturr.
Pogonomyces hydroides (Sw.) Murrill

Bi-polar species. These species have both boreo-nemoral and sub-antarctic circumpolar distribution but are lacking in the tropics and arid areas of the Northern Hemisphere. Biogeographical notes on some species are given by Rajchenberg (1989).

Examples of bi-polar species:
Phellinus inermis (Ellis & Everh.) G. Cunn.
Polyporus melanopus Fr.
Rigidoporus undatus (Fr.) Donk
Antrodia stratosa (J.E. Wright & J.R. Deschamps) Rajch.
Fibroporia gossypia (Speg.) Parmasto
Fibroporia vaillantii (DC.) Parmasto
Fistulina hepatica (Schaeff.) With.

Pantropical species. These type of species are present in American, African and Asian tropics (radiating to subtropics). Biogeographically, these could be “omnivorous” Gondwanian derivatives. Some basic tropical wood Mycotas are treated by:

- Fidalgo and Fidalgo (1966)—polypores: tropical Central America;
 Fidalgo and Fidalgo (1968)—polypores: tropical South America;
 David and Rajchenberg (1985)—polypores: tropical South America;
 Roy and De (1996)—polypores: tropical South Asia;
 Parmasto (1986)—former Aphyllophorales; *Lentinus*: tropical East Asia;
 Imazeki et al. (1988)—all groups: East Asia (Japan);
 Wu (1990)—corticoids: East Asia (Taiwan);
 Núñez and Ryvar den (2001)—polypores: tropical East Asia;

Examples of Pantropical species:

- Pycnoporus sanguineus* (L.) Murrill
Earliella scabrosa (Pers.) Gilb. & Ryvar den
Leiotrametes menziesii (Berk.) Welti & Courteq
Trametes tephroleuca Berk.
Microporus vernicipes (Berk.) Kuntze
Phellinus merrillii (Murrill) Ryvar den
Cyclomyces tabacinus (Mont.) Pat.

Paleoaustral species. Such species are distributed basically in the Southern Hemisphere, but also occur in gravitating tropical areas of the Northern Hemisphere. Mycogeographical aspects of this union are discussed by Rajchenberg (1989). Some basic paleoaustral wood Mycotas are mentioned by:

- Ryvar den and Johansen (1980)—polypores: East Africa;
 Härkonen et al. (2003)—polypores, corticoids, some other groups: East Africa;
 Hood (2003)—wood-inhabiting fungi: Australia.
 Paleoaustral species are subdivided here as follows:

- a) Gondwanic (e.g., Southern South America, Australia, New Zealand, North of India or East of Africa):

Examples of Gondwanic species:

- Microporus xanthopus* (Fr.) Kuntze
M. affinis (Blume & T. Nees) Kuntze
Hexagonia niam-niamensis P. Henn.
Macrohyporia dictyopora (Cooke) I. Johans. & Ryvar den
Postia dissecta (Lév.) Rajchenb.
Postia pelliculosa (Berk.) Rajchenb.
Biscogniauxia philippinensis (Ricker) Whalley et Læssøe

b) Subantarctic (Southern South America, Australia and vicinities):

Examples of Subantarctic species:

Ceriporiopsis merulinus (Berk.) Rajchenb.

Grifola sordulenta (Mont.) Singer

Laetiporus portentosus (Berk.) Rajchenb.

Polyporus maculatissimus Lloyd

Ryvardenia campyla (Berk.) Rajchenb.

R. cretacea (Lloyd) Rajchenb.

c) South East Asian:

Examples of South East Asian species:

Lentinus polychrous Lév.

Phellinus fastuosus (Lév.) Ryvarden

Corioloopsis aspera (Jungh.) Teng

C. telfairii (Klotzsch) Ryvarden

T. conchifera (Schwein.) Pilát

T. orientalis (Yasuda) Imazeki

T. pocas (Berk.) Ryvarden

Nothofagus-area species. These types of fungi are found in warm-temperate areas of South America and in some Pacific islands, and are more or less associated with the distribution area of *Nothofagus*. This area is climatically isolated. Mycogeographical aspects of this union are discussed by Rajchenberg (1989). Such wood Mycotas are treated by:

Wright and Deschamps (1972, 1975)

Rajchenberg (1989)

Examples of Nothofagus-area species:

Bondarzewia guaitecasensis (P. Henn.) J.E. Wright

Phellinus crustosus (Speg.) A.M. Gottlieb, J.E. Wright & Moncalvo

Phellinus andinus Plank & Ryvarden

Polyporus gayanus Lév.

Skeletocutis australis Rajchenb.

Cyttaria darwinii Berk.

Biscogniauxia nothofagi Whalley, Læssøe et Kile.

Ecology

Substrate Groupings

According to Kirk et al. (2001), a substrate is "a material on which an organism is growing or to which it is attached". Therefore, we can distinguish nutritive substratum and attachment substratum (Yurchenko, 2006). In most

of the cases both substrate types represent a union, but in some cases, the sporulation and nutrient consumption is spatially incongruent.

Table 2.4 shows some key substrata, colonized by the most important wood-decay fungi. It is necessary to note that many wood-destroying fungi are capable of forming a secondary colonization of non-lignified substrata, such as mosses protonemata or algal cells. These phenomena were exhaustively presented by Yurchenko (2001, 2006). As a rule, greater amount of fungal mycelia colonize core lignin-containing substrate, but surface-associated hyphae form appressoria in the zone of interactions with green epiphytic cells. In some *Athelia*-species these green-cells—mycelium associations are rather stable (Zmitrovich, 2008), so are also in some representatives of the so-called *Rickenella*-family (Larsson et al., 2006).

The other circle of secondary phenomena is connected to the colonization of herbaceous plants by wood-rot fungi. These plants contain H-lignin (hydrophenilous lignin) (Manskaya and Kodina, 1975; Zmitrovich, 2010) and are probably derived from woody predecessors (Church, 1919; Chadefaud, 1950; Takhtajan, 1950). The most prominent lignifying component of such plants is in xerophylized forms, where parenchymatous living tissues are reduced. The fungi colonizing such a substrate are presumably omnivorous and xerotolerant.

Obviously, the capacity of a wide-range of biopolymer decomposition is present in many taxa, whereas a real substrate specialization has ecological control and is correlated to insolation niche occupied by fungi and their biomorphic status.

Microsuccessions

In nature, groupings of wood-inhabiting fungi colonizing dried and fallen wood are temporally localized. The wood decay in forest ecosystems passes through several stages (Renvall, 1995; Kotiranta and Niemelä, 1993; Lindgren, 2001; Spirin, 2002). As shown in Table 2.5, in boreal forests, where soil water evaporation is non-intensive, the process of wood humification ranges from 15 to 20 years (in arid climates and rainy tropical forests with intensive evaporation, the decay rate is low).

In incipient stages of wood degradation, there is no contact with the ground; therefore, decay develops rather slowly. As a result, in such stages, pathogenic saprotrophs with some other xerotolerant saprotrophs are predominant.

After roots and gross branches are destroyed, the logs become gradually immersed into the ground, where contact with capillary connected water and soil mycelium is present. This contact represents a key event in the destruction process of wood. In spruce forests, the pioneer groupings of wood fungi are substituted by decortical fungi and strong saprotrophic

Table 2.4. An overview of key species of wood-destroying fungi on most widespread substrates of basic world biomes

Key substrata	Key fungal pathogens/decomposers	Literature
Trees and shrubs		
<i>Betula</i> sect. <i>Albae</i>	<i>Inonotus obliquus</i> (Ach. ex Pers.) Pilát, <i>Fomes fomentarius</i> , <i>Piptoporus betulinus</i> (Bull.) P. Karst., <i>Phellinus laevigatus</i> (P. Karst.) Bourdot & Galzin, <i>Ph. nigricans</i> (Fr.) P. Karst. f <i>betulae</i> comb. ined., <i>Ph. lundellii</i> Niemelä; <i>Trichaptum bifforme</i> (Fr.) Ryvardeen, <i>Antrodiella faginea</i> Vampola & Pouzar, <i>Gloeoporus dichrous</i> (Fr.) Bres.	Arefiev (2010)
<i>Populus tremula</i>	<i>Phellinus tremulae</i> , <i>Inonotus rheades</i> (Pers.) Bondartsev & Singer, <i>Peniophora rufa</i> (Fr.) Boidin, <i>Punctularia strigosozonata</i> (Schwein.) P.H.B. Talbot	Ershov and Ezhov (2009)
<i>Alnus incana</i>	<i>Biscogniauxia nummularia</i> (Bull.) Kuntze, <i>Vulleminia alni</i> Boidin, Lanq. et Gilles, <i>Phellinus nigricans</i> var. <i>alni</i> Zmitr. et V. Malysheva, <i>Ph. conchatus</i> (Pers.) Quéél, <i>Ph. punctatus</i> (Fr.) Pilát, <i>Stereum rugosum</i> Pers., <i>Bisporella citrina</i> (Batsch) Korf et S.E. Carp., <i>Hyphodontia crustosa</i> (Pers.) J. Erikss.	Strid (1975); Zmitrovich (2012)
<i>Salix</i> spp.	<i>Trametes suaveolens</i> (Fr.) Fr., <i>Haploporus odorus</i> (Sommerf.) Bondartsev & Singer, <i>Phellinus conchatus</i> , <i>Ph. punctatus</i> , <i>Lentinus suavissimus</i> Fr.	Andersson et al. (2009)
<i>Picea abies/obovata</i>	<i>Phellinus chrysoloma</i> (Fr.) Donk, <i>Fomitopsis rosea</i> (Alb. & Schwein.) P. Karst., <i>Pycnoporellus fulgens</i> (Fr.) Donk	Andersson et al. (2009)
<i>Pinus sylvestris</i>	<i>Phellinus pini</i> (Brot) Bondartsev & Singer, <i>Fomitopsis pinicola</i> (Sw.) P. Karst., <i>Phlebiopsis gigantea</i> (Fr.) Jülich	Sinadsky (1983)
<i>Larix sibirica</i>	<i>Phaeolus schweinitzii</i> (Fr.) Pat., <i>Phellinus niemelaei</i> (M. Fisch.) Zmitr., Malysheva & Spirin	Ezhov et al. (2011); Spirin et al. (2006)
<i>Juniperus communis</i>	<i>Amylostereum laevigatum</i> (Fr.) Boidin	Davydkina (1980)
<i>Quercus robur</i>	<i>Laetiporus sulphureus</i> (Bull) Murrill, <i>Phellinus robustus</i> (P. Karst.) Bourdot & Galzin, <i>Inonotus dryophilus</i> (Berk.) Murrill, <i>I. nidus-pici</i> Pilát, <i>Xylobolus frustulatus</i> (Fr.) Boidin	Chamur is (1988); Larsen and Cobb-Pouille (1990); Spirin (2002); Ghobad-Nejhad and Kotiranta (2008)

Table 2.4. contd....

Table 2.4. contd.

Key substrata	Key fungal pathogens/decomposers	Literature
<i>Tilia cordata</i>	<i>Polyporus squamosus</i> (Huds.) Fr., <i>Spongipellis spumea</i> (Sowerby) Pat., <i>Neolentinus schaefferi</i> (Weinm.) Redhead & Ginns	Malysheva and Malysheva (2008)
<i>Juglans regia</i>	<i>Inonotus plorans</i> (Pat.) Bondartsev & Singer	Ghobad-Nejhad and Kotiranta (2008)
<i>Ceratonia siliqua</i>	<i>Ganoderma australe</i> (Fr.) Pat., <i>Phellinus torulosus</i> (Pers.) Bourdot & Galzin	Ṭura et al. (2011)
<i>Robinia pseudoacacia</i>	<i>Phellinus robiniae</i> (Murrill) A. Ames	Larsen and Cobb-Pouille (1990)
<i>Quercus virginiana</i>	<i>Phellinus coffeatorporus</i> Kotl. & Pouzar, <i>Ph. grenadensis</i> (Murrill) Ryvardeen	Larsen and Cobb-Pouille (1990)
<i>Eucalyptus camadulensis</i>	<i>Laetiporus gilbertsonii</i> Burds., <i>Ganoderma australe</i> (Fr.) Pat.	Burdsall and Banik (2001); Ṭura et al. (2011)
<i>Tamarix aphylla</i>	<i>Inonotus tamaricis</i> (Pat.) Maire, <i>Phellinus torulosus</i> , <i>Ganoderma australe</i> , <i>Peniophora tamaricicola</i> Boidin & Malençon	Ghobad-Nejhad and Kotiranta (2008); Ṭura et al. (2011).
<i>Cupressus sempervirens</i>	<i>Phellinus torulosus</i>	Ṭura et al. (2011)
<i>Casuarina cunningghamiana</i>	<i>Inonotus ochroporus</i> (Van der Bijl) Pegler, <i>I. patouillardii</i> (Rick) Imazeki	Gottlieb et al. (2002)
<i>Nothofagus dombei</i>	<i>Phellinus crustosus</i> (Speg.) Gottlieb, Wright & Moncalvo, <i>Ph. andinopatagonicus</i> (J.E. Wright & J.R. Deschamps) Ryvardeen	Larsen and Cobb-Pouille (1990); Gottlieb et al. (2002)
<i>Brugiera gymnorhiza</i>	<i>Trametes cingulata</i> Berk., <i>T. flavida</i> (Lév.) Zmitr., Wasser & Ezhov	Gilbert et al. (2008)
<i>Rhizophora apiculata</i>	<i>Trametes sanguinaria</i> (Klotzsch) Corner, <i>T. nivosa</i> (Berk.) Murrill	Gilbert et al. (2008)
<i>Sonneratia alba</i>	<i>Phellinus fastuosus</i> (Lév.) Ryvardeen, <i>Inonotus luteoumbrinus</i> (Romell) Ryvardeen, <i>Trametes cingulata</i>	Gilbert et al. (2008)
<i>Avicennia germinans</i>	<i>Phellinus swieteniae</i> (Murrill) S. Herrera & Bondartseva, <i>Trichaptum biforme</i> (Fr.) Ryvardeen	Gilbert and Sousa (2002)
Small shrubs and semi-arboreous plants		

<i>Calluna vulgaris</i>	<i>Acanthobasidium norvegicum</i> (J. Erikss. & Ryvardeen) Boidin, <i>Acanthophysium apricans</i> (Bourdot) G. Cunn., <i>Corticium macrosporopsis</i> Jülicj, <i>Hyphodontia hastata</i> (Litsch.) J. Erikss., <i>Phanerochaete ericina</i> (Bourdot) J. Erikss. & Ryvardeen, <i>Ph. martelliana</i> (Bres.) J. Erikss. & Ryvardeen, <i>Sistotrema dennisii</i> Malençon	Domański (1988, 1991, 1992); Yurchenko (2006)
<i>Rubus idaeus</i>	<i>Ceratobasidium cornigerum</i> (Bourdot) D.P. Rogers, <i>Peniophora cinerea</i> (Pers.) Cooke, <i>P. incarnata</i> (Pers.) P. Karst., <i>Acanthobasidium norvegicum</i> , <i>Corticium macrosporopsis</i> , <i>Phanerochaete tuberculata</i> (P. Karst.) Parmasto	Domański (1988, 1991, 1992); Yurchenko (2006)
<i>Actinidia</i> spp.	<i>Peniophora sphaerocystidiata</i> Burds. & Nakasone	Yurchenko (2006)
Lignified herbaceous and succulent plants		
<i>Chamaerion angustifolium</i>	<i>Ceratobasidium pseudocornigerum</i> M.P. Christ., <i>Peniophora cinerea</i> , <i>Sistotrema octosporum</i> (J. Schröt.) Hallenb	Yurchenko (2006)
<i>Humulus lupulus</i>	<i>Aleurodiscus cerussatus</i> (Bres.) Höhn. & Litsch.	Yurchenko (2006)
<i>Juncus</i> sp.	<i>Tomentella juncicola</i> Svrček	Domański (1992)
<i>Carnegiea</i> spp.	<i>Hyphoderma fouquieriae</i> Nakasone & Gilb., <i>Peniophora tamaricicola</i> , <i>Phanerochaete omnivorum</i> (Schear) Burds. & Nakasone	Nakasone and Gilbertson (1978)
<i>Opuntia</i> spp.	<i>Crustoderma opuntiae</i> Nakasone & Gilb., <i>Uncobasidium calongei</i> (Tellería) Hjortstam & Tellería	Nakasone and Gilbertson (1978); Yurchenko (2006)
Bryophyta	<i>Ceratobasidium bicornis</i> J. Erikss. & Ryvardeen, <i>Sistotrema muscicola</i> (Pers.) S. Lundell, <i>Lindtneria leucobryophila</i> (Henn.) Jülich, <i>Athelia epiphylla</i> Pers., <i>Tomentella sublilacina</i> (Ellis & Holw.) Wakef., <i>Amphimena byssoides</i> (Pers.) J. Erikss., <i>Tubulicrinis subulatus</i> (Bourdot & Galzin) Donk	Eriksson and Ryvardeen (1973); Eriksson et al. (1984); Domański (1988, 1991); Yurchenko (2001, 2006)
Chlorophycophyta (epiphytic)	<i>Athelia epiphylla</i> , <i>A. phycophila</i> Jülich, <i>A. andina</i> Jülich, <i>Resinicium bicolor</i> (Alb. et Schwein.) Parmasto, <i>Hyphoderma</i> spp., <i>Sistotrema sernanderi</i> (Litsch.) Donk, <i>Sistotremastrum succicum</i> Litsch. ex J. Erikss., <i>Sidera lenis</i> (P. Karst.) Miettinen, <i>Hyphodontia rimosissima</i> (Peck) Gilb.	Jülich (1972); Eriksson et al. (1981, 1984); Eriksson and Ryvardeen (1975, 1976); Yurchenko and Golubkov (2003); Yurchenko (2006); Zmitrovich (2008); Miettinen and Larsson (2011)

Table 2.4. contd....

Table 2.4. contd.

Key substrata	Key fungal pathogens/decomposers	Literature
Lichenized Ascomycota	<i>Athelia arachnoidea</i> (Berk.) Jülich, <i>A. epiphylla</i> , <i>A. salicum</i> Pers., <i>Botryobasidium candicans</i> J. Erikss., <i>Peniophora cinerea</i> , <i>Sistotrema brinkmannii</i> (Bres.) J. Erikss.	Eriksson et al. (1978); Parmasto (1998); Yurchenko and Golubkov (2003); Zmitrovich (2008)
Chitinous substrata	<i>Hyphoderma setigerum</i> (Fr.) Donk (pyrenomycete stromata, insect exoskeleton), <i>Peniophora cinerea</i> (pyrenomycete stromata), <i>Antrodiella pallescens</i> (Pilát) Niemelä & Miettinen, <i>Sistotrema brinkmannii</i> , <i>Peniophora incarnata</i> , <i>Phanerochaete laevis</i> (Fr.) J. Erikss. & Ryvarden (polypore basidiomata)	Yurchenko and Zmitrovich (2001); Miettinen et al. (2006); Yurchenko (2006)
Humus soil horizon	<i>Piloderma croceum</i> , <i>Tylospora fibrillosa</i> , <i>Amphinema byssoides</i> , <i>Byssocorticium</i> spp., <i>Tomentella</i> spp., <i>Tomentellastrum</i> spp., <i>Tomentellopsis</i> spp., <i>Conohypha terricola</i> (Burt) Jülich, <i>Echinotrema clanculare</i> Park.-Rhodes, <i>Sistotrema hypogaeum</i> Warcup & P.H.B. Talbot, <i>Waitea circinata</i> Warcup & P.H.B. Talbot, <i>Dacryobasidium coprophilum</i> (Wakef.) Jülich	Jülich (1984); Yurchenko (2006); Zmitrovich (2008)
Antropogenic Composites	<i>Coniophora marmorata</i> Desm., <i>Serpula lacrymans</i> (Wulfen) J. Schröt., <i>Leucogyrophana olivascens</i> (Berk. & M.A. Curtis) Ginns & Weresub	Bondartsev (1956); Jülich (1984); Yurchenko (2006)

Table 2.5. Humification of spruce wood in boreal forersts with microsuccessions of wood-inhabiting fungi (according to Spirin, 2002).

Stage	Description
Fallen log (0–2 years)	Fresh wood material has intact branches and bark and their mechanical properties as in living trees. Predominate pathogenic saprotrophs: <i>Fomitopsis pinicola</i> , <i>Heterobasidion</i> spp.
Origin of decomposition (2–10 years)	The bark partially falls off and the skeletal branches break up. The wood located at the bottom side of the log changes its mechanical properties. Pathogenic saprotrophs continue the growth. The core saprotrophs species occur: <i>Phellinidium ferrugineofuscum</i> , <i>Fomitopsis rosea</i> (Alb. & Schwein.) P. Karst.
Intensive decomposition (10–15 years)	In this stage only the bark located above remains, whereas the log merges into the ground. The wood strongly changes its mechanical properties (becomes friable and stratified); on contact with the ground the humification process starts. The pioneer species complexes are substituted as follows: <i>Fomitopsis rosea</i> → <i>Skeletocutis odora</i> (Sacc.) Ginns and <i>Phlebia centrifuga</i> P. Karst.; <i>Heterobasidion</i> spp. → <i>Junghuhnia collabens</i> (Fr.) Ryvarde, <i>Dichostereum boreale</i> (Pouzar) Ginns & M.N.L. Lefebvre; <i>Fomitopsis pinicola</i> → <i>Pycnoporellus fulgens</i> (Fr.) Donk, <i>Phellinidium sulphurascens</i> (Pilát) Y.C. Dai
Full decomposition (15–20 years)	The bark falls or is humified. The wood softens completely and changes into a red-brown color. Saprotrophic fungi groups are represented by many ephemeral hygrophilic species as <i>Postia</i> spp., <i>Leptoporus mollis</i> (Pers.) Quél., <i>Physisporinus</i> spp., <i>Asterodon ferruginosus</i> Pat.

wood-colonizers: for example, *Heterobasidion parviporum* is changed by *Junghuhnia collabens*, *Perenniporia* spp., or *Dichostereum boreale*. A primary decayer such as *Fomitopsis pinicola* as a rule is changed by *Amylocystis lapponica* (Romell) Bondartsev & Singer, *Fomitopsis rosea*, *Pycnoporellus fulgens* then, the latter are changed with a rather large suite of tertiary successors such as *Postia* spp., *Skeletocutis* spp., *Crustoderma* spp., or *Phlebia centrifuga*, fungi responsible for starting the humification process.

Simultaneously, terminal branches and branchlets are decayed by certain specific wood fungi such as [*Peniophora pini* (Schleich.) Boidin—pine, *P. rufa* (Fr.) Boidin, *Punctularia strigosozonata* (Schwein.) P.H.B. Talbot—aspens, *Vuilleminia alni* Boidin, Lanq. & Gilles—alder] and non-specific [*Hyphodontia* spp., *Hyphoderma* spp., *Byssomerulius corium* (Pers.) Parmasto, *Cylindrobasidium evolvens* (Fr.) Jülich].

In the stage of humification, numerous ephemeral hygrophilic wood-inhabiting fungi (*Anomoporia* spp., *Ceriporiopsis* spp., *Ceriporia* spp., *Physisporinus* spp., *Trechispora* spp. and other corticioids) colonize the rest of the cavernous wood mass. There are many threads and rhizomorph-forming wood fungi. The fallen log remnants become amorphous and

protruded by roots of young trees and shrubs. Often these are overgrown by moss groupings and form certain "soil bolsters".

As a result of wood humification, the virgin boreal forests are characterized by fractured microrelief formed by the so-called "wood remnants-soil complexes" (Smirnova, 2004) and rather gross amorphous wood debris layer reaching 15 cm in thickness (Fig. 2.12). This layer is the main producer of humic and fulvic acids (Dighton et al., 2005), that migrate into the water bodies and accumulate colloids-linked Ca^{2+} , Mg^{2+} and K^+ . Therefore, the boreal soils are acidic, and dominated by oligotrophic moss communities.

In a placore nemoral forests, water does not reach the ground surface during the warm period. In this type of forests, the rate of wood destruction and humification is lower, though humus accumulates at a high rate, whereas humic acids production falls. Such pioneers as *Ganoderma applanatum*, *Neolentinus schaefferi*, *Hypsizygos ulmarius* (Pers.) Singer, *Pleurotus dryinus* (Pers.) P. Kumm., *Inonotus dryophilus* (oak), *Aurantiporus fissilis* (Berk. & M.A. Curtis) H. Jahn, *Phellinus* spp., and *Spongipellis* spp. start the decaying process of stands and stumps. Fallen logs and dry stumps are colonized by such key species as *Bjerkandera adusta*, *Hapalopilus croceus* (Pers.) Donk (oak) or *Fomes fomentarius*. Transcortical species of *Junghuhnia* spp., *Oxyporus* spp., and *Hypochnicium* spp. are leader species in the process of wood decortications. Many *Peniopora* species decompose fallen terminal branches. After partial decortication and branch degradation the rich



Figure 2.12. Subvirgin boreal forest (Eu-Piceetum abietis) with abundance of overmossed spruce fallen logs on various stages of decaying. The fruit bodies of the key destructor *Fomitopsis pinicola* is seen on the spruce stump (Veps Plateau).

wood-inhabiting fungi communities are revealed by marker fungi species as *Crepidotus* spp., *Pluteus* spp., *Phlebia* spp. and many other corticioids (see Malysheva and Malysheva, 2008).

In the south of nemoral zone, the role of pathogenic saprotrophs (e.g., *Ganoderma* spp., *Phellinus* spp.) in the wood decay process is increasing. The fallen wood decomposes very slowly, and the key role within non-pathogenic decayers is held by the genus *Trametes*, represented in the southern areas by more than 50 species (Zmitrovich et al., 2012).

Syntaxonomical Aspects

The wood-inhabiting fungi constitute one of the basic functional blocks of forest ecosystems. Their main functions are to destroy and humify the wood debris and optimize the mineral exchange. In oligotrophic environments of the taiga forest communities containing wood fungi and ectomycorrhizal formers (often these functions are performed by the same species) determine the development of forest vegetation (Zmitrovich, 2011).

The fungal communities represent a specific part of biogeocoenoses which do not have a description and a conventional classification yet. There were some attempts to classify the fungal communities in connection with phytosphere of coenosis-forming trees and bonds of edaphotop (Jahn, 1966; Darimont, 1973; Šmarda, 1972; Bon, 1981); however, most authors traced fungal species complexes into phytosociological classifications (Jahn, 1986; Bujakiewicz, 1992; Richard, 2000). Recently, a new approach has been proposed by Zmitrovich (2011). The approach is based on a strong dependence of mycosynusia from environment-making role of dominating trees. Our basic knowledge on communities of wood-inhabiting, litter, and mycorrhizal fungi in boreal and sub-nemoral European forests has been summarized (Table 2.6).

Concluding Remarks

The progress achieved during the past decades in research on wood-inhabiting fungi highlights both, their importance in nature and their high potential in biotechnology. In nature, wood fungi are key agents involved in the decomposition of wood, soil humus formation and nutrient recycling. In terms of evolution, various wood fungi species belong to different groupings. Some fungi are restricted to colonizing one type of substrate and follow the distribution range of the substrate that they prefer [e.g., *Inonotus tamaricis* (Pat.) Maire], while other fungal species evolved differently. For example, fungal species able to colonize wood at a fast rate, occurring on a broad range of substrata including both living and dead hardwoods and

Table 2.6. Syntaxonomical aspects of wood inhabiting fungi in boreal and subnemoral forests of Europe (according to Zmitrovich, 2011).

Fungal community syntaxonomy	Corresponding element of phytocoenotic mosaics	Key fungal species*	Synonymy (authors)
[1]. <i>Pilodermato crocei</i> - <i>Amylocystidietum</i> prov.	<i>Picea abies</i> (<i>Rubo chamaemori-Piceetum</i> ; <i>Vaccinio myrtilli-Piceetum</i> ; <i>Melico nutantis-Piceetum</i>)	<i>Piloderma croceum</i> , <i>Amanita pantherina</i> , <i>Tylospora fibrillosa</i> , <i>Russula claroflava</i> , <i>Cantharellus tubae formis</i> , <i>Phellodon niger</i> , <i>Clitocybe ditopa</i> , <i>Cortinarius</i> sp. div., <i>Tylopilus felleus</i> , <i>Phellinus chrysoloma</i> , <i>Amylocystis lapponica</i> , <i>Postia caesia</i> , <i>P. lateritia</i> , <i>Climacocyatis borealis</i> , <i>Onnia leporina</i> , <i>Fomitopsis rosea</i> , <i>Trichaptum abietinum</i> , <i>Phellinus nigrolimitatus</i> , <i>Phlebia centrifuga</i> , <i>Hyphodontia breviseta</i>	<i>Caloceretum viscosae</i> Rícek (1967); <i>Tyromyces caesii</i> Rícek (ibid.); <i>Clitocybo-Phellodontetum nigrae</i> Šmarda (1973)
[2]. <i>Pilodermato crocei</i> - <i>Amyloporietum</i> prov.	<i>Pinus sylvestris</i> (<i>Vaccinio myrtilli-Pinetum</i> , <i>Vaccinio vitis-idaea-Pinetum</i>)	<i>Piloderma croceum</i> , <i>Amanita fulva</i> , <i>Rozites caperata</i> , <i>Leccinum vulpinum</i> , <i>Fomitopsis pinicola</i> , <i>Antrodiella citrinella</i> , <i>Amyloporia xantha</i> , <i>Antrodia sinuosa</i> , <i>A. serialis</i> , <i>Postia fragilis</i> , <i>Trichaptum fuscoviolaceum</i> , <i>Tapinella atrotomentosa</i> , <i>Serpulomyces borealis</i> , <i>Phlebiella vaga</i>	<i>Caloceretum viscosae</i> Rícek (1967)
[3]. <i>Pilodermato crocei</i> - <i>Piptoporetum</i> prov.	<i>Betula pubescens</i> (<i>Vaccinio myrtilli-Pinetum</i> , <i>Vaccinio vitis-idaea-Pinetum</i> ; <i>Rubo chamaemori-Piceetum</i> ; <i>Vaccinio myrtilli-Piceetum</i> ; <i>Melico nutantis-Piceetum</i>)	<i>Piloderma croceum</i> , <i>Russula emetica</i> , <i>Cantharellus cibarius</i> , <i>Leccinum variicolor</i> , <i>Boletus edulis</i> , <i>Hydnum rufescens</i> , <i>Phellinus nigricans</i> f. <i>betulae</i> , <i>Piptoporus betulinus</i> , <i>Antrodiella pallescens</i> , <i>Mycena galericulata</i> , <i>M. haematopoda</i> , <i>Trichaptum bifforme</i> , <i>Exidia repanda</i> , <i>Hyphodontia aspera</i>	<i>Mycenetum galericulatae</i> Rícek (1967)

[4]. <i>Piloderma crocei</i> - <i>Crepidotetum calolepidis</i> prov.	<i>Populus tremula</i> (<i>Vaccinio myrtilli</i> - <i>Piceetum</i> ; <i>Melico nutantis</i> - <i>Piceetum</i>)	<i>Piloderma croceum</i> , <i>Leccinum aurantiacum</i> , <i>L. albostipitatum</i> , <i>Phellinus tremulae</i> , <i>Iunghuhnia pseudozilingiana</i> , <i>Inonotus rheades</i> , <i>Oxyporus corticola</i> , <i>Antrodia mellita</i> , <i>A. pulvinascens</i> , <i>Crepidotus calolepis</i> , <i>Ceriporiopsis aneirina</i> , <i>Radulodon erikssonii</i> , <i>Punctularia strigosozonata</i>	<i>Phellinetum tremulae</i> Jahn (1966); <i>Crepidotetum calolepidis</i> Jahn (ibid.)
[5]. <i>Thelephora terrestridis</i> - <i>Gloeophylletum</i> prov.	<i>Pinus sylvestris</i> (<i>Ledo</i> - <i>Pinetum</i> ; <i>Pino</i> - <i>Polytrichetum</i> ; <i>Vaccinio uliginosi</i> - <i>Pinetum</i> ; <i>Betulo</i> - <i>ledetum</i> ; <i>Betulo pubescentis</i> - <i>Vaccinietum uliginosi</i>)	<i>Thelephora terrestris</i> , <i>Russula paludosa</i> , <i>Suillus variegatus</i> , <i>Cantharellus aurora</i> , <i>Hypholoma polytrichi</i> , <i>Gloeophyllum sepiarium</i> , <i>Trametes velutina</i> , <i>Pycnoporus cinnabarinus</i> , <i>Phyllotopsis nidulans</i> , <i>Chaetodermella luna</i>	-
[6]. <i>Galereto</i> - <i>Chaetodermetum</i> prov.	<i>Pinus sylvestris</i> (<i>Sphagno magellanici</i> - <i>Ledetum</i>)	<i>Galerina sphagnorum</i> , <i>G. paludosa</i> , <i>G. tibiicystis</i> , <i>Exobasidium andromedae</i> , <i>Chaetodermella luna</i>	-
[7]. <i>Galereto</i> - <i>Pycnoporetum</i> prov.	<i>Betula pubescens</i> (<i>Sphagno magellanici</i> - <i>Ledetum</i>)	<i>Russula paludosa</i> , <i>Galerina</i> sp. div., <i>Exobasidium</i> sp. div., <i>Pycnoporus cinnabarinus</i>	-
[8]. <i>Bankero</i> - <i>Amyloporietum</i> prov.	<i>Pinus sylvestris</i> (<i>Cladonio stellaris</i> - <i>Pinetum</i>)	<i>Bankera fuligineoalba</i> , <i>Sarcodon scabrosus</i> , <i>S. lundellii</i> , <i>Boletus pinophilus</i> , <i>Ramaria</i> sp. div., <i>Hydnellum ferrugineum</i> , <i>Fomitopsis pinicola</i> , <i>Amyloporia xantha</i> , <i>Phlebiopsis gigantea</i> , <i>Dacrymyces tortus</i> , <i>Exidia saccharina</i> , <i>Calocera viscosa</i>	<i>Caloceretum viscosae</i> Ricek (1967)
[9]. <i>Suillo bovinis</i> - <i>Amylostereetum laevigatidis</i> prov.	<i>Juniperus communis</i> —young <i>Pinus sylvestris</i> on fire places (<i>Cladonio stellaris</i> - <i>Pinetum</i>)	<i>Suillus bovinus</i> , <i>S. luteus</i> , <i>Chalciporus piperatus</i> , <i>Thelephora terrestris</i> , <i>Coltricia perennis</i> , <i>Fomitopsis pinicola</i> , <i>Dacrymyces tortus</i> , <i>D. chrysocomus</i> , <i>Amylostereum laevigatum</i> , <i>Resinicium furfuraceum</i>	-

Table 2.6. contd....

Table 2.6. contd.

Fungal community syntaxonomy	Corresponding element of phytocoenotic mosaics	Key fungal species*	Synonymy (authors)
[10]. <i>Leccino versipelle-Trametetum ochraceae</i> prov.	<i>Betula pubescens</i> (<i>Cladonio stellaris</i> - <i>Pinetum</i>)	<i>Leccinum versipelle</i> , <i>Suillus granulatus</i> , <i>Thelephora terrestris</i> , <i>Ramaria</i> sp. div., <i>Fomitopsis pinicola</i> , <i>Piptoporus betulinus</i> , <i>Postia tephroleuca</i> , <i>Trametes ochracea</i> , <i>Skeletocutis amorpha</i> , <i>Resinicium bicolor</i>	-
[11]. <i>Cortinario uliginosi-Cytidietum</i> prov.	<i>Salix</i> spp. frutic. (<i>Salicetum triandrae-viminalis</i>)	<i>Cortinarius uliginosus</i> , <i>Inocybe glabripes</i> , <i>I. lacera</i> , <i>Laccaria laccata</i> , <i>Leccinum scabrum</i> , <i>Phellinus punctatus</i> , <i>Physisporinus vitreus</i> , <i>Cytidia salicina</i> , <i>Peniophora violaceolivida</i> , <i>Tremella mesenterica</i> , <i>Exidia recisa</i>	<i>Tremelletum mesentericae</i> Darimont (1973)
[12]. <i>Cortinario uliginosi-Trametetum suaveolentis</i> prov.	<i>Salix fragilis</i> (<i>Salicetum triandrae-viminalis</i>)	<i>Cortinarius uliginosus</i> , <i>Inocybe</i> sp. div., <i>Laccaria laccata</i> , <i>Paxillus involutus</i> , <i>Phellinus igniarius</i> s.str., <i>Trametes suaveolens</i>	<i>Fometum igniarii</i> Pirk (1952)
[13]. <i>Lactario lilacini-Phellinetum</i> prov.	<i>Alnus glutinosa</i> , <i>A. incana</i> , <i>Salix caprea</i> , <i>Betula pubescens</i> (<i>Salici pentandrae-Betuletum pubescentis</i> ; <i>Urtico dioicae-Alnetum glutinosae</i>)	<i>Lactarius lilacinus</i> , <i>L. mitissimus</i> , <i>Laccaria laccata</i> , <i>Paxillus involutus</i> , <i>Pluteus cervinus</i> , <i>Mycena galericulata</i> , <i>M. haematopoda</i> , <i>Phellinus punctatus</i> , <i>Ph. nigricans</i> var. <i>alni</i> , <i>Ph. laevigatus</i> , <i>Ph. lundellii</i> , <i>Peniophora erikssonii</i>	<i>Mycetentum galericulatae</i> Ricek (1967)
[14]. <i>Naucorio-Phellinetum</i> prov.	<i>Alnus incana</i> , <i>Sorbus aucuparia</i> , <i>Salix caprea</i> , <i>Padus avium</i> , <i>Sambucus racemosa</i> (<i>Alnetum incanae</i> ; <i>Alno incanae-Padetum avii</i>)	<i>Naucoria alnetorum</i> , <i>Hebeloma crustuliniforme</i> , <i>Paxillus filamentosus</i> , <i>Xerocomus chrysenteron</i> , <i>Mycena haematopoda</i> , <i>Pleurotus dryinus</i> , <i>Phellinus punctatus</i> , <i>Ph. nigricans</i> var. <i>alni</i> , <i>Phellinus lundellii</i> , <i>Inonotus radiatus</i> , <i>Bisporella pallescens</i> , <i>Byssomerulius corium</i> , <i>Chondrostereum purpureum</i> , <i>Cylindrobasidium evolvens</i> , <i>Schizopora paradoxa</i> , <i>Hyphodontia crustosa</i> , <i>H. sambuci</i>	<i>Bisporetum antennatae</i> Jahn (1968)

[15]. <i>Thelephora caryophillei</i> - <i>Meruliopsisidetum</i> prov.	<i>Pinus sylvestris</i> (<i>Thymo serpylli</i> - <i>Pinetum</i>)	<i>Thelephora caryophillea</i> , <i>Suillus bovinus</i> , <i>Strobilurus tenacellus</i> , <u><i>Auriscalpium vulgare</i></u> , <u><i>Meruliopsis taxicola</i></u> , <u><i>Peniophora pini</i></u>	–
[16]. <i>Thelephoretum terrestridis</i> prov.	Gaps parcels (<i>Thymo serpylli</i> - <i>Pinetum</i>)	<i>Thelephora terrestris</i> var. <i>infundibuliformis</i> , <i>Th. caryophillea</i> , <i>Amphinema byssoides</i>	–
[17]. <i>Pilodermato byssini</i> - <i>Pluteetum cervinicus</i> prov.	<i>Picea abies</i> (<i>Maianthemo bifoliae</i> - <i>Piceetum abietis</i>)	<u><i>Piloderma byssinum</i></u> , <i>Boletus piceinus</i> , <i>Leccinum vulpinum</i> , <i>Lactarius</i> sp. div., <i>Cortinarius</i> sp. div., <i>Marasmius androsaceus</i> , <u><i>Phellinus chrysoloma</i></u> , <u><i>Gloeophyllum odoratum</i></u> , <u><i>Postia caesia</i></u> , <u><i>Phellinus ferrugineofuscus</i></u> , <u><i>Ph. viticola</i></u> , <u><i>Junghuhnia collabens</i></u> , <u><i>Pseudohydnum gelatinosum</i></u> , <u><i>Pluteus cervinus</i></u>	<i>Osmoporetum odorati</i> Ricek (1967); <i>Tyromyces caesii</i> (ibid.)
[18]. <i>Pilodermato byssini</i> - <i>Phellinetum populicolis</i> prov.	<i>Populus tremula</i> (<i>Maianthemo bifoliae</i> - <i>Piceetum abietis</i>)	<u><i>Piloderma byssinum</i></u> , <i>Leccinum aurantiacum</i> , <i>Paxillus involutus</i> , <i>Lactarius controversus</i> , <u><i>Phellinus nigricans</i></u> var. <i>populicola</i> , <u><i>Ganoderma applanatum</i></u> , <u><i>Polyporus badius</i></u> , <u><i>Oxyporus obducens</i></u> , <u><i>Ceriporiopsis aneirina</i></u> , <u><i>C. resinascens</i></u> , <u><i>Postia alni</i></u> , <u><i>Pluteus cervinus</i></u> , <u><i>Peniophora nuda</i></u> , <u><i>Lentaria mucida</i></u> , <u><i>Clavicornia pyxidata</i></u> , <u><i>Xylaria hypoxylon</i></u>	<i>Xylarietum hypoxylonis</i> Ricek (1967)
[19]. <i>Laccario</i> - <i>Pluteetum umbrosatis</i> prov.	<i>Alnus</i> spp., <i>Acer platanoides</i> , <i>Ulmus glabra</i> , <i>Tilia cordata</i> (<i>Alno incanae</i> - <i>Fraxinetum</i>)	<u><i>Laccaria laccata</i></u> , <i>Lactarius obscuratus</i> , <i>Lepiota cristata</i> , <u><i>Marasmius epiphyllus</i></u> , <u><i>Collybia fusipes</i></u> , <u><i>Oxyporus populinus</i></u> , <u><i>Phellinus nigricans</i></u> var. <i>alni</i> , <u><i>Ganoderma adpersum</i></u> , <u><i>Polyporus squamosus</i></u> , <u><i>Lentinus schaefferi</i></u> , <u><i>Pluteus umbrosus</i></u> , <u><i>Chondrostereum purpureum</i></u> , <u><i>Cylindrobasidium evolvens</i></u>	–

* Underlined species resemble wood-inhabiting fungi.

conifers and being able to spread over throughout boreal, temperate as well as most tropical regions of the world are represented by fungi well adapted to environmental fluctuations. This group of fungi evolved by developing various survival strategies and is able to cause serious damage to forest and urban ecosystems (e.g., some of the most feared wood destroying fungi able to kill living trees, decompose their wood structure and remain in soil living on root fragments for several decades until new seedlings are planted: *Armillaria mellea*, *A. tabescens*, *Heterobasidion annosum*, *Ganoderma* spp., etc.), some other wood fungi spread over wood surfaces poor in moisture content [dry-rot fungi: e.g., *Serpula lacrymans*, *S. himantioides* (Fr.) P. Karst., *Coniophora puteana*, *Fibroporia vaillantii*, etc.] causing serious damage to material used in construction or wood made historical artifacts. In terms of disease control the most reliable strategy remains prevention by implementing detailed analyses and careful choice when planting new tree species or adopting "healthy" pruning habits, though when infection is observed correct fungus identification by observing both mycelia of fruitbody characters and tree disease symptoms are necessary followed by disease spreading control strategies. Making people aware of the ecological and economical impact correlated to such dangerous wood fungi species probably would ensure a higher degree of prevention, tree disease control and focus on adopting stronger regulations for dispersal of alien aggressive pathogenic species throughout borders. Another aspect refers to directing research towards finding practical solutions including eco-friendly biological control and not only by adopting the "chemical" approach as already experimented.

Regarding timber fungi, close attention is needed when selecting wood type for construction purposes. For example, *Cinnamomum osmophloeum* is one of the hardwood species known to show significant antifungal activity. However, on the first hand knowledge is a key factor in the selection of proper wood material. By taking into account wood preference of indoor dry-rot causing fungi or causes leading to their presence in an indoor environment combined with a careful selection of wood type used for construction seems to be a good prevention strategy.

Applied biotechnology uses wood-decaying fungi in many processes, mainly involving pharmacy, industry, environmental protection and cultivation. Therapeutically valuable by-products are increasingly demanded across the world, while enzymes resulted from wood-decaying fungi are widely required for diverse industrial applications. Medicinal wood-decaying fungi play a significant role in human health, demonstrating an increased scientific and public interest materialized through several thousands of publications worldwide; however, it is still unclear what type of extract is more potent to cure various diseases. This point is also supported by Wasser (2010) listing some other important unsolved issues of medicinal science including: the role of polysaccharide-protein or

polysaccharide-peptide complexes in pharmacological activity of medicinal mushrooms; the development of new methods and processes in the study of medicinal mushrooms; high quality, long-term, double blinded, placebo-controlled studies with large trial populations; more attention must be paid to research on farm animals and medicinal mushrooms; and protection of intellectual properties of medicinal mushrooms' genetic resources for invention and innovation.

Some of the most important wood-decaying fungal species and their potential in biotechnology as a current research interest are oriented towards mycoremediation including bioconversion of agricultural wastes into eco-friendly valuable products, and the use of wood-inhabiting fungi in bioremediation of organo-pollutants, industrial contaminants or polyethylene degradation. Because such applications are strongly correlated to enzymatic activity of wood fungi, special attention is paid on how to increase enzyme production in various wood-inhabiting fungal species. We need to understand that the concept "everything is strain related" is strongly connected not only to quality and quantity of enzyme production but it is a powerful feature that is generally used in biotechnological companies and mushroom growing farms. Studies on nutrient requirements of some substrates for enhanced growth of some fungal species are still needed—such studies have value for industrial applications.

We will here briefly underline some important issues in cultivation of fungi.

1. Bioconversion of agricultural wastes should be a concept highly appreciated especially in poor and developing countries; however, there is a lack of knowledge on how this may be done. Therefore, we need to bring this knowledge and make it available to public, so that they can learn and change their habits of burning agricultural wastes or disposing unnecessary paper that represent a valuable source of protein and with a possible powerful local economic impact.
2. More attention must be paid to developing methods and encouraging fungi cultivation as an easy procedure without misleading the general public that this can be done only in highly equipped facilities. This is a significant step especially necessary in poor and developing countries.
3. A serious concern for public health is represented by the fact that the public is still unaware of the heavy metals accumulation potential and other undesirable pollutants in some fungal species. According to this, farmers should avoid usage of chemical substances in the cultivation process. Some books published 20–30 years ago still give instructions on how to cultivate mushrooms by using formaldehyde (currently known as a carcinogenic substance) in order to avoid contamination

during fungi cultivation and obtain higher yields and of course profits. Infact professional cultivators are encouraging the use of chemicals in mushroom cultivation. Therefore, making knowledge available for the public interested in mushroom cultivation is necessary.

4. Most publications on fungi cultivation are focused on commonly known cultivated species and little attention is paid to the harder to cultivate fungi (e.g., *Morchella* sp., or *Grifola frondosa*). New experiments should be employed in order to find easier ways to cultivate and obtain high biological efficiencies in the cultivation of such fungi.
5. Some cost effective mushroom growing methods are still missing for some commonly cultivated fungi: in the US widely vehiculated are the hydrated lime treatment method of substrate used for growing oyster mushrooms versus pasteurization of substrate. Which one is best over the other and for what type of fungi the hydrated lime method works?
6. Less information is available related to the phenomenon known as “fungal strain senescence”. Some mushroom growers believe in this concept while others are rather passive when hearing about it. What are the factors involved producing strain senescence and how they can be observed at chemical and molecular level for most cultivated fungi and what strategies should be implemented to overcome this phenomenon? These are questions that interests mushroom growers and are still without a clear answer.
7. Not enough information is present on fungal strain preferences for cultivation; therefore mushroom growers are often puzzled when purchasing fungal strains from various fungal culture banks. Scientific studies on some noteworthy strains would help many growers in choosing what’s best for them.

This chapter embodies the biodiversity aspects of wood-inhabiting fungi and is dedicated to the memory of Prof. E. Parmasto (1928–2012), a great mycologist.

References

- Aisenstadt, M.A. and Bogolytzin, K.G. 2009. A peroxidase-dependent oxidation of lignin and its model substances. *Chem. Pl. Mater.*, 2: 5–18 (in Russian).
- Andersson, L., Alexeeva, N. and Kuznetsova, E. 2009. Revealing and investigation of biologically important forests in North-West Russia. T. 2. Guide to species identification. St Petersburg, Pobeda, pp. 139–217.
- Arefiev, S.P. 2010. A system analysis of biota of xylotrophic fungi. Nauka, Novosibirsk., 260 pp. (in Russian).
- Aro, N., Pakula, T. and Penttilä, M. 2005. Transcriptional regulation of plant cell degradation by filamentous fungi. *FEMS Microbiol. Rev.*, 29: 719–739.
- Bandoni, R.J. 1961. The genus *Naematelia*. *Am. Midland Nat.*, 66: 319–328.

- Bandoni, R.J. 1987. Taxonomic overview of the Tremellales. *Stud. Mycol.*, 30: 87–110.
- Binder, M. and Hibbett, D.S. 2006. Molecular systematics and biological diversification in Boletales. *Mycologia*, 98: 917–925.
- Bon, M. 1981. *Lactarietum lacunarum*, nouvelle association fongique des lieux inondables. *Docum. Mycol.*, 11: 19–28.
- Bon, M. 1991. Les tricholomes et ressemblants (Tricholomoideae et Leucopaxilloideae). Genres: *Tricholoma*, *Tricholomopsis*, *Callistosporium*, *Porpoloma*, *Floccularia*, *Leucopaxillus* et *Melanoleuca*. *Fl. Mycol. Eur.*, 2: 1–163.
- Bondartsev, A.S. 1956. A guide to the house fungi. Academy of Sciences, Leningrad., 80 pp. (in Russian).
- Bondartsev, A.S. 1971. The Polyporaceae of the European USSR and Caucasia. Israel Program for scientific translations, Jerusalem, 896 pp.
- Bondartseva, M.A. 1998. The handbook on fungi of Russia. Order Aphyllophorales. Ser. 2. 391 pp.
- Bondartseva, M.A. 2001. Strategies of adaptation and functions of aphyllophoroid basidiomycetes in forest ecosystems. Kuprevich's lectures. III. Minsk., pp. 5–49.
- Buchanan, P.K. and Ryvarden, L. 2000. An annotated checklist of polypore and polypore-like fungi recorded from New Zealand. *N.Z. J. Bot.*, 38: 265–323.
- Bujakiewicz, A. 1992. Macrofungi on soil in deciduous forests. Handbook of vegetation science founded by R. Tüxen. Vol. 19/1. Fungi in vegetation science. Dordrecht, pp. 49–78.
- Burdshall, H.H. and Banik, M.T. 2001. The genus *Laetiporus* in North America. *Harvard Papers in Botany*, 6: 43–55.
- Chadefaud, M. 1950. Les Psilotinées et l'évolution des Archégoniates. *Bull. Soc. Bot. France*, 97: 99–100.
- Chamuris, G.P. 1988. The non-stipitate stereoid fungi in the Northern United States and adjacent Canada. *Mycol. Mem.*, 14: 1–247.
- Chen, D.M., Taylor, A.F.S., Burke, R.M. and Cairney, W.G. 2001. Identification of genes for lignin peroxidases and manganese peroxidases in ectomycorrhizal fungi. *New Phytol.*, 152: 151–158.
- Church, A.H. 1919. Thalassiphyta and the subaerial transmigration. *Bot. Mem.*, 3: 1–95.
- Cooke, R.C. and Whipps, J.M. 1980. The evolution of modes of nutrition in fungi parasitic on terrestrial plants. *Biol. Rev.*, 55: 341–362.
- Cowling, E.G. 1961. Comparative biochemistry of the decay of sweetgum sapwood by white-rot and brown-rot fungi. *US Dept. Agric. Tech. Bull.*, 258: 1–75.
- D'Souza, T.M., Boominathan, K. and Reddy, C.A. 1996. Isolation of laccase gene-specific sequences from white-rot and brown-rot fungi by PCR. *Appl. Environ. Microbiol.*, 62: 3739–3744.
- Darimont, F. 1973. Recherches mycosociologiques dans les forêts de Haute Belgique. *Inst. Roy. Sci. Nat. Belg. Mem.*, 170: 1–220.
- David, A. and Rajchenberg, M. 1985. Pore fungi from French Antilles and Guiana. *Mycotaxon*, 22: 285–325.
- Davydkina, T.A. 1980. Stereaceous fungi of Soviet Union. *Nauka, Leningrad.*, 143 pp. (in Russian).
- Dennis, R.W.G. 1978. *British Ascomycetes*. J. Cramer, Vaduz.
- Dighton, J., White, J.F. and Oudemans, P. (eds). 2005. *The fungal community. Its organization and role in the ecosystem*. Third edition. Taylor & Francis, L.; N.Y.; Singapore., 936 pp.
- Domański, S. 1988. Mała flora grzybów. Basidiomycetes (Podstawczaki). *Aphyllophorales* (Bezblaszkowce). 5. Corticiaceae: *Acanthobasidium-Irpicodon*. PWN, Warszawa-Krakow., 427 pp. (in Polish).
- Domański, S. 1991. Mała flora grzybów. I. Basidiomycetes (Podstawczaki). *Aphyllophorales* (Bezblaszkowce). *Stephanosporales* (Stefanosporowce). 6. Corticiaceae: *Kavinia-Rogersella*, *Stephanosporaceae: Lindtneria*. PWN, Warszawa-Krakow., 272 pp. (in Polish).

- Domański, S. 1992. Mała flora grzybów. I. Basidiomycetes (Podstawczaki). Aphyllophorales (Bezblaszkowce). 7. Corticiaceae: *Sarcodontia-Ypsilonidium*, *Christiansenia* and *Sygygospora*. W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow., 258 pp. (in Polish).
- Eriksson, J. and Ryvarden, L. 1973. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 2: *Aleurodiscus-Confertobasidium*. Fungiflora, Oslo., pp. 60–261.
- Eriksson, J. and Ryvarden, L. 1975. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 3: *Coronidium-Hyphoderma*. Fungiflora, Oslo., pp. 287–546.
- Eriksson, J. and Ryvarden, L. 1976. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 4: *Hyphodermella-Mycoacia*. Fungiflora, Oslo., pp. 549–886.
- Eriksson, J., Hjortstam, K. and Ryvarden, L. 1978. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 5: *Mycoaciella-Phanerochaete*. Fungiflora, Oslo., pp. 889–1047.
- Eriksson, K.E., Grunwald, A., Nilsson, T. and Vallander, L. 1980. A scanning electron microscopy study of the growth and attack on wood of three white-rot fungi and their cellulase-less mutants. *Holzforschung*, 34: 207–213.
- Eriksson, J., Hjortstam, K. and Ryvarden, L. 1981. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 6: *Phlebia-Sarcodontia*. Oslo: Fungiflora., pp. 1051–1276.
- Eriksson, J., Hjortstam, K. and Ryvarden, L. 1984. The Corticiaceae of North Europe/With drawings by John Eriksson. Vol. 7: *Schizopora-Suillosporium*. Fungiflora, Oslo., pp. 1281–1449.
- Eriksson, K.E., Blanchette, R.A. and Ander, P. 1990. Microbial and enzymatic degradation of wood components. Springer, Berlin-Heidelberg-N.Y., 407 pp.
- Erland, S. and Taylor, A.F.S. 1999. Resupinate ectomycorrhizal fungal genera. pp. 347–363. *In*: Ectomycorrhizal Fungi: Key Genera in Profile. Springer Verl., Heidelberg.
- Ershov, R.V. and Ezhov, O.N. 2009. Aphylloporoid fungi of aspen on North-West of Russian Plain. *Arkhangelsk*, 123 pp. (in Russian).
- Ezhov, O.N., Ershov, R.V., Ruokolainen, A.V. and Zmitrovich, I.V. 2011. Aphylloporaceous fungi of Pinega Reserve. *Arkhangelsk*, 147 pp. (in Russian).
- Fidalgo, O. and Fidalgo, M.E.P.K. 1966. Polyporaceae from Trinidad and Tobago. *Mycologia*, 58: 862–904.
- Fidalgo, O. and Fidalgo, M.E.P.K. 1968. Polyporaceae from Venezuele. 1. *Mem. N.Y. Bot. Gdn.*, 17: 1–34.
- Gamauf, C., Metz, B. and Seiboth, B. 2007. Degradation of plant cell wall polymers by fungi. pp. 325–340. *In*: Esser, K. (ed.). *The Mycota. A comprehensive treatise of fungi as experimental systems for basic and applied research. Environmental and microbial relationships*. 2nd ed. Springer, Heidelberg.
- Ghobad-Nejhad, M. and Kotiranta, H. 2008. The genus *Inonotus* sensu lato in Iran, with keys to *Inocutis* and *Mensularia* worldwide. *Ann. Bot. Fennici*, 45: 465–476.
- Ghobad-Nejhad, M. 2011. Updated checklist of corticioid and poroid basidiomycetes of the Caucasus region. *Mycotaxon*, 117: 1–70.
- Gilbert, G.S. and Sousa, P. 2002. Host specialization among wood-decay polypore fungi in a Caribbean mangrove forest. *Biotropica*, 34: 396–404.
- Gilbert, G.S., Gorospe, J. and Ryvarden, L. 2008. Host and habitat preferences of polypore fungi in Micronesian tropical flooded forests. *Mycological Research*, 112: 674–680.
- Gilbertson, R.L. 1980. Wood-rotting fungi of North America. *Mycologia*, 72: 1–49.
- Gilbertson, R.L. and Ryvarden, L. 1986. North American polypores. Vol. 1. Fungiflora, Oslo., pp. 1–436.
- Gilbertson, R.L. and Ryvarden, L. 1987. North American polypores. Vol. 2. Fungiflora, Oslo., pp. 437–885.
- Giñas, J. 1998. How many species are there? *Folia cryptogamica Estonica*, 33: 29–33.
- González García, V., Portal Onco, M.A. and Rubio Susan, V. 2006. Review. Biology and systematics of the form genus *Rhizoctonia*. *Spanish J. Agricultural Res.*, 4: 55–79.

- Gottlieb, A.M., Wright, J.E. and Moncalvo, J.-M. 2002. *Inonotus* s. l. in Argentina—morphology, cultural characters and molecular analyses. *Mycological Progress*, 1: 299–313.
- Hansen, L. and Knudsen, H. (eds.). 1997. Nordic macromycetes. Vol. 3: heterobasidioid, aphyllorphoroid and gastromycetoid Basidiomycetes. Copenhagen: Nordsvamp, 445 pp.
- Hansen, L. and Knudsen, H. (eds.). 2000. Nordic macromycetes. Vol. 1: Ascomycetes. Copenhagen: Nordsvamp, 309 pp.
- Härkönen, M., Niemelä, T. and Mwasumbi, L. 2003. Tanzanian mushrooms. Edible, harmful and other fungi. Helsinki., 200 pp.
- Heal, O.W. and Dighton, J. 1985. Resource quality and trophic structure of soil system. pp. 339–354. *In*: Fitter, A.H., Atkinson, D., Read, D.J. and Usher, M.B. (eds.). *Ecological Interactions in Soil*. Blackwell, Oxford.
- Hibbett, D.S., Binder M. and Bischoff J.F. 2007. A higher-level phylogenetic classification of the Fungi. *Mycological Research*, 111: 509–547.
- Hibbett, D.S. and Donoghue, M.J. 1995. Progress toward a phylogenetic classification of the Polyporaceae through parsimony analysis of mitochondrial ribosomal DNA-sequences // *Can. J. Bot.*, 73: S853–S861.
- Hood, I. 2003. An introduction to fungi on wood in Queensland. University of New England School of Environmental Sciences and Natural Resources Management, Armidale., 388 pp.
- Imazeki, R., Otani, Y. and Hongo, T. 1988. *Nihon no Kinoko* [Fungi of Japan]. Tokyo, 623 pp.
- Isikov, V.P. and Konoplya, N.I. 2004. *Dendromycology*. Alma Mater, Lugansk., 347 pp. (in Russian).
- Jahn, H. 1966. Pilzgesellschaften an *Populus tremula*. *Z. Pilzk.*, 32: 26–42.
- Jahn, H. 1968. Das *Bisporium antennatae*, eine Pilzgesellschaft auf den Schnittflächen von Buchenholz. *Westf. Pilzbr.*, 7: 41–47.
- Jahn, H. 1986. Der “Stanspilzhang” bei Glesse (Ottenstein), Süd-Niedersachsen Zur Pilzvegetation des Seggen-Hangbuchenwaldes (Carici-Fagetum) im Weserbergland und außerhalb. *Pilzbriefe*, 10/11: 289–351.
- James, T.Y., Kauf, F., Schoch, C.L. 2006. Reconstructing the early evolution of fungi using a six-gene phylogeny. *Nature*, 443: 818–822.
- Jing, H.U.I., Wenjing, Z. and Zhiyan, Z. 2007. Changes in extracellular enzyme activities during submerged culture of *Tremella aurantialba*. *Acta Edulis Fungi*, 14: 33–36.
- Jülich, W. 1972. Monographie der Athelieae (Corticaceae, Basidiomycetes). *Willdenowia Beih.*, 7: 1–283.
- Jülich, W. and Stalpers, J.A. 1980. The resupinate non-poroid Aphyllorphorales of the Northern Hemisphere. *North-Holland Pub. Comp.*, Amst.; Oxf.; N.Y., 335 pp.
- Jülich, W. 1984. Die Nichtblätterpilze, Gallertpilze und Bauchpilze. Aphyllorphorales, Heterobasidiomycetes, Gastromycetes. *Gustav Fischer, Jena*: 626 S.
- Karatygin, I.V. 1993. Coevolution of Fungi and Plants. *St Petersburg*, 118 pp. (in Russian).
- Kirk, P.M., Cannon, P.F., David, J.C. and Stalpers, J.A. 2001. *Ainsworth and Bisby's Dictionary of the Fungi*. 9th edition. Oxford Univ. Press, N.Y. etc., 672 pp.
- Kirk, T.K. 1983. Degradation and conversion of lignocelluloses. pp. 266–295. *In*: Smith, J.E. et al. (ed.). *The Filamentous fungi*. Vol. 4. Fungal technology. E. Arnold, London.
- Knudsen, H. and Vestrholt, J. (eds.). 2008. *Funga Nordica: New edition of “Nordic macromycetes, volume 2”*. Copenhagen: Nordsvamp, 968 pp.
- Koenigs, J.W. 1972. Effects of Hydrogen peroxidase on cellulose and on its susceptibility to cellulose. *Mater. Organismen*, 7: 133–147.
- Kotiranta, H. and Niemelä, T. 1993. Uhanalaiset käävät Suomessa (Threatened polypores in Finland)—Vesi-ja ympäristöhallinnon julkaisuja, sarja B 17: 1–116. Painatuskeskus, Helsinki.
- Larsen, M. and Cobb-Poulsen, L.A. 1990. *Phellinus* (Hymenochaetaceae). A survey of the world taxa. *Synopsis Fungorum*, 3: 1–206.

- Larsson, K.-H., Parmasto, E., Fischer, M., Langer, E., Nakasone, K.K. and Redhead, S.A. 2006. Hymenochaetales: a molecular phylogeny for the hymenochaetoid clade. *Mycologia*, 98: 926–936.
- Lindgren, M. 2001. Polypores (Basidiomycetes) species richness and community structure in natural boreal forest of NW Russian Karelia and adjacent areas in Finland. *Acta Bot. Fennica*, 170: 1–41.
- Malysheva, V.F. and Malysheva, E.F. 2008. The higher basidiomycetes in forest and grassland communities of Zhiguli. St Petersburg, 242 pp. (in Russian).
- Manskaya, S.M. and Kodina, L.A. 1975. Geochemistry of lignin. Nauka, Moscow, 229 pp. (in Russian).
- Miettinen, O., Niemelä, T. and Spirin, W. 2006. Northern *Antrodiella* species, the identity of *A. semisupina*, and type studies of related taxa. *Mycotaxon*, 96: 211–239.
- Miettinen, O. and Larsson, K.-H. 2011. *Sidera*, a new genus in Hymenochaetales with poroid and hydroid species. *Mycological Progress*, 10: 131–141.
- Nakasone, K.K. and Gilbertson, R.L. 1978. Cultural and other studies of fungi that decay Ocotillo in Arizona. *Mycologia*, 70(2): 266–299.
- Nobles, M.K. 1958. Cultural characters as a guide to the taxonomy and phylogeny of the Polyporaceae. *Can. J. Bot.*, 36: 883–926.
- Núñez, M. and Ryvarde, L. 2001. East Asian polypores. Vol. 2. *Fungiflora*, Oslo., pp. 170–522.
- Olive, L.S. 1946. New or rare Heterobasidiomycetes from North Carolina 2. *J. Elisha Mitchell Sci. Soc.*, 62: 65–71.
- Parmasto, E. 1986. Preliminary list of vietnamense Aphyllophorales and Polyporaceae s. str. *Scripta Mycol.*, 14: 1–88.
- Parmasto, E. 1998. *Athelia arachnoidea*, a lichenicolous basidiomycete in Estonia. *Folia Cryptogamica Estonica*, 32: 63–66.
- Pirk, W. 1952. Die Pilzesellschaften der Baumweiden im mittleren Wesertal. *Mitt. Flor.-Soz. Arbeit. N.F.*, 3: 93–96.
- Pirozynski, K.A. 1983. Pacific Mycogeography: an appraisal. *Aust. J. Bot. Suppl.*, 10: 137–159.
- Polizeli, M.L., Rizzatti, A.C., Monti, R., Terenzai, H.F., Jorge, J.A. and Amorim, D.S. 2005. Xylanases from fungi: properties and industrial applications. *Appl. Microbiol. Biotechnol.*, 67: 577–591.
- Rabinovich, M.L., Bolobova, A.V. and Kondrashchenko, V.I. 2001. Theoretical bases for biotechnology of wood composites. Book 1: Wood and wood-destroying fungi. Nauka, Moscow, 264 pp. (in Russian).
- Ragan, M.A. and Chapman, D.J. 1978. Biochemical phylogeny of the protists. N.Y., 127 pp.
- Rajchenberg, M. 1989. Polyporaceae (Aphyllophorales, Basidiomycetes) from Southern South America: a mycogeographical view. *Sydowia*, 41: 277–291.
- Renvall, P. 1995. Community structure and dynamics of wood-rotting Basidiomycetes on decomposing conifer trunks in northern Finland. *Karstenia*, 35: 1–51.
- Ricek, E.W. 1967. Untersuchungen über die Vegetation auf Baumstümpfen 1. *Jahrb. Obst Mus.*, 112: 185–252.
- Richard, B. 2000. Les mycocoenoses des pelouses calcicoles du Barrois lorrain. Analyse inventoriale, patrimoniale et conservatoire. These pour obtenir le Diplôme d'Etat de Docteur en Pharmacie. Univ. H. Poincaré, Nancy., 65 pp.
- Roy, A. and De, A.B. 1996. Polyporaceae of India. R.P. Singh Gahlot, Dahra Dun., 287 pp.
- Ryvarden, L. and Johansen, I. 1980. A preliminary polypore flora of East Africa. *Fungiflora*, Oslo, 225 pp.
- Ryvarden, L. and Gilbertson, R.L. 1993. European polypores. Part 1. *Abortiporus-Lindtneria*. *Fungiflora*, Oslo., pp. 1–387.
- Ryvarden, L. and Gilbertson, R.L. 1994. European polypores. Part 2. *Meripilus-Tyromyces*. *Fungiflora*: Oslo., pp. 388–743.

- Schmidt, O. 2006. Wood and tree fungi. Biology, damage, protection, and use. Springer, Berlin-Heidelberg-N. Y., 334 pp.
- Sinadsky, Yu.V. 1983. Pine: their diseases and destroyers. Moscow, 335 pp. (in Russian).
- Šmarda, F. 1972. Pilzgesellschaften einiger Laubwälder Mährens. Acta Sc. Nat. Brno, 6: 1–53.
- Šmarda, F. 1973. Die Pilzgesellschaften einiger Fichtenwälder Mährens. Acta. Nat. Acad.
- Smirnova, O.V. (ed.). 2004. East European forests: Holocene history and modern state. Nauka, Moscow, 479 pp. (in Russian).
- Spirin, W.A. 2002. Aphyllphoraceous fungi of Nizhegorod Region: species composition and ecological peculiarities. Thesis. St Petersburg, 242 pp. (in Russian).
- Spirin, W.A., Zmitrovich, I.V. and Malysheva, V.F. 2006. On the systematics of *Inonotus* s.l. and *Phellinus* s.l. (Mucronoporaceae, Hymenochaetales). Nov. Syst. Pl. non Vasc., 40: 153–188 (in Russian).
- Strid, A. 1975. Wood-inhabiting fungi of alder forests in North-Central Scandinavia 1. Aphyllphorales (Basidiomycetes). Taxonomy, ecology and distribution. University of Umea, Umea, 237 pp.
- Stubblefield, S.P., Taylor, T.N. and Beck, C.B. 1985. Studies of Paleozoic fungi. V. Wood-decaying fungi in *Callixylon newberryi* from the Upper Devonian. Am. J. Bot., 72: 1165–1174.
- Takhtajan, A.L. 1950. Phylogenetic bases of vascular plants system. Botanical Journal, 13: 135–139.
- Teng, S.C. 1996. Fungi of China. Ithaka: Mycotaxon Ltd., pp. 1–586.
- Torkelsen, A.-E. 1997. Tremellaceae Fr. pp. 86–90. In: Hansen, L. and Knudsen, H. (eds.). Nordic macromycetes 3. Heterobasidioid, aphyllphoroid and gastromycetoid Basidiomycetes. Nordsvamp, Copenhagen.
- Țura, D., Zmitrovich, I.V., Wasser, S.P., Spirin, W.A. and Nevo, E. 2011. Biodiversity of Heterobasidiomycetes and non-gilled Hymenomycetes (former Aphyllphorales) of Israel. A.R.A. Gantner Verlag K.-G., Ruggell, 566 pp.
- Vasilyeva, L.N. and Stephenson, S.L. 2010. Biogeographical patterns in pyrenomycetous fungi and their taxonomy. 1. The Grayan disjunction. Mycotaxon, 114: P. 281–303.
- Wright, J.E. and Deschamps, J.R. 1972. Basidiomycetes xilofilos de los Bosques Andinopatagonicos. Rev. Invest. Agrop. INTA, 9: 111–195.
- Wright, J.E. and Deschamps, J.R. 1975. Basidiomycetes xilofilos de la region mesopotamica. II. Los generos *Daedalea*, *Fomitopsis*, *Heteroporus*, *Laetiporus*, *Nigroporus*, *Rigidoporus*, *Perenniporia* and *Vanderbylia*. Rev. Invest. Agrop. INTA, 12: 127–204.
- Wright, J.E. 1985. Los hongos xilofagos: una revista. Anal. Acad. Nac. Cs. Ex. Fis. Nat., Buenos Aires, 37: 121–135.
- Wu, S.H. 1990. The Corticiaceae (Basidiomycetes) subfamilies Phlebioideae, Phanerochaetoideae and Hyphodermoideae in Taiwan. Acta Bot. Fennica, 142: 1–123.
- Yurchenko, E.O. 2001. Corticioid fungi on mosses in Belarus. Mycena, 1: 71–91.
- Yurchenko, E.O. and Zmitrovich, I.V. 2001. Variability of *Hyphoderma setigerum* (Corticiaceae s. l., Basidiomycetes) in Belarus and northwest Russia. Mycotaxon, 78: 423–434.
- Yurchenko, E.O. and Golubkov, V.V. 2003. The morphology, biology, and geography of a necrotrophic basidiomycete *Athelia arachnoidea* in Belarus. Mycological Progress, 2: 275–284.
- Yurchenko, E.O. 2006. Natural substrata for corticioid fungi. Acta Mycol., 41: 113–124.
- Zmitrovich, I.V., Malysheva, V.F. and Malysheva, E.F. 2003. Some concepts and terms of mycogeography: a critical review. Bulletin of Ecology, Forest management and Landscape management, 4: 173–188 (in Russian).
- Zmitrovich, I.V., Psurtseva, N.V. and Belova, N.V. 2007. Evolutionary-taxonomical aspects of search and research of lignotrophic fungi as active producers of oxidative enzymes. Mycol. Phytopathol., 41: 57–78 (in Russian).
- Zmitrovich, I.V. 2008. Definitorium fungorum Rossicum. Familia Atheliaceae et Amylocorticiaceae. KMK, Petropolis, 278 pp. (in Russian).

- Zmitrovich, I.V. 2010. Epimorphology and tectomorphology of higher fungi. *Folia Cryptogamica Petropolitana*, 5: 1–279.
- Zmitrovich, I.V. 2011. Middle taiga of Karelian Isthmus: zonal, intrazonal and extrazonal phenomena. *Bulletin of Ecology, Forest management and Landscape management*, 12: 54–76 (in Russian).
- Zmitrovich, I.V. 2012. Features of structure and dynamics of floodland gray alder forests in North-Western European Russia. *In: Human and North: Anthropology, Archaeology and ecology*. Tjumen', 425 pp. (in Russian).
- Zugmaier, W., Bauer, R. and Oberwinkler, F. 1994. Mycoparasitism of some *Tremella* species. *Mycologia*, 86: 49–56.