Identification, Names and Nomenclature
of Common Edible Mushrooms

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1. TAXONOMY IS FUNDAMENTAL TO MUSHROOM SCIENCE

Taxonomy is fundamental to biological science and is the basis of information exchange. Names are the key to all knowledge about a species. Increased taxonomic knowledge of edible mushrooms benefits research on cultivation technology and breeding. For example, an awareness of current taxonomy will help to focus breeding strategy, avoiding crosses between two apparent ‘species’ (strains bearing different names) that are taxonomically identical.

Name changes typically derive from improved scientific knowledge of an organism in comparison with related taxa. Other reasons for changes include the existence of an earlier name which has priority, the replacement of an incorrect name (e.g. a homonym), and misidentification. The literature on systematic mycology is extensive and diverse, and is likely to be consulted infrequently by applied mushroom researchers. Taxonomists have a responsibility to transfer important information on taxonomic reassessment to relevant users in a form that can be understood and applied. Name changes of fungi of economic importance are explained in a series of papers prepared by the International Commission on the Taxonomy of Fungi, although only one mushroom species, shiitake, has been treated (Cannon, 1986).

International conferences allow a multidisciplinary approach to mushroom science in which the contributions of taxonomists can be assimilated by applied scientists. This paper considers the species concept in the basidiomycete fungi, and reviews clarification and current usage of names for cultivated edible mushroom species of the seven most important genera (Chang, 1991). The genera are treated in order of total production. The lack of taxonomic consensus for names of certain species, and unresolved variability in other species is discussed.
2. THE SPECIES CONCEPT IN THE BASIDIOMYCETES

The application of fungal names is determined by means of permanently preserved type specimens, a foundation Principle of the governing International Code of Botanical Nomenclature (the Code) and the cornerstone of nomenclatural stability.

Morphology of the fungi fruit-body is the traditional basis for classification in fungi. Macroscopic features, in isolation, are rarely adequate to support taxonomic conclusions. Cap colour, for example, can vary considerably. Albinism has been reported in *Auricularia cornea*, *Lentinula edodes*, *Pleurotus ostreatus* and *P. salmoneostramineus*, arising spontaneously from mutation of a single recessive gene (Murakami & Takemaru. 1990). Microscopic feature – in particular of spores, sterile elements of the spore-bearing region, and hyphal arrangement-provide more reliable characters.

Intercompatibility studies (Boidin, 1986) have frequently resolved questions about morphological variability within a single ‘species’, and apparent similarities between ‘species’ which carry different names. Monokaryotic strains derived from single spores or by neohaploidisation of dikaryotic strains (e.g. Petersen, 1993) are mated. In species with clamp connections at septa of dikaryotic hyphae, Intercompatibility is judged by the presence of connections on stable mycelia of mated colonies. True ‘interfertility’, however, requires successful fruiting of the mated colony and determination of the viability of progeny (Boidin, 1986). Intercompatibility is frequently sufficient to infer species relationships, though possible misinterpretations, in particular resulting from use of too few strains, have been discussed by Boidin (1986). Intercompatibility studies assist taxonomists in determining whether collections should be regarded as representing different species or grouped into a single species. Partial Intercompatibility may indicate speciation in progress.

The biological species concept, based on genetic isolation between species, is widely accepted (Hallenberg, 1987). Hallenberg (1987) divided species (of corticioid basidiomycetes) into three groups: a majority of species with uniform morphology distinct from that of other species; a second group of ‘species complexes’ where species circumscription suggests than more than one biological species may be present, though these entities are not easily separated by morphology; and a third group where a species is considered to be morphologically uniform but interincompatible groups (cryptic or sibling species) are discovered among strains through Intercompatibility studies. Examples of the second and third groups among the edible mushrooms include the *Pleurotus ostreatus* ‘complex’, recently resolved, and the siblings of *Tremella fuciformis*, respectively. The nomenclatural treatment of siblings varies. Hallenberg (1978) is
followed here in requiring at least some distinguishing features of morphology, ecology or distribution before detected sibling entities receive Latin binomials.

3. NAMES OF COMMONLY CULTIVATED EDIBLE MUSHROOMS

3.1. Agaricus

The choice of name for the white button mushroom remains open to debate, following the reports of Malloch (1976) and Malloch et al. (1987) that *Agaricus bisporus* (Lange) Imbach, the basionym of which was described in 1926, is a synonym of the earlier name *A. brunnescens* Peck. described in 1900. Applying the principle of priority, the earlier name *A. brunnescens* is nomenclaturally correct. Neither name was originally applied to the cultivated mushroom (Malloch et al., 1987). Comparison of type material of the two names is unfortunately not possible since there is no extent holotype material of *A. bisporus*.

Singer (1984) compared fresh collections with the holotype of *A. brunnescens* and with published descriptions of *A. bisporus* and *A. brunnescens*, and concluded that the names refer to two distinct species separated by fine morphological differences including colour change in context tissue presence of 4-spored basidia in young fruit-bodies of *A. brunnescens*. Malloch al. (1987) reported that a fresh Canadian collection was both conspecific in morphology with the holotype of *A. brunnescens* and, on the evidence of mitochondrial and nuclear DNA restriction patterns, conspecific with cultivated Agaricus strains. While questioning validity of Single’s distinguishing characters. Kerrigan (1987) did not emphatically support synonymy. Rather, he suggested that synonymy be accepted as a ‘working hypothesis’ and that the name *A. bisporus* be considered for conservation has not yet been made.

The other important cultivated Agaricus species, *A. bitorquis* (Quel.) Sacc., is clearly separated from *A. bisporus/brunnescens* (Smith, 1978; Malloch et al., 1978). In addition to morphology, electrophoretic analysis of isozymes of extracellular laccases can reliably separate Agaricus species (Kerrigan & Ross, 1988).

3.2. Pleurotus

*Pleurotus* production increased over four-fold between 1986 and 1989/90 (Chang, 1991). The taxonomic confusion so apparent in the genus (Rajarathnam & Bano, 1987) may be due, in part, to the rapid development of cultivation of several species and the misapplication and misinterpretation of names of newly cultivated strains. Commercial strains may carry ambiguous or incorrect names, thus perpetuating early errors in
identification.

Only recently has significant taxonomic analysis brought necessary clarification. The genus is taxonomically difficult because of variability in fruit-body morphology in several species, resulting in species being described under more than one name, especially from different regions of the world. Through Intercompatibility studies, a number of apparently morphologically distinct taxa have been found to belong to a common biological species. Similarly, Intercompatibility studies have enabled discrimination of taxa for which distinguishing morphological characters were lacking or apparently inconsistently present in different geographic regions.

Other means of discriminating species of *Pleurotus* include electrophoretic analysis of enzymes (Magae *et al*., 1990), and differences in nuclear DNA content correlated with different chromosome number and ploidy (Bresinsky *et al*., 1987). Allozyme analyses of May & Royse (1988) suggest that a number of strains labelled *P. ostreatus* have been misidentified.

The following list cites epithets of commonly cultivated *Pleurotus* species, with references to synonymy and descriptions. Currently accepted names and in bold. Names followed an asterisk are discussed further.

*abalones* Han *et al.* - (Han *et al.* 1977; Hilber 1982).
*citrinopileatus* Singer = *P. cornucopiae* var. *citrinopileatus* (Singer) Ohira - (Hilber, 1982; Ohira, 1990; Petersen. 1993).
*cornucopiae* (Paul.) Roll. - (Hilber, 1982; Boekhout, 1990).
*djamor* (Fr.) Boedijn-(Corner 1981; Pegler 1986).
*eryngii*(DC.) Quel.- (Hilber, 1982; Partially inter-incompatible varieties or ecotypes-Hilber, 1982; Bresinsky *et al*., 1987; Boekhout. 1990).
*fossulatus* (Cooke) Sacc-(Pegler, 1976).
*Ostreatoroseus* Singer= *P. djamor* - (Petersen & Hughes. 1993).
sp. ‘florida’ *(unpublished and ambiguous name)=*P. ostreatus* and P. pulmonarius* - (Hilber, 1989).

sajo-caju*(Fr.) Singer (misapplied name)=Lentinus sajor-caju* (Fr.) Fr.- (Pegler. 1983; Hilber, 1989).


salmoneostramineus L. Vassilieva=P. djamor* - (Corner, 1981; Neda et al., 1988).

sapidus* (Schulz.)Sacc.= P. cornucopiae* - (Hilber, 1989).

spodoleucus Fr. = P. ostreatus* - (Magae et al., 1990).

squamulosus (Mont.) Singer= Lentinus squarrosulus* Mont.- (Pegler. 1977).

3.2.1. Pleurotus abalones and P. cystidiosus.

Both species have an anamorphic (asexual) fruiting phase characterised by production of coremia. Macro- and microscopic differences between the species and their geographical separation support distinction (Han et al., 1977; Hilber, 1989), even though monokaryons from each showed partial Intercompatibility (Hilber, 1982). Intercompatible crosses produced fertile fruit-bodies and viable spores (Bresinsky et al., 1987). The two species are considered to be distinct, the partial Intercompatibility suggestive of allopatric (geographically separated) speciation in progress.

3.2.2. Pleurotus cornucopiae.

This species, described from Europe, is characterised by pale cream to pale brown, funnel-shaped caps. *P. citrinopileatus* Singer, from eastern Asia, was separated from *P. cornucopiae* by its bright yellow caps, an often branched stipe, and smaller basidiospores. Corner (1981) reported specimens of the former as P. aff. cornucopiae. Ohira (1990) and Petersen & Hughes (1993) found complete Intercompatibility between monokaryotic strains of both species. Fruit-bodies produced from these crosses were yellow, and basidiospores, intermediate in size between those of the parents, were able to germinate (Ohira, 1990). In recognition of a single biological species containing morphologically and geographically separated variants, *P. citrinopileatus* was reduced to varietal status as *P. cornucopiae* var. citrinopileatus (Singer) Ohira.

3.2.3. Pleurotus djamor.

Corner (1981) divided this variable species into six varieties reflecting differences in cap and gill colour, form of stipe, and substrate. *P. salmoneostramineus* (as *P. incarnatus* Hongo) was considered to be a synonym of var. roseus, and this was confirmed by
Intercompatibility between strains of *P. djamor* and *P. salmoneosramineus* (Neda *et al*., 1988).

### 3.2.4. Pleurotus pulmonarius and *P. ostreatus*.

*P. pulmonarius* (grey oyster mushroom, phoenixtail mushroom) is arguably the species with the species with the most frequently misapplied name. It has been repeatedly confused with the morphologically similar *P. ostreatus*. *P. pulmonarius* is the correct name for some strains labelled *Pleurotus* sp. ‘florida’ and for others misidentified as *P. sajor-caju*.

Mycologists have differing opinions on the usefulness of morphological characters for discrimination of *P. pulmonarius* from *P. ostreatus*. Discriminating characters relevant for European collections (Hilber, 1982; Bresinsky *et al*., 1987; Boekhout, 1990) and Japanese collections (Ohira & Matsumoto, 1980) include:

- **P. pulmonarius** - pale coloured cap, smaller size (laterally cap < 10-13 cm), stipe typically more eccentric than lateral, fruiting in late spring to early autumn, sweet odour like anise, under humid conditions upper surface of cap glabrous, thinner pileipellis (40-50 &micro;m thick), and presence of sclerified hyphae.

- **P. ostreatus** - dark grey-brown cap (sometimes with blue tint), larger size (laterally cap usually 12-18 cm), stipe typically more lateral than eccentric, fruiting in autumn until early spring, fungoid odour, under humid conditions upper surface of cap pubescent-tomentose, thicker pileipellis (90-120 &micro;m thick), and usual absence of sclerified hyphae.

Petersen & Hughes (1993) reported that in North America the two species could not be separated by these characters. For example, North American *P. ostreatus* has tan to pale tan caps, and could be considered an allopatric ‘morphotaxon’ distinguishable morphologically from the European form.

The two species are, however, distinct genetically and are separate biological species. A complete barrier to hybridisation has been documented by several intercompatibility studies using single spore strains sourced from widely separated geographic regions, while intraspecific crosses within each species are uniformly intercompatible (Bresinsky *et al*., 1977, 1987; Hilber, 1982; Petersen & Hughes, 1993).

Exceptions noted were two strains of *P. pulmonarius* found to be completely intersterile with all other strains of *P. pulmonarius* (Bresinsky *et al*., 1987), possibly representative of an independent species, and partial intercompatibility between monokaryons of a strain of *P. pulmonarius* and one of *P. ostreatus* (Magae *et al*., 1990). A high similarity index was also reported by Magae *et al*. (1990) from enzyme analyses between the two species. While regarding the two taxa as variants of a single species, they acknowledged that further strains of *P. pulmonarius* should be studied before their
conclusion could be substantiated.

Both species lack a type specimen on which to base taxonomic decisions. For *P. pulmonarius*, Petersen & Hughes (1993) propose a ‘representative specimen’, to serve in the interim until a neotype can be designated. The neotype should be from the same host, Betula, and geographic area as was originally described for the species, and should be the source of single spore tester strains Intercompatible with the *P. pulmonarius* intersterility group. Typification of *P. ostreatus* has not yet been proposed.

3.2.5. *Pleurotus sajor-caju*.

This is a synonym of *Lentinus sajor-caju*, a very common species in tropical forests. The *Pleurotus* combination has been cited frequently in error in literature on cultivated mushrooms. Kurtzman & Zadrazil (1982) reported differences in morphology between published descriptions of the species (Corner, 1981;Pegler, 1983) and a commercially available cultivated strain labelled *P. sajor-caju* (ITCCF 1725=ATCC 32978). Several commercial strains labelled *P. sajor-caju* have proved to be misidentified and are Intercompatible with *P. pulmonarius* (Hiber, 1989). Another misidentification is suggested from the description of a synnematous anamorph from a strain of *P. sajor-caju* (Nair & Kaul 1980), probably based on either *P. cystidiosus* or *P. abalones* or a related species.

3.2.6. *Pleurotus sapidus*.

This is a synonym of *P. cornucopiae*. Usage of the name in North America has only recently been clarified (Hilber, 1989). Eugenio & Anderson (1968) reported a common decay fungus on hickory, sugar maple and American elm as *P. ostreatus*. Anderson et al. (1973), in error, redetermined this species as *P. sapidus*. Hiber (1989) found that Eugenio & Anderson’s material was Intercompatible with *P. ostreatus*. The fungus from aspen, which Anderson et al. (1973) mistakenly identified as *P. ostreatus*, is now distinguished as a new species, to be published as *P. populinus* (Hiber, 1989).

3.2.7. *Pleurotus sp. ‘florida’*.

Though never published nor intended as a binomial, the name appears frequently in literature on cultivated mushrooms. The origin and history of the name were reviewed by its originator, G. Eger, in Eger et al. ‘Florida’ strains were found to be compatible with *P. ostreatus* (Eger et al. 1979), while Bresinsky et al., (1977) had previously
reported intercompatibility with *P. pulmonarius*. These results were misinterpreted by Eger et al. (1979) to indicate that *P. pulmonarius* and *P. ostreatus* were conspecific. Bresinsky et al. (1987) and Hilber (1982) concluded that strains available under the name ‘florida’ represent two taxa, a majority being *P. ostreatus* and at least one strain being *P. pulmonarius*. Clearly, strains should not be designated ‘florida’ in future scientific literature. The unfortunate confusion surrounding this name has called into question several scientific results, e.g., Yoo et al. (1986), where interspecific hybrids were reported between *P. ostreatus* and ‘*P. florida’* Hilber (1989) noted that *P. floridanus* Singer is unrelated to the two species represented by *P. ‘florida’*.

### 3.3. Lentinula

*Lentinula*, sensu Pegler (1975), and *Lentinus*, sensu Singer (1986), are both currently used to accommodate the shiitake mushroom, as *Lentinula edodes* (Berk.) Pegler and *Lentinus edodes* (Berk.) Singer.

According to Pegler hyphal composition and gill form separate *Lentinula* from *Lentinus* and *Pleurotus*, both genera that have formerly accommodated shiitake. Hyphal composition of the fruit-body is an important taxonomic character for classification of polypore fungi, to which *Lentinus* and *Pleurotus* are related. Hyphae are not inflated and septa are not constricted. *Lentinula*, in contrast, in considered to belong in the agaric family Tricholomataceae (Pegler, 1975), with a monomitic hyphal system (one type of hypha) of inflated, thick-walled hyphae with constricted septa. The gills of *Lentinula* species do not extend down the stipe (non-decurrent), unlike those characteristic of species in the other two genera. Pegler (1972) separates *Lentinus* from *Pleurotus* on the basis of the former being dimitic and the latter monomitic.

Singer (1986) listed *Lentinula* as a synonym of *Lentinus*. He accepted both *Lentinus* and *Pleurotus* as including species with monomitic or dimitic hyphal systems, separated by differences including the structure of gill hyphae (trama) underlying the spore-bearing layer. Hyphal systems were considered by Singer to be useful to delimit sections within these two genera, but not the genera themselves.

Corner (1981) accepted *Lentinula*, while including within *Pleurotus* species with a monomitic or a dimitic hyphal system, thus blurring Pegler’s distinction between *Pleurotus* and *Lentinus*.

### 3.4. Auricularia

*auricular* (L.) Underwood – (Lowy, 1952).

*auricular-judae* (Bull.) Schrot = *A. auricular* - (Lowy, 1952).
cornea (Ehr.) Ehr. ex Endl. – (Wong & Wells, 1987).
fuscosuccinea (Mont.) Farl. – (Lowy, 1952).
polytricha (Mont.) Sacc. = A. cornea – (Wong & Wells, 1987).
tenuis (Lev.) Farl. = A. cornea - (Wong & Wells, 1987).

Morphological characters of basidiocarps, especially the nature of internal, hyphal, cross-sectional zones and hairs of the upper surface, were used as discriminating characters for species of Auriculara, the wood ear fungi (Lowy, 1951, 1952; Cheng & Tu, 1978; Quimio & de Guzman, 1982). Duncan (1982) reported that within a sample of 7 strains of A. polytricha, a strain from the U.S.A. was inter-incompatible with all others; among the latter group intercompatibility varied from complete to partial. Wong & Wells (1987) found that morphological variability in A. cornea, A. polytricha and A. tenuis prevented discrimination. Monokaryotic strains of these species from Hawaii were fully intercompatible, and basidiocarps arising from ‘interspecific’ cross conformed to A. polytricha (Wong & Wells, 1987). These authors concluded that described morphological distinctions between species were environmentally induced, and that the earliest name, A. cornea, should be adopted for A. polytricha and A. tenuis, and for an albino form (Wong, 1989). Formal synonymy, however, awaits designation of a neotype for A. cornea in the absence of available type material (Wong, 1989).

3.5. Volvariella

The cultivated paddy straw mushroom is widely accepted as Volvariella volvacea (Bull.: Fr.) Singer (Chang, 1978; Kurtzman & Chang-Ho, 1982), with the varietal name masseei Singer applicable to most strains grown in southeast Asia (Samarawira & Fernando, 1973; Singer & Harris, 1987). Orton (1986) questioned whether the cultivated fungus of Asia is conspecific with V. volvacea from the U.K., on the basis of reported differences in spore size. The genus lacks a recent monographic treatment. Further taxonomic comparison of the temperature and tropical species of Volvariella, using morphological, biochemical and genetic characters, would benefit clarification of species names.

3.6. Flammulina

Flammulina velutipes (Curt.: Fr.) Sing. (winter mushroom, enokitake) is a variable species. Bas (1983) distinguished from within the velutipes complex a new,
morphologically distinct European species, *F. fennae* Bas. Monokaryons of *F. velutipes* and *F. fennae* were inter-incompatible (Bas, 1983; Lamoure, 1989), and the two species have different enzyme activities (Klan & Baudisova, 1992). *F. velutipes* was itself divided into two macroscopically distinct varieties, *F. velutipes* var. lacteal (Quel.) Bas, and var. *velutipes*. Within the latter, distinguished two forms, forma longispora and forma *velutipes*, separated by different spore dimensions and periods of fruiting. Lamoure (1989) reported incomplete genetic isolation between monokaryons of the two forms, and inconclusive results in intercompatibility studies between var. lacteal and var. *velutipes*, indicating that speciation may be in progress. Monokaryons from two collections of var. lacteal were typically inter-incompatible (Lamoure 1989), supporting Bas’s (1983) suggestion that var. lacteal could also be divided into two forms.

Field strains of *F. velutipes* from Japan were reported to be intercompatible with strains from New Zealand, western and eastern U.S.A., the U.K., the Netherlands, and South Korea, but inter-incompatible with strains from boreal and Northern Hemisphere alpine regions (Yokoyama, 1991). The latter were considered to belong to a separate species, which differed from *F. velutipes* in having a lower optimal temperature for mycelial growth, a higher optimum for fructification and more rounded spores.

It is not clear from published literature available to me which of the varieties and forms of *F. velutipes* are represented among cultivated strains.

3.7. *Tremella*

While the name *Tremella fuciformis* Berk, is taxonomically well accepted, intraspecific differences have been recently documented. Fox & Wong (1990) found both homothallic and heterothallic from different geographic locations, and incomplete intercompatibility between some geographically separated heterothallic strains. These results were interpreted by Fox & Wong to suggest that *T. fuciformis* comprises either two morphological species, or else a single species in which homothallic forms have arisen through deletion of mating factors.

4. ‘LISTS OF NAMES IN CURRENT USE’, IMPROVING STABILITY OF NAMES?

Nomenclature of fungi is governed by the Principle, Rules and Recommendations of the Code, which provide order and stability through precise definition of requirements for valid publication of names and provisions by which names can be changed. Measures allowing for conservation and rejection of names are built into the Code to avoid name changes judged to be disadvantageous.
Criticism of the frequency to name changes and the resulting disruption and confusion caused, from both users of taxonomy and practitioners, has stimulated considerable recent debate towards improvement (Hawksworth, 1991). In 1989 the General Committee of the International Association for Plant Taxonomy established a committee to coordinate discussion and preparation of ‘Lists of Names in Current Use’ for all plant groups covered by the Code, beginning with the estimated 36,500 generic names. At the XVth International Botanical Congress (IBC) in Tokyo (August 1993) delegates will vote on the principle of such lists, the resulting necessary changes to the Code, and the procedure for production of lists.

Opinions among mycologists are strongly divided over the criteria for exclusion of name from the list, and the need for ‘protected status’ of listed names against those excluded. Protected status is a direct on Principle III of the Code: ‘The nomenclature of a taxonomic group is based upon priority of publication’. The ‘digging-up’ of old and forgotten names to replace names in current use is cited by Hawksworth (1991) as the main cause of nomenclatural change, hence justifying the diminution of the priority rules, but this view is contested by Korf (1991). In agreement with Korf, mushroom name changes discussed in this paper, with the exception in part of the debate surrounding Agaricus bisporus/brunnescens, have arisen from new knowledge of species enabling better discrimination and are reflected in the establishment of a more accurate and stable nomenclature. Such advances in systematic science are essential to improved understanding of fungi and their interrelationships, and should not in any way be limited by the proposed lists. It is generally agreed that the lists must cater for alternative taxonomies where such taxonomies are currently employed. Gams & Kuyper (1991) favour comprehensive computerised lists which include all typified fungal names, excluding only those names with insufficient description or lacking authentic type material. Any expectation among users that the lists will effectively freeze existing names is unwarranted (Anderson, 1991).

A draft list of the estimated 64,000 accepted fungal species names, coordinated from the International Mycological Institute, U.K., is expected to be completed during 1993, but will not be ready for formal adoption at the Tokyo IBC. Whether names on the list are given protected status or not, the list once vetted and approved will serve as a reference document to standardize spelling of names, authorship and place of publication. This will provide tangible benefits to all uses.

5. RECOMMENDATION

Authors in mushroom science are encouraged to obtain authoritative identification of mushroom strains before publication, and to use validly published species names.
Spawn suppliers are similarly encouraged to confirm identification of commercial stains, as used of incorrect and invalid names can enter and confuse the scientific literature. Culture strains should be deposited in an internationally recognized culture collection, ensuring long-term preservation and availability to other workers. The International holding facility for commercial strains of edible mushrooms, with the supplier retaining security of ownership.

Accuracy in the application of mushroom names will benefit mushroom science by reducing confusion and duplication of effort, and improving the reliability and reproducibility of published results.

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