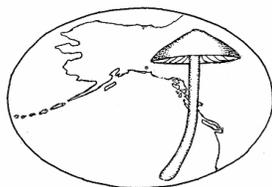


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***Cortinarius lucorum* (Fr.) Karst., a *Populus* associate from North America**

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Abstract: *Cortinarius lucorum* is reported from low-elevation forests in Washington where it associates with *Populus trichocarpa*. It shares affinities with *C. saturninus*, a species associated with *Salix*, *Populus*, *Corylus*, and perhaps other woody angiosperm hosts. Both species share a bulbous stipe, thick veil, and violaceous coloration in at least some part of the basidiomata. Analysis of nucleotide sequences of the internal transcribed spacer (ITS) region of the nuclear ribosomal RNA tandem repeat indicates a single base pair difference between North American and northern European material. These data also affirm the autonomy of *C. lucorum* and a possible sister relationship with *C. saturninus*.

Key Words: biodiversity, biogeography, Cortinariaceae, ITS, systematics, telamonia clade

Introduction: Several recent studies of *Cortinarius* (Pers.) S. F. Gray have revealed a number of new taxa and clarified the status of others in western North America.

Habitats in the western region are heterogeneous and diverse. Moser (2002), for instance, treated four new species of subgenus *Telamonia* (Fr.: Fr.) Trog from

coniferous forests in the Rocky Mountains; Moser and Ammirati (1997, 1999, 2000) proposed 18 new taxa in subgenus *Phlegmacium* (Fr.: Fr.) Trog, many of which are associated with *Quercus* in various western states; Cripps and Miller (1994) described a new *Cortinarius* in subgenus *Phlegmacium* from an Aspen (*Populus*) stand in Montana; and in other studies Moser and Ammirati (1996) confirmed that several miscellaneous European species of *Cortinarius* occur in the northern Cascades of Washington state and in the greater Yellowstone region of Wyoming (Moser, McKnight, and Ammirati 1995).

Recent documentation of agarics and allied fungi from low-elevation forested wetlands near Seattle, Washington has uncovered a new *Alnus*-associated species of *Cortinarius*—*C. helodes* M. Moser, Matheny & Daniele (Moser 2001) that also occurs in Wyoming and Argentina. A second *Cortinarius* species, *C. lucorum* (Fr.) Karst. from the same locality and with affinities to subgenus *Telamonia* is reported here. This species occurs along the periphery of a *Populus trichocarpa* (*Salicaceae*) stand mixed with the shrubs *Acer circinatum* and *Oemleria cerasiformis* (*Rosaceae*). It is characterized by its large size, bulbous stipe base, heavy veil, violet brown colors, and association with *Populus*. DNA sequences of the ITS region, including the 5.8S rRNA gene, were produced from two accessions of Washington material and compared with publicly available ITS sequences of *Cortinarius* to test their autonomy.

Materials and Methods: Colors of basidiomata were compared with plates of Kornerup and Wanscher (1967). For example, the charted sample 9C4 refers to plate 9, column C, and row 4. Color of spore deposits are based on Ridgway (1912) and indicated by (R). Sections of dried material were rehydrated in 3% KOH and observed under a light microscope. Photos of anatomical figures were taken with a Nikon coolpix 4300. Accessions referenced in this study are curated at the University of

Washington (WTU).

About 20 mg of dried tissue of basidiomata were ground in liquid nitrogen and suspended in extraction buffer provided by an E.Z.N.A. fungal DNA kit (Omega Bio-tek, Inc., PO Box 47310, Doraville, GA 30362, USA). The remainder of the DNA extraction followed that of the protocol supplied by the manufacturer except for the addition of RNase. PCR (polymerase chain reaction) was performed in 25 µl reactions following the protocol of Wang, Binder, and Hibbett (2002) using primers ITS1F and ITS4 (White et al. 1990; Gardes and Bruns 1993). The ITS1, 5.8S, and ITS2 regions of the nuclear ribosomal RNA tandem repeat have been widely used to reconstruct the phylogeny of *Cortinarius* (Liu, Rogers and Ammirati 1997; Seidl 2000; Høiland and Holst-Jensen 2000; Peintner et al. 2001; Peintner et al. 2003; Peintner, Moncalvo and Vilgalys 2004; Frøslev, Matheny, and Hibbett 2005; Garnica et al. 2005). After agarose gel confirmation, PCR products were cleaned with a QIAquick PCR purification kit (QIAGEN Inc., 28159 Avenue Stanford, Valencia, California 91355, USA) and incorporated with BigDye terminators using the ABI Prism cycle sequencing kit (Applied Biosystems, Foster City, California, USA). Sequencing primers included ITS1F, ITS4, and 5.8S. The 5.8S primer sequence can be found at <http://www.biology.duke.edu/fungi/mycolab/>. Pellet Paint (Novagen, Madison, Wisconsin, USA) was used to purify sequencing reactions that were run on an Applied Biosystems 377XL automated DNA sequencer. Resulting chromatograms were edited and compiled with Sequencher 4.1 (GeneCodes Corporation, Ann Arbor, Michigan). The two ITS sequences generated for this study are deposited at GenBank (accession numbers AY695793 and AY695794).

Using MacClade 4.0 (Maddison and Maddison 2000) the new sequences were aligned with sequences of matrix M988 (Peintner et al. 2001), which was

downloaded from TreeBASE (<http://www.treebase.org/treebase/>). Two European sequences of *Cortinarius lucorum* (UDB000681 from Sweden and UDB000744 from Norway) were downloaded from UNITE (<http://unite.zbi.ee/index.php3>), an ITS sequence database of ectomycorrhizal Basidiomycota and Ascomycota (Köljalg et al. 2005), and aligned to the data matrix. This alignment is available from the authors upon request. A neighbor-joining analysis in PAUP* (Swofford 2003), using the Kimura 2-parameter distance correction, was done to assess the phylogenetic placement of Washington material in a global context among 107 cortinarioid taxa. The global analysis suggested an affinity of *C. lucorum* with members of the *Telamonia* clade (Peintner et al. 2003). A subset of 20 closely related ITS sequences, including *C. lucorum* isolates and *C. keralensis* K. A Thomas et al. (Peintner et al. 2003) was then pruned and analyzed separately. For outgroup purposes, we used two taxa, *C. mucifluus* Fr. and *C. obtusus* (Fr.), which are positioned outside the *Telamonia* clade (Peintner et al. 2004).

The less inclusive data set of 20 taxa was then analyzed with Modeltest 3.06 (Posada and Crandall, 1998) to determine the model of evolution best-fit to the ITS data. The model and alignment were then analyzed under the Maximum Likelihood (ML) criterion (Swofford et al. 1996) in PAUP*. A total of 746 characters was included in the dataset, of which 146 were excluded due to alignment ambiguities. The final number of sites analyzed was 600. A total of 4312 rearrangements was tried, in which a single ML tree was retained (-ln = 2289.46743). 100 ML bootstraps (Felsenstein 1985) were performed to measure the confidence of internodes in the topology.

Results: *Cortinarius lucorum* is described and illustrated below.

Cortinarius lucorum (Fr.) Karst.,
Hattsvampar:366. 1879
Protologue: E. M. Fries, Epicr.: 294. 1838.
Figs. 1-6.

Pileus 1.0-2.0 cm diam when very young, expanding to 6.0-7.0 (-9.5) cm diam in age, hemispherical in button stages to broadly pulvinate, later parabolic then convex; margin incurved at first, later decurved, more or less even in extreme age; surface dry, glabrous at the center, appressed fibrillose streaked towards the margin, buttons with whitish cortinate veil material on margin, hygrophanous (Fig. 5), color when young vinaceous gray-brown (11E3) to brown (7E6) on disc, pallid towards the margin with vinaceous gray-brown (11E3) tones, or light brown or brown (6D6-E6) on disc and lighter towards the margin with vinaceous brown tones or radial streaks (10E3-9E3), in age disc near brownish orange (6C4) and margin light brown or gray brown (6D4), vinaceous streaks remaining evident; surface brownish with 3% KOH (no distinct change); context vinaceous or purplish (14E3) to dingy whitish with violet gray (14D2) tones when young, or dingy with grayish brown (6D3) tones (Figs. 3,6), firm, up to 11 mm thick under the disc, taste mild, fungoid and slightly bitterish, odor mild to more or less pungent or fungoid/raphanoid.

Lamellae close, adnate to ascending-adnate, purplish or magenta when young (14F5) becoming light brown (7D4) to brown (6D6-E7) in age, edges more or less even, up to 5-6 (-10) mm diam.

Stipe (2.0-) 6.0-7.0 (-14.0) cm long, 7-14 (-18) mm at the apex, terete above the bulbous base that is 14-25 (-35) mm broad (Figs. 3-5), surface dry, coated with silky-fibrillose whitish veil material when young, dingy pale brown below with a grayish vinaceous (12D3) tone beneath the white silky fibrils, fibrillose in age, color of stipe on mature specimens more or less dingy whitish with brownish orange (5C4) streaks and tones scattered the entire length; universal veil a peronate sheath around the bulbous base in younger specimens, thick; cortina white, heavy, collapsing near the apex becoming rust brown colored in age; context of young material with purplish apex

(14E3) but brownish at the base, in age context also brownish at the base but grayish vinaceous (12C2-10C2) with whitish areas elsewhere; base of stipe sometimes with rhizomorphs.

Basidiospores (8.1-) 8.9-11.1 (-13) × 5.2-6.8 (-8) μm, Q = 1.6 (n= 20 spores), mostly elliptical to broadly elliptical but shape somewhat variable (Figs. 1,6), apicular end distinctly pointed in some spores, suprahilar area evident in some spores (reduced size in ornamentation), spore color rich medium brown with distinct moderate- to coarser-sized ornamentation (verrucose to verruculose), at times coarser at the distal end. Spore deposit Prout's Brown (R) to Cinnamon Brown (R).

Basidia 4-spored, mostly 31.1-44.4 × 8.9-9.6 μm, clavate, thin-walled but in age occasionally with thickened, dark sterigmata, colorless or filled with refractive colorless to yellowish contents, or yellowish to brown-yellow pigment, often collapsed in age.

Lamellar edge fertile but in places with many short-clavate to clavate elements mostly 12-21 × 6-12 μm; many sterile cells present on young material, colorless to yellowish in age.

Lamellar trama more or less regular, of somewhat parallel to interwoven cylindrical to enlarged hyphae, more parallel and cylindrical adjacent to subhymenium, 3-9 (-13) μm diam in buttons, in mature sporocarps 4-23 μm diam, cells of hyphae mostly 25-85 μm long, colorless or sometimes yellowish brown, walls thin or slightly thickened, somewhat refractive.

Pileipellis composed of a more or less well developed layer (epicutis) of cylindrical, radial to more or less interwoven, or in some places more entangled and ascending hyphae (Figs. 2,5), mostly 2-7.4 μm wide, colorless or occasionally yellowish, rarely slightly encrusted, walls thin, more or less refractive, subgelatinous in places; subcutis

of cylindrical to enlarged hyphae mostly 5.2-20 μm wide, not distinctly cellular, but in places with a number of enlarged cells or subcellular, subtended by a distinctly pigmented layer. Pileus trama of cylindrical to inflated interwoven hyphae, mostly 5-22 μm, thin-walled, colorless to slightly pigmented, scattered refractive, pale yellowish brown oleiferous hyphae present. Pileus sections with a distinct brownish layer (area beneath subcutis) when sections mounted in KOH. Clamp connections present on hyphae and basidia.

Scattered to gregarious, not clustered, on soil in mixed, lowland forests under *Populus trichocarpa*, *Acer circinatum*, *Alnus rubra*, *Oemleria cerasiformis*, and *Acer macrophyllum* (the conifers *Thuja plicata*, *Tsuga heterophylla*, and *Pseudotsuga menziesii* also occur in the general vicinity), Hazel Wolf Wetlands, Sammamish plateau, near Issaquah, also Redmond, King County, Washington state, June and September to October.

Material examined: Norway: Østfold: Fredrikstad: T.E. Brandrud 150-79 (O 123350), leg. T.E. Brandrud, 1 Sept. 1979; Sogn og Fjordane: Sogndal, O 145977, leg. E. Johannesen, 8 Sept. 2000 (ITS sequence voucher). USA: Washington, King County, Hazel Wolf Wetlands, Sammamish plateau, near Issaquah: PBM 156, leg. P.B. Matheny, 20 Sept. 1996; same location: PBM 741 and PBM 742, leg. P.B. Matheny, 27 Sept. 1997; PBM 1182, leg. P.B. Matheny 24 Sept. 1998; JFA 13094, leg. J.F. Ammirati, 16 Sept. 2004; JFA 13096, leg. J.F. Ammirati, 23 Sept. 2004; JFA 13099, leg. J.F. Ammirati, 17 Oct. 2004. Redmond Watershed Preserve, Redmond, JN 6-28-2005-3, leg. J. Nance, 28 June 2005.

Remarks: *Cortinarius lucorum* from western Washington fits well the description of *C. lucorum* given in Brandrud et al. (1995). It is most similar in appearance to *C. saturninus* (Fr.) Fr. *sensu* Brandrud et al. (1995). It differs from the latter by its larger

basidiospores, purplish to magenta lamellae when young, and more violaceous colors of the sporocarps overall when fresh. However, Brandrud et al. (1995) state that the extent of the development of violaceous color in *C. saturninus* is variable. Moser (1978) allows for violaceous colors in the lamellae and stipe of *C. saturninus* as do Moënné-Loccoz and Reumaux (1990). The spores from a collection of *C. saturninus* (JFA 12537 at WTU) collected in beech (*Fagus*) woods near Femsjö, Sweden, are elliptical and agree in size with the measurements ($7-9 \times 4-5 \mu\text{m}$) given in *Flora Photographica* (Brandrud et al. 1995) for this species. Basidiospores of *C. lucorum* from O 123350 are $(7.8-8.5-11.1 \times 5.2-5.4-6.3 (-7) \mu\text{m})$. These spore measurements are very similar to those of the Hazel Wolf Wetland material and those given by Bidaud et al. (1999), but somewhat larger than the measurements given for *C. lucorum* in Brandrud et al. (1995). The collection made by Jeremy Nance (6-28-2005-3) has spores that are $8.5-10 (-10.4) \times 5.6-6.3 \mu\text{m}$. A study of the pileus surface of this collection shows a relatively well developed subcutis (hypodermium) as also noted by these authors. *Cortinarius lucorum* has a less distinct layer of inflated or enlarged cells forming the subcutis, but the development of this layer in our material may be more or less distinctly cellular depending on age and other features of the basidiomata.

Washington collections of *C. lucorum* from Hazel Wolf Wetlands were made in September and October. The collection from the Redmond Watershed Preserve made at the end of June seems unusual by comparison. However, the phenology of this species for the Pacific Northwest is poorly known because of the few documented collections to date. The spring of 2005 was wetter and somewhat cooler than usual in the Puget Sound Basin, which may have triggered the production of basidiomata in late June.

Cortinarius lucorum is somewhat reminiscent of *C. umidicola* Kauffman (= *C. canabarba* Moser) in Moser and Ammirati (1996), a species that is rare in conifer forests of western North America. *Cortinarius lucorum* is likely an ectomycorrhizal associate of *Populus*, and has not been seen in conifer forests of the Pacific Northwest. Its likely association with this host plant makes it ecologically similar to *C. saturninus*, which also occurs with angiospermous hosts, particularly the Salicaceae. See also comments under *Cortinarius cohabitans* Karst. in Arnold and Kuyper (1995). Interestingly, *C. saturninus* in *Atlas des Cortinaires*, Pars II, Pl. 41, Fiche 81, is applied to specimens with larger spores than usually given for this species. Also, Moser (1978) gives a large spore size for *C. saturninus*, indicating that the species with smaller spores represents *C. saturninus* var. *bresadolae* Moser (ined.), the fungus Arnold and Kuyper (1995) call *C. cohabitans*, a name adopted by Melot (1986) because of the doubtful identity of the original *C. saturninus*. Overall the features of the basidiocarps and the ecology of *C. lucorum* and *C. saturninus sensu* Brandrud et al. (1995) indicate a close relationship between these two species, which appears supported by ITS sequence data but with only marginal ML bootstrap support (Fig. 7).

The name *Cortinarius lucorum* was applied by Kauffman (1932), but its application is unclear since he used it for collections from both "frondose and coniferous forest" and considered it the same as *C. umidicola* Kauffman. This problem is discussed further in Moser and Ammirati (1996) under *C. umidicola*. See also *C. lucorum sensu* Arnold (1993).

ITS sequences of western North American *C. lucorum* are identical except for one position that is polymorphic in ITS1. Both sequences differ by the same nucleotide position from *C. lucorum* of northern Europe, the accessions of which are associated with *Populus tremula*. All four

accessions of *C. lucorum* are indicated in a gray box in Fig. 7 and nested within the *Telamonia* clade following the phylogenetic nomenclature of Peintner et al (2003, 2004).

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Literature cited

- Arnold, E. and T.W. Kuyper. 1995. Some rare and interesting *Cortinarius* species associated with *Salix repens*. *Beih. Sydowia* 10: 5-27.
- Arnold, N. 1993. Morphologisch-anatomische und chemische Untersuchungen an der Undergattung *Telamonia* (*Cortinarius*, Agaricales). *Libri Botanici* 7: 3-214.
- Bidaud, A., P. Moënne-Loccoz, P., P. Reumaux and R. Henry. 1999. Atlas des Cortinaires, Pars 9. Annecy: Editions Fédération Mycologique Daupiné-Savoie. Pl. 258, Fiche 419.
- Brandrud, T.E., H. Lindström, H. Marklund, J. Melot and S. Muskos. 1995. *Cortinarius*, Flora Photographica Vol. 3. Härmösand: *Cortinarius* HB.
- Cripps, C. and O.K. Miller, Jr. 1994. A new *Cortinarius* from a mature Aspen stand in Montana. *Mycotaxon* 50: 315-321.
- Felsenstein, J. 1985. Confidence limits on phylogenies: an approach using the bootstrap. *Evolution* 39: 783-791.
- Frøslev, T.G., P.B. Matheny, and D.S. Hibbett. 2005. Lower level relationships in the mushroom genus *Cortinarius* (Basidiomycota, Agaricales): a comparison of RPB1, RPB2, and ITS phylogenies. *Molecular Phylogenetics and Evolution* 37: 602-618.
- <http://dx.doi.org/10.1016/j.ympev.2005.06.016>
- Garnica, S., M. Weiß, B. Oertel, and F. Oberwinkler. 2005. A framework for a phylogenetic classification in the genus *Cortinarius* (Basidiomycota, Agaricales) derived from morphological and molecular data. *Canadian Journal of Botany* 83: 1457-1477. <http://dx.doi.org/10.1139/b05-107>
- Gardes, M. and T.D. Bruns. 1993. ITS primers with enhanced specificity of basidiomycetes: application to the identification of mycorrhizae and rusts. *Molecular Ecology* 2: 113-118.
- Høiland, K. and A. Holst-Jensen. 2000. *Cortinarius* phylogeny and possible taxonomic implications of ITS rDNA sequences. *Mycologia* 92: 694-710.
- Kauffman, C.H. 1932. *Cortinarius* Fries. *North American Flora* 10: 282-348.
- Koljalg, U., K.H. Larsson, K. Abarenkov, R.H. Nilsson, I.J. Alexander, U. Eberhardt, S. Erland, K. Hoiland, R. Kjöller, E. Larsson, T. Pennanen, R. Sen, A.F.S. Taylor, L. Tedersoo, T. Vralstad and B.M. Ursing. 2005. UNITE: a database providing web-based methods for the molecular identification of ectomycorrhizal fungi. *New Phytologist* 166: 1063-1068. <http://dx.doi.org/10.1111/j.1469-8137.2005.01376.x>
- Kornerup, A. and J.H. Wanscher. 1967. *Methuen handbook of color*. Methuen & Co Ltd, London. Second edition.
- Liu, Y.J., S.O. Rogers and J.F. Ammirati. 1997. Phylogenetic relationships in *Dermocybe* and related *Cortinarius* taxa based on nuclear ribosomal DNA internal transcribed spacers. *Canadian Journal of Botany* 75: 519-532.
- Maddison, D.R. and W.P. Maddison. 2000. *MacClade 4: analysis of phylogeny and*

character evolution. Sinauer Associates, Sunderland, Massachusetts.

Melot, J. 1986. Contribution a l'étude du genre *Cortinarius*. *Doc. Mycol.* 16(63-64): 109-142.

Moëgne-Loccoz, P. and P. Reumaux. 1990. Atlas des Cortinaires, Pars 2. Annecy: Editions Fédération Mycologique Daupiné-Savoie. Pl. 41, Fiche 81.

Moser, M.M. 1978. Keys to Agarics and Boleti. Roger Phillips. The White Friars Press, Ltd., Tonbridge, UK.

Moser, M.M. 2001. Some aspects of *Cortinarius* associated with *Alnus*. *Assoc. Journées Européennes du Cortinaire* 3: 47-101.

Moser, M.M. 2002. Studies in the North American Cortinarii VII. New and interesting species of *Cortinarius* subgen. *Telamonia* (Agaricales, Basidiomycotina) from the Rocky Mountains. *Feddes Repertorium* 113: 48-62.

Moser, M.M. and J.F. Ammirati. 1996. Studies in North American Cortinarii II. Interesting and new species collected in the North Cascade Mountains, Washington. *Mycotaxon* 58: 387-412.

Moser, M.M. and J.F. Ammirati. 1997. Studies on North American Cortinarii IV. New and interesting *Cortinarius* species (subgenus *Phlegmacium*) from oak forests in northern California. *Sydowia* 49: 25-48.

Moser, M.M. and J.F. Ammirati. 1999. Studies in North American Cortinarii V. New and interesting *Phlegmacia* from Wyoming and the Pacific Northwest. *Mycotaxon* 72: 289-321.

Moser, M.M. and J.F. Ammirati. 2000. Studies in North American Cortinarii VI. New and interesting taxa in subgenus *Phlegmacium* from the Pacific states of North America. *Mycotaxon* 74: 1-36.

Moser, M.M. and J.F. Ammirati. 2001. Studies on North American Cortinarii IV. New and interesting *Cortinarius* species (subgenus *Phlegmacium*) from oak forests in Northern California. *Sydowia* 49: 25-48.

Moser, M.M., K.H. McKnight and J.F. Ammirati. 1995. Studies on North American Cortinarii I. New and interesting taxa from the greater Yellowstone area. *Mycotaxon* 55: 301-346.

Peintner, U., N.L. Bougher, M.A. Castellano, J.M. Moncalvo, M.M. Moser, J.M. Trappe and R. Vilgalys. 2001. Multiple origins of sequestrate fungi related to *Cortinarius* (Cortinariaceae). *American Journal of Botany* 88: 2168-2179.

Peintner, U., M.M. Moser, K.A. Thomas and P. Manimohan. 2003. First records of ectomycorrhizal *Cortinarius* species (Agaricales, Basidiomycetes) from tropical India and their phylogenetic position based on rDNA ITS sequences. *Mycological Research* 107: 485-494.
<http://dx.doi.org/10.1017/S0953756203007585>

Peintner, U., J.M. Moncalvo and R. Vilgalys. 2004. Toward a better understanding of the infrageneric relationships in *Cortinarius* (Agaricales, Basidiomycota). *Mycologia* 96: 1042-1058.

Posada, D. and K.A. Crandall. 1998. MODELTEST: testing the model of DNA substitution. *Bioinformatics* 14: 817-818.
<http://dx.doi.org/10.1093/bioinformatics/14.9.817>

Ridgway, R. 1912. Color standards and color nomenclature. Washington, D. C.: published by the author.

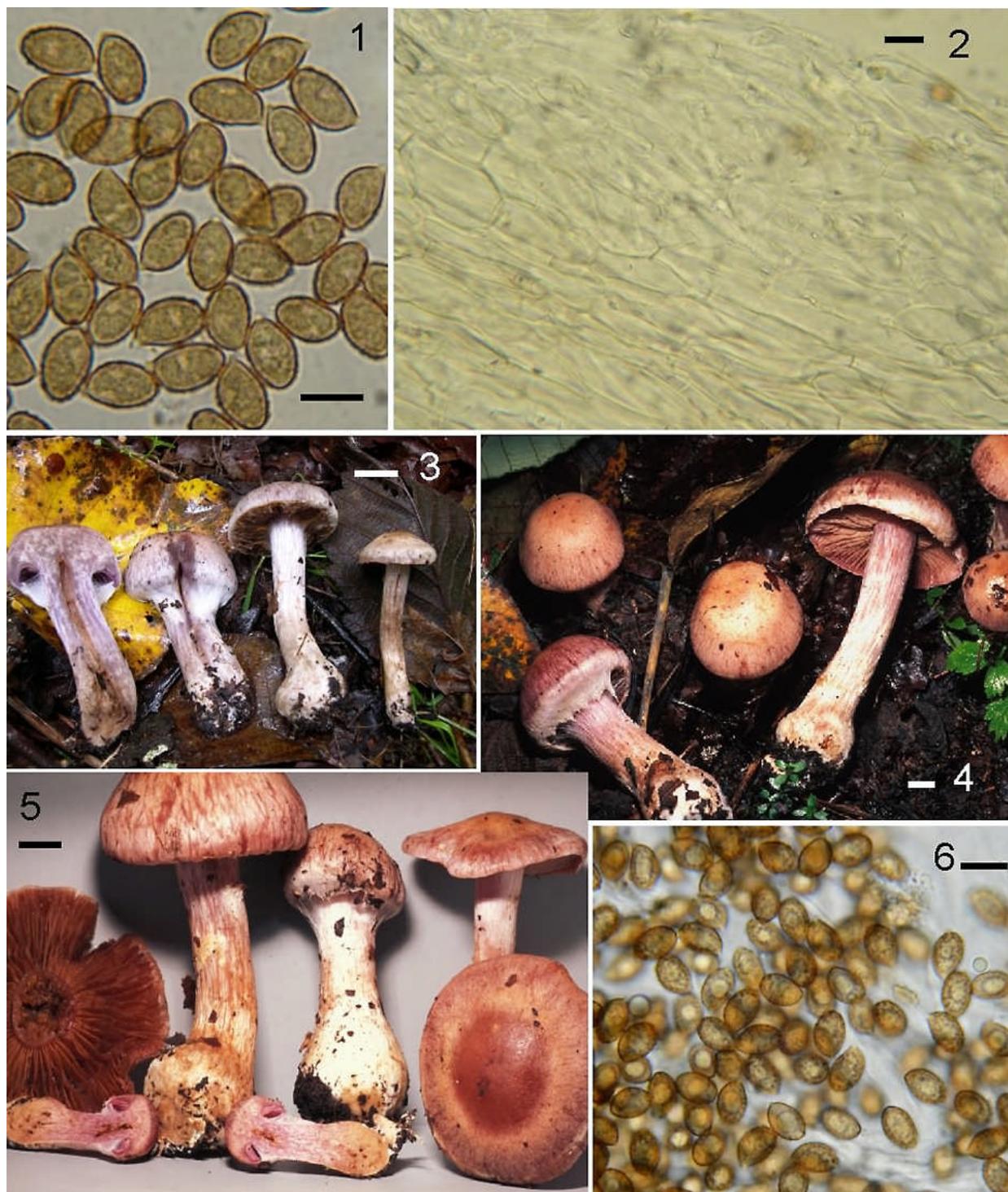
Seidl, M.T. 2000. Phylogenetic relationships within *Cortinarius* subgenus *Myxacium*, sections *Defibulati* and *Myxacium*. *Mycologia* 92: 1091-1102.

Swofford, D.L., G.J. Olsen, P.J. Waddell and D.M. Hillis. 1996. Phylogenetic inference. In: *Molecular Systematics*, 2nd edition (eds) D.M. Hillis, C. Mortiz, and B.K. Mable. pp. 407-514. Sinauer, Sunderland, Massachusetts, USA.

Swofford, D.L. 2003. PAUP*. Phylogenetic analysis using parsimony (*and other methods), Version 4. Sinauer, Sunderland, Massachusetts, USA.

Wang, Z., M. Binder and D.S. Hibbett. 2002. A new species of *Cudonia* based on morphological and molecular data. *Mycologia* 94: 641-650.

White, T.J., T. Bruns, S. Lee and J. Taylor. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: *PCR protocols: a guide to methods and applications* (eds) M. Innis, D. Gelfand, J. Sninsky & T. White, pp. 315-322. Academic Press, New York, USA.



Figs. 1-6. Anatomical and gross morphological features of *Cortinarius lucorum*. Fig. 1. Basidiospores of JFA 13094. Fig. 2. Pileus cuticle (epicutis, subcutis, and trama) of JFA 13094. Fig. 3. Basidiomata of JFA 13094. Fig. 4. Basidiomata of PBM 741. Fig. 5. Basidiomata of PBM 741. Fig. 6. Basidiospores of JFA 13094. Scale bars = 10 µm for anatomical features and 1 cm for basidiomata.

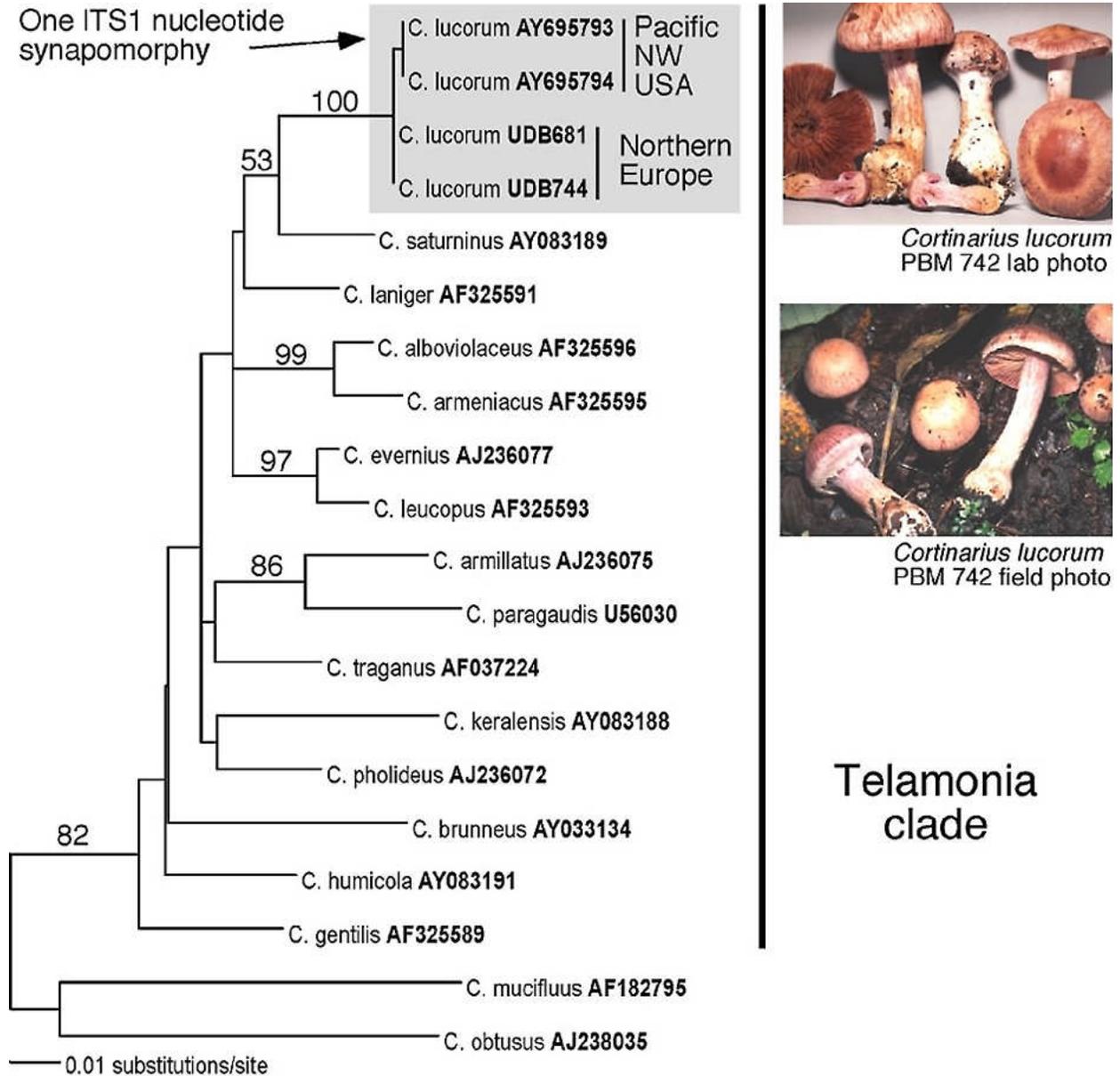


Fig. 8. The tree with the highest likelihood for ITS sequence data of members of the Telamonia clade. GenBank and UNITE accession numbers are shown in bold font. Four accessions of *Cortinarius lucorum* from Washington state and northern Europe are boxed in gray. Washington material is distinguished from European material by a single base pair substitution. Numbers above branches reflect maximum likelihood bootstrap proportions.