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SIMILARITIES AND DIFFERENCES BETWEEN SOME SPECIES OF SECOTIOID AND GASTEROID FUNGI IN ROMANIA

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Abstract: The article presents five species of macromycetes: *Chlorophyllum agaricoides*, *Montagnea arenaria*, *Mycenastrum corium*, *Tulostoma fimbriatum*, and *Calvatia gigantea*. Three of these species—*Chlorophyllum agaricoides*, *Mycenastrum corium*, and *Tulostoma fimbriatum*—are reported for the first time from Oltenia. *Calvatia gigantea* has previously been reported from Oltenia, while *Montagnea arenaria* was reported from Dobrogea, where it was collected by the author in 2012. The nomenclature of the species has been updated, synonyms are presented, the current global distribution, ecological and morphological characteristics are presented and compared, in contrast, of these species, diagnostic features relevant to their systematic placement. The known distribution of these species in Romania is also updated.

Keywords: secotioid, gasteroid, macromycetes, Oltenia, Dobrogea, chorology

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Introduction

All species of macromycetes do not forcibly discharge their spores their spores and have mature spores enclosed in the fruiting body have traditionally been placed in the were traditionally grouped under the Gasteromycetes: Lycoperdales, Tulostomatales, Sclerodermatales, Phallales and Nidulariales. Alongside these, three lesser-known orders, including Gautieriales, Melanogastrales, and Leucogastrales, are also included in this group (Miller & Miller 1988).

Also, a series of secotioid and agaricoid mushrooms, considered to be gasteromycetes, but related to gilled fungi or those with smooth hymenophore [truffle-like (sequestrate) forms] and to boletoid or poroid fungi, are included in the section „Gasteromycetes Loculate, Secotioide and Agaricoide" (Miller & Miller 1988).

Gasteromycetization has resulted in a great diversity of gasteroid forms within the Agaricaceae and has evolved independently multiple times within Agaricomycetes (Heim 1971; Singer 1986; Matheny et al. 2006). It is evolutionary transition from open fruiting bodies, with exposed spores, actively discharged, toward enclosed fruiting bodies with passive spore dispersal. It is known that the prefix „gastero-" („gaster" = „stomach") refers to the developmental process in which spores mature inside the fruiting body and are protected by the outer sterile layers known as the peridium. After the development process, mature basidiospores are spread by various means, the main ones being wind, rain, insects, and mammals, but the forcible discharge of the spore from the basidiocarp does not occur in gasteromycetes.

Studies of gasteroid fungi using transmission electron microscopy (TEM) and scanning electron microscopy (SEM) has been complemented by more ecological studies. The analysis of rDNA sequences revealed that there are close relationships between

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secotioid forms, sequestrate fungi, and agaricoid forms. Examples include the species *Coprinus comatus* and the gasteroid forms *Montagnea* and *Podaxis* (Vilgalys et al. 1993 in Alexopoulos et al. 1996).

As a result of these studies, many mycologists have been convinced that some basidiomycetes, which are treated as fungi traditionally classified as Gasteromycetes, are very closely related to Russulales, Boletales, and Agaricales, which forcibly eject their spores. Morphological and evolutionary relationships between secotioid/gasteroid and agaricoid or boletoid forms have long been recognized. For example, the relationship between secotioid fungi and agarics or boletes is well documented by Smith 1973; Thiers 1984, Miller & Miller 1988.

The secotioid species of the genus *Endoptychum* (*Chlorophyllum*) and *Agaricus* have common ecological and morphological characteristics; the secotioid forms are common decomposers of organic matter, such as wood or needles/leaves, found in disturbed xeric regions (Alexopoulos et al. 1996), or they form mycorrhizae with higher plants.

Until 2009, in the specialized literature from Romania, secotioid species were classified under the artificial class Gasteromycetes, ord. Gasteromycetales: Secotiaceae: *Chlorophyllum agaricoides* and *Montagnea arenaria*; Tulostomataceae: *Tulostoma fimbriatum* and Lycoperdaceae: *Calvatia gigantea* and *Mycenastrum corium*. For example: Tănase et al. (2009: 260) include *Calvatia gigantea* in ord. Agaricales, fam. Lycoperdaceae; Simion-Ciortan unpubl. (2010), Ciortan (2013) in ord. Agaricales, fam. Agaricaceae.

The objectives of this paper are to present the chorology of species in Romania, the similarities and differences between several secotioid and gasteroid fungi identified in Oltenia and Dobrogea (comparing morphological, and developmental characteristics) and to test Thiers' hypothesis (1984), which can be summarized as follows: the tendency towards the hypogeal habitus and a reduction of the basidiocarp toward the gasteroid type is an adaptation to xeric conditions. In conclusion, there has been a natural selection towards this type of basidiocarp that provides protection against the dry and hot environment.

Material and methods

Taxa included in this study is accompanied by synonyms, the description from Sălăgeanu & Sălăgeanu (1985); comments on the terminology used, the ecology of the species, occurrences in the world, occurrences in Romania, new distribution records, edibility, and conservation status are presented.

The comparison that highlights the similarities and differences that determined the classification in the secotioid or gasteroid group was made by analyzing the ecological, morphological, and developmental characteristics. This is done to illustrate how the construction of the fruiting body has incorporated adaptive features that help both protect the developing hymenium and release mature spores.

The nomenclatural/taxonomic authority followed throughout the study was Cannon & Kirk 2007), Index Fungorum. Distribution maps for Romania were generated by plotting each choronim of the respective species in Google Earth (yellow - previously published records, red - records obtained in the present study). Occurrence in the world from The Global Fungal Red List initiative (2026).

Results and discussion

Agaricaceae Chevall. 1826

Chlorophyllum Massee 1898

***Chlorophyllum agaricoides* (Czern.) Vellinga**, Mycotaxon 83: 416 (2002)

-Puffball parasol

Synonymy: *Endoptychum agaricoides* Czern., Bull. Soc. Imp. Nat. Moscou 18(no. 3): 148 (1845); *Secotium agaricoides* (Czern.) Hollós, Term. Füz. 25: 93 (1902).

Endoptychum Czern. 1845 nom. rej. = Chlorophyllum-secotioid fungus, formerly recognised as separate genus, fide Vellinga & De Kok (Taxon 51: 563, 2002) (in Kirk et al. 2008: 235).

The species was described by Sălăgeanu & Sălăgeanu (1985: 292) as *Secotium agaricoides* (Czern.) Holl.: „Pear-shaped basidiocarp, with a conical tip, 1-8 cm tall. The whitish, then brown peridium, cracked from the base to the top in strips, remaining supported only on the central columella. Very short stem, widened toward the tip. Gleba of labyrinthine chambers, with walls transformed into lamellae, at maturity brown and powdery. Numerous cystidia. Spores measuring 7-13 x 6-8 µm. In sandy, sunny places, through steppe meadows. July-October. Gs."

In the secotioid genera key, the author notes that at maturity the basidiocarp has the appearance of a young Shaggy Mane (*Coprinus comatus*) (Sălăgeanu & Sălăgeanu (1985: 291).

Similarities, differences. It is noted that in the species description, terms such as „peridium," „columella," and „gleba" are used, all of which are characteristics of gasteroid fungi, since in 1985, this species was classified in the family Secotiaceae, order Gasteromycetales. However, the term „lamellae" also appears, characteristic of the order Agaricales.

C. agaricoides is an epigeous secotioid macromycetes [type of basidioma in which the edge of the pileus does not detach from the stipe or detachment is only partial (the pileus is never fully expanded), convoluted and anastomosed lamellae, statismospores], formerly placed in Gasteromycetes. The secotioid morphology of the species is very well illustrated by Loizides et al. (2020).

Ecology. Terrestrial, saprotrophic [Gs = mycetogeophyta saprophytica (Sălăgeanu & Sălăgeanu (1985: 292)]. „Nitrophilic, in anthropogenic silvopastural lands, pastures, arid steppes, wood edges, and fertilized grasslands, epigeous on richly manured soil or directly onto sheep or cattle dung..." (Loizides et al. 2020). Ecological information is also provided by Bontea (1953: 484), which indicates the species as *Secotium agaricoides*.

Global distribution. Widespread (especially tropical) (Kirk et al. 2008); from Singer & Smith (1958), Miller & Miller (1988), *C. agaricoides* is widely distributed in the Northern and Southern Hemisphere, occurring in North America, Africa, Australia, New Zealand (Segedin 1987), Asia: China and Mongolia (Ge & Yang 2006), Europe: Ukraine, Romania (Eliade 1965: 271), Bulgaria (Lacheva 2012, 2014), Turkey (Sezgin et al. 2019), Hungary (https://www.miskolcigombasz.hu/). From The Global Fungal Red List initiative (2026): Algeria, Australia, Brazil, Canada, China, France, Greece, Hungary, Italy, Mongolia, Pakistan, Romania, Russian Federation, Serbia, Spain, Switzerland, Turkey, Turkmenistan, Ukraine, U.S.A., Uzbekistan.

The Romanian distribution was summarized by Eliade (1965: 271), who reported the species, as *Secotium agaricoides*, from several localities: Bacău: commune

Soveja (Toma 1964, 1967); Caraș-Severin County: Mehadia, Reșița (Hollós, 1903); București: Cotroceni (Alexandri 1932b: 14/48); Dragomirești din Deal, Grădiștea (Alexandri 1932b: 14/48)); Hobaia, Urziceni (Brândză & Solacolu 1932: 8); Arad County: commune Buteni (Toma 1964); Iași: between Focșani and the Crângul Forest, (Brândză & Solacolu 1932: 8); Iași: Poiana Stândoală, near Sorănești (Racoviță 1948: 28), Cârlig (Chifu et al. 1964), commune Helești, village Movileni (Toma 1964); Ploiești: Chițorani, Bucov (Alexandri 1934: 61).

The species is also reported from Florei, Posada, of Fagetum dacicum (*Carpinus betulus*, *Populus tremula*) (Barbu 1979: 67); Ținutul Secuiesc, without a precise locality (Pál-Fám & Benedek 2025: 277).

New distribution records. Dolj: Băilești (08.04.2015), near a former livestock farm, on sandy soil along a roadside, under *Populus nigra*, 43°59'54.33"N/23°20'31.72"E; Ciupercenii Noi – Ciurumela forest (28.09.2024) at the edge of a *Robinia pseudoacacia* stand, on sandy steppes, pastures, 43°52'24.56"N/23°4'47.14"E. The habitat characteristics of the present records are consistent with those reported by Loizides et al. (2020).

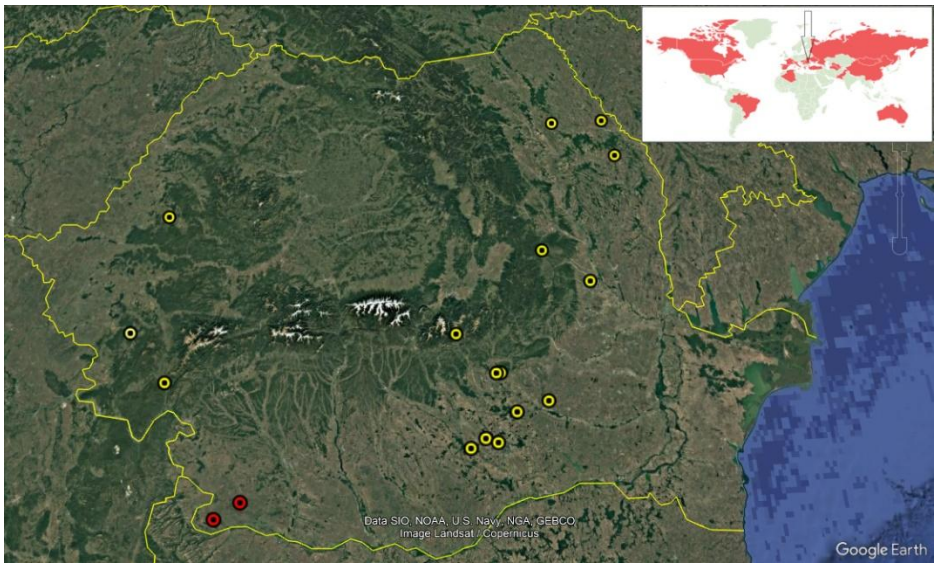


Fig. 1. *Chlorophyllum agaricoides*: Occurrence in Romania and in the world
(● - records obtained in the present study, ● - previously published records)

Edibility. Suspect. Young specimens have traditionally been consumed by Turks for many years (Sezgin et al. 2019).

Conservation status. In Europe, it is believed to be in decline due to habitat destruction (Siller et al. 2006). Proposed by Mikael Jeppson on the Fungal Red List (The Global Fungal Red List Initiative 2026) with Least Concern (LC) status. In Hungary, the species is protected (Siller et al. 2006, https://www.miskolcigombasz.hu/).

Montagnea Fr. 1836

***Montagnea arenaria* (DC.) Zeller** [as 'arenarius'], Mycologia 35(4): 418 (1943)

-Desert inkcap

Synonymy: *Agaricus arenarius* DC., Fl. franç., Edn 3 (Paris) 5/6: 45 (1815); *Montagnea arenaria* var. *macrospora* D.A. Reid & Eicker, S. Afr. J. Bot. 57(3): 166 (1991); *Montagnea delilei* Fr., Fl. Scan.: 339 (1836) [1835]; *Montagnea pallasii* (Fr.) Mont., Annls Sci. Nat., Bot., sér. 2 20: 77 (1843); *Montagnites arenarius* (DC.) Morse, Mycologia 40(2): 256 (1948); *Montagnites pallasii* Fr., Epicrisis Systematis Mycologici: 241 (1838) [1836-1838], *Montagnites radiosus* (Pall.) Hollós. Természetrajzi Füzetek 25 96 (1902).

The genus *Montagnea* was circumscribed by Fries în *Fl. Scan.*: 339 (1836) [1835] and it was transferred to the genus *Montagnea* by Sanford Myron Zeller in 1943.

Montagnites radiosus (Pall.) Hollós, as indicated in the Romanian literature [Alexandri 1932a, 1934; Bontea (1953: 484, 486)] is synonymous with *Montagnea arenaria* (DC.) Zeller 1943 (Reid & Eicker 1991).

The species was described by Sălăgeanu & Sălăgeanu (1985: 291-292), as *Montagnea arenaria* (DC.) Zell.: „Basidiocarp with a stem of 8-28 cm x 0.5-2 cm, tough, whitish, with a pale ochre volva at the base, with a free, irregularly fringed edge. The plan-convex pileus, 1-6 cm in diameter, white ochre, with a turned-back margin and equipped with radial gills. The gleba is represented by black radial gills. Spores measuring 10-16 x 7-11 µm. On sandy soil, through steppe meadows. May-August. Gs".

Similarities, differences. In the description of this species we observe terms such as: „stipe", „volva", „pileus", „gills", all characteristics of the order Agaricales. „Gleba" (characteristic of the order Gasteromycetales), however, it is described as in the form of radial gills.

For this species, the morphological characteristics (predominantly agaricoid) are very well described by Ribes Ripoll (2011), who compares the species in its mature (dehydrated) stage to a *Coprinus* sp.

Ecology. Terrestrial, saprotrophic [Gs = mycetogeophyta saprophytica (Sălăgeanu & Sălăgeanu (1985: 291-292], decomposer of plant organic matter under xeric conditions or in desert regions (Smith et al. 1981, Cleland 1934, Hóllos 1904, Pilat 1958). A xerothermophilic species of sand dunes, sandy steppe areas, semi-deserts/deserts (The Global Fungal Red List initiative 2026). Ecological information is also provided by Bontea (1953: 484, 486) which indicates the species as *Montagnites radiosus* (Pall.) Hollós.

Global distribution. Known from North America (Miller & Miller 1988), but widespread (subtropical dry areas) (Kirk et al. 2008): North and South Africa, North, South and Central America, Australia and Southern and Central Europe (Stasińska & Prajs 2002). Spread in Europe: Austria, the Czech Republic, France, Germany, Greece, Italy, Hungary, Poland, Romania, Russia, Spain and Ukraine (Stasińska & Prajs 2002). From The Global Fungal Red List initiative (2026): Afghanistan, Algeria, Argentina, Australia, Austria, Brazil, Canada, Chad, Chile, China, Cyprus, Czech Republic, Egypt, France, Germany, Greece, India, Iran, Iraq, Israel, Italy, Kazakhstan, Libya, Mexico, Mongolkia, Morocco, Pakistan, Poland, Puerto Ricco, Qatar, Romania, Russian Federation, Saudi Arabia, South Africa, Spain, Sudan, Tajikistan, Tunisia, Turkey, Turkmenistan, Ukraine, U.S.A., Uzbekistan, Yemen.

The Romanian distribution was summarized by Eliade (1965: 271), who reported the species, as *Montagnites radiosus* (Pall.) Hollós, from several localities Ialomița: Mărculești (Alexandri 1934: 61); Timișoara: Marmorac-Timiș, Tulcea: Sfântu Gheorghe (Flămânda) (Alexandri 1932a: 1-3); between Babadag and Enisala, leg. Tr. Savulescu & AI. V. Alexandri (Herbarium Mycologicum Romanicum, Fasc. X, no. 481 (Alexandri 1932a: 1-3, Săvulescu 1932: no 481), Babadag (Herbarul Micoflorei Republicii Socialiste România); Constanța: Medgidia (Alexandri 1934: 61), Danube Delta (leg. Zotta, according to Brândză & Solacolu 1932: 7); Iași: Iași (Turenschi et al. 1963, Bontea 1953).

New distribution records. Tulcea: Enisala Fortress (05.05.2012), on sandy steppes, 44°53'0.53"N/28°50'9.08"E.



Fig. 2. *Montagnea arenaria*: Occurrence in Romania and in the world
(● - records obtained in the present study, ● - previously published records)

Edibility. Inedible.

Conservation status. Proposed by Mikael Jeppson on the Fungal Red List (The Global Fungal Red List Initiative 2026) with Least Concern (LC) status. In Poland appears on the „red list" of Polish threatened macrofungi as Endangered (E) (Wojewoda & Ławrynowicz 1992).

Mycenastrum Desv. 1842

***Mycenastrum corium* (Guers.) Desv.,** Annls Sci. Nat., Bot., sér. 2 17: 147 (1842)

-Pușca dracului, Giant pasture puffball, Leathery puffball, Tough puffball

Synonymy: *Lycoperdon corium* Guers., in Lamarck & de Candolle, Fl. franç., Edn 3 (Paris) 2: 598 (1805); *Mycenastrum corium* subsp. *ferrugineum* O.K. Mill., R.-L. Brace & V.S. Evenson, Mycologia 97(2): 532 (2005); *Mycenastrum corium* var.

diabolicum Homrich & J.E. Wright, Mycologia 65(4): 792 (1973); *Mycenastrum corium* var. *ferrugineum* (O.K. Mill., R.-L. Brace & V.S. Evenson) Blanco-Dios, Yesca, Revista Sociedad Micólogica de Cántabria 33: 108(2021); *Mycenastrum corium* var. *kara-kumianum* Sorokin, Bull. Soc. Imp. nat. Moscou 59(1-2): 147 (1884); *Scleroderma corium* (Guers.) L. Graves, in Duby, Bot. Gall., Edn 2 (Paris) 2: 852 (1830); *Scleroderma corium* var. *kara-kumianum* (Sorokin) Berl., De Toni & E. Fisch., in Berlese, De Toni & Fischer, Syll. fung. (Abellini) 7(1): 142 (1888); *Scleroderma corium* var. *sterlingii* Lloyd, Mycol. Writ. (Cincinnati) 1(no. 12): 120 (1902); *Scleroderma verrucosum* subsp. *corium* (Guers.) Laterrade, Flore bordelaise, Edn 4: 547 (1846); *Sterrebekia corium* (Guers.) Fr., K. svenska Vetensk-Akad. Handl., ser. 3: 150 (1849) [1848].

Sălăgeanu & Sălăgeanu (1985: 293) provided the following description: „Basidiocarp 2-10 cm in diameter, cracking at the top when mature, star-shaped, with a mycelial cord at the base. Thin exoperidium, whitish-yellow or gray, deciduous at maturity. Scorched endoperidium, brown-gray or chocolate-colored. Yellowish gleba, then olive or brown-purple. Basidiospores 10–12 µm in diameter, ornamented with warts. On sandy soil. June-October. Gs.".

Similarities, differences. This species, in its description, contains only terms assigned to the order Gasteromycetes, being one of the species that has the greatest morphological similarity with gasteroid fungi. Zeller (1948) defined the family Mycenastraceae with the typical genus *Mycenastrum*, however this genus would be assigned to the family Lycoperdaceae, even though molecular data confirm its placement in the order Agaricales (Cannon & Kirk 2007).

Ecology. Terrestrial, saprotrophic [Gs = mycetogeophyta saprophytica (Sălăgeanu & Sălăgeanu 1985: 293)]; nitrophilous; in grazed grassland, manured grassland, wasteland, gardens and parks; often in anthropogenous habitats (The Global Fungal Red List initiative 2026); growing alone or gregariously in grassy areas-especially in manure-rich meadows and pastures, but also in lawns; summer and fall (Kuo 2008). Ecological information is also provided by Bontea (1953: 476, 485).

Global distribution. Wide spread (Kirk et al. 2008); From The Global Fungal Red List initiative (2026): Algeria, Argentina, Armenia, Australia, Azerbaijan, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Denmark, Ecuador, Ethiopia, Finland, France, French Polynesia, Georgia, Germany, Hungary, Israel, Italy, Jordan, Kyrgyz Republic, Latvia, Lithuania, Madagascar, Mexico, Netherlands, New Zealand, Norway, Poland, Romania, Russian Federation, Slovakia, South Africa, Spain, Sweden, Tajikistan, Tanzania, Turkey, Uganda, United Kingdom, United States of America, Uruguay.

The Romanian distribution was summarized by Eliade (1965: 268), who reported the species from several localities: București: Cotroceni, Herăstrău (Alexandri 1932b: 52/86); Mihai Bravu (Alexandri 1932b: 52/86), Hagieni, Urziceni, Hobaia, Domnești, Herăstrău, Dor Mărunt, Comana (Brândză & Solacolu 1932: 26); Tulcea: Babadag (Toma 1964, 1967); Tecuci, Focșani Cotești, Gugești, Sihlea, Zoița, Mărășești, Pătăști (Putna and Râmnicul Sărat) (Brândză & Solacolu 1932: 26, Panțu 1929, Bontea 1953, Corlățeanu 1959, Eftimiu-Heim 1937).

The species has also been reported from: Baiului Mountains: Fața Găvanei, 28.X.1966 (Barbu 1970); Bărăgan Experimental Station – Ialomița (Fodor 2000: 122) forest shields; The Land of Amlaș (Sălișteș, Sibiu) (Szász 2013: 39).

New chorological data: Gorj: Ionești-Capu Dealului (21.04.2021), mature basidiomata that have survived the winter, on sandy soil, in pastures, 44°37'21.41"/23° 27'11.78".

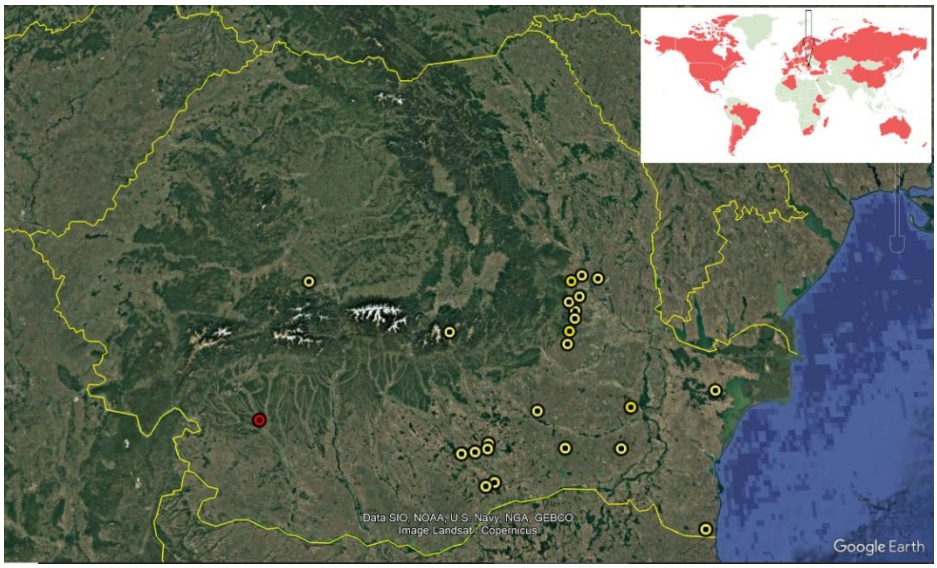


Fig. 3. *Mycenastrum corium*: Occurrence in Romania and in the world
(● - records obtained in the present study, ● - previously published records)

Edibility. According to Sălăgeanu & Sălăgeanu (1985: 293), edible with little nutritional value.

Conservation status. Proposed by Mikael Jeppson on the Fungal Red List (The Global Fungal Red List Initiative 2026) with Least Concern (LC) status.

Tulostoma Pers. 1794

***Tulostoma fimbriatum* Fr.**, Syst. mycol. (Lundae) 3(1): 43 (1829)

- Stalked puffballs

Synonymy: *Tulasnodea fimbriata* (Fr.) Fr., Summa veg. Scand., Sectio Post. (Stockholm): 440 (1849); *Tulostoma brumale* var. *fimbriatum* (Fr.) Quél., C. r. Assoc. Franç. Avancem. Sci. 18(2): 508 (1890) [1889]; *Tulostoma campestre* Morgan, J. Cincinnati Soc. Nat. Hist. 12(4): 165 (1889); *Tulostoma fimbriatum* var. *campestre* (Morgan) G. Moreno, An. Jard. bot. Madr. 36: 18 (1980) [1979]; *Tulostoma granulosum* var. *campestre* (Morgan) J.E. Wright, in Wright, Herrera & Guzmán, Ciencia Méx. 27(4-5): 116 (1972).

Sălăgeanu & Sălăgeanu (1985: 303) provided the following description of the species: „The endoperidial aperture is flat or less pronounced and has a hairy or fringed edge. The basidiocarp is 3-7 cm tall, with a flattened-spherical fertile part, 1-1.5 cm in diameter. The exoperidium divides into small scales at maturity, forming a brown tomentum at the base of the endoperidium. The stem without a volva at the base, brown,

sometimes scaly, with a small bundle of mycelial fibers at the base. Brown-ochre gleba. Spores of 6-8 µm. In sandy places, in the steppe region. March-December. Gs".

Similarities, differences. It is also noticeable here terms such as „gleba" (dimitic, heterogeneous, formed both from generative, fertile hyphae and from vegetative, sterile hyphae with thick walls and a supporting role; the supporting hyphae organize a mechanical network throughout the gleba mass, called a capillitium), „exoperidium", „endoperidium", „capillitium" specific to the order Gasteromycetes, but also „stipe" – specific to the order Agaricales.

Ecology: Saprotrophic and thermophilous in dry and exposed habitats on sand or in grassland, steppe, semideserts, sand dunes. Gs = mycetogeophyta saprophytica (Sălăgeanu & Sălăgeanu 1985: 303). Calciphilous but also sometimes under more acid conditions (The Global Fungal Red List initiative (2026). Ecological information is also provided by Bontea (1953: 487).

Global distribution. Widespread (especially dry regions) (Kirk et al. 2008). Common species in Europe and North America. From The Global Fungal Red List initiative (2026): Algeria, American Samoa, Argentina, Australia, Austria, Brazil, Canada, China, Czech Republic, Denmark, France, Germany, Hungary, Israel, Italy, Kazakhstan, Mexico, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Spain, Sweden, Tajikistan, U.S.A.

The Romanian distribution was summarized by Eliade (1965: 268)], who reported the species from several localities: București: Herăstrău (Alexandri 1932b: 62/96); Herbarium Mycologicum Romanicum „Traian Săvulescu", Săvulescu 1932); Hanul Conachi (Tecuci), Putna Seacă (Putna), Siret train station, Argeș, Hobaia, Râioasa Forest, Pisculești, Grădina Botanică Cotroceni (leg. Olga Mălinescu) (Brândză & Solacolu 1932: 9).

It has also been cited from Ciumai, Basarabia (leg. C. Zahariadi-Herb. Myc. Rom. F. X. no: 469) (Alexandri 1934: 74) and from Ținutul Secuiesc without specifying the locality (Pál-Fám & Benedek 2025: 949).

New distribution records. Mehedinți: Borovăț Valley (16.04.2013), on sandy soil, 44°46'1.41"N/22°36'35.94"E; Dolj: Craiova on the banks of the Jiu (15.02.2020), 44°22'40.93"N/23°42'12.36"E; Drăgotești (27.02.2023), in pastures, 44°14'58.51"N/24°5' 3.72"E.

Edibility. Inedible.

Conservation status. Proposed by Mikael Jeppson on the Fungal Red List (The Global Fungal Red List Initiative 2026) with Least Concern (LC) status.

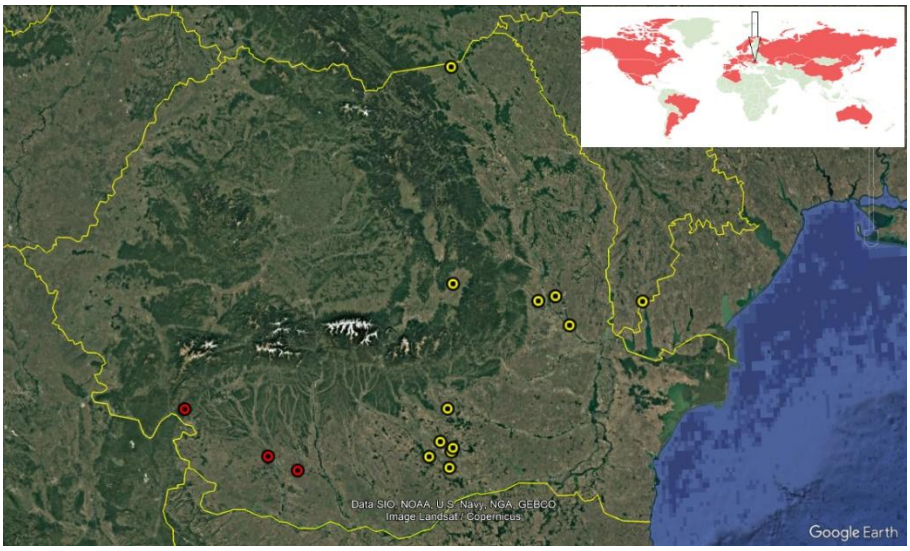


Fig. 4. *Tulostoma fimbriatum*: Occurrence in Romania and in the world
(● - records obtained in the present study, ● - previously published records)

Lycoperdaceae Chevall. 1829
Calvatia Fr. 1849 nom. cons.
***Calvatia gigantea* (Batsch) Lloyd**, Mycol. Writ. 1 (Lycoperd. Australia) 1: 166 (1904)
- Răsuflătoarea pământului, Giant Puffball

Synonymy: *Bovista gigantea* (Batsch) Gray, Nat. Arr. Brit. Pl. (London) 1: 583 (1821); *Bovistaria gigantea* (Batsch) P. Karst., Bidr. Känn. Finl. Nat. Folk 48: 10 (1889); *Globaria gigantea* (Batsch) Quél., Mém. Soc. Émul. Montbéliard, Sér. 2 5: 370 (1873); *Langermannia gigantea* (Batsch) Rostk., in Sturm, Deutschl. Fl., 3 Abt. (Pilze Deutschl.)(18): 23 (1839); *Lasiosphaera gigantea* (Batsch) F. Šmarda, Fl. ČSR, B-1, Gasteromycetes: 308 (1958); *Lycoperdon giganteum* Batsch, Elench. fung. (Halle): 237 (1783).

The species was described by Sălăgeanu & Sălăgeanu (1985: 294) as *Lasiosphaera gigantea* (Pers.) F. Šmarda: „Globular basidiocarp, 20-65 cm in diameter and up to 25 kg. Floury-granular exoperidium, white then yellowish-white, brown, crumbly. White then brown endoperidium, fragile, breaking into pieces at maturity, leaving the gleba exposed. The gleba is woolly, yellow, then brown-olive. Spores are 4-5 µm, almost smooth, short-pedunculate. Through pastures and hayfields. August-November. Gs. X".

Similarities, differences. Terms that „gleba" (flabellate, in which the hymen is made up of palisade structures supported by a kind of hyphal branches), „exoperidium", „endoperidium", „capillitium" specific to the order Gasteromycetes. Specific terms of the order Agaricales are missing, as it is a typical gasteroid species, classified in the family Lycoperdaceae.

Ecology. Grows in pastureland and meadows, as well as beside overgrown, grassy hedgerows (Sterry 2011), and rural gardens (The Global Fungal Red List initiative 2026). Gs = mycetogeophyta saprophytica (Sălăgeanu & Sălăgeanu 1985: 294). Ecological

information is also provided by Bontea (1953: 485) which indicates the species as *Calvatia maxima* (Schaeff.) Morg.

Global distribution. From The Global Fungal Red List initiative (2026): Algeria, Andorra, Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Iceland, Ireland, Isle of Man, Italy, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States of America.

The Romanian distribution was summarized by Eliade (1965: 264), who reported the species, as *Calvatia maxima*, then Pázmány (1994-1995: 27-36) publishes the distribution of the species in Romania, also taking up the data from Eliade (1965): Jepii Valley, Sighetul Marmației (Béreș & László 1982: 124, as *Lagermania gigantea*); Suceava, Hințești, The Siret Meadow (Chifu et al. (1995: 174, as *Calvatia maxima*); Bihor, Marghita (Pázmány 1986: Herb. Pázmány); Bistrița-Năsăud, Petri Hill (Eliade & Cristurean 1971: 85, as *Calvatia maxima*); Iași, Mârzești Forest (Redeiu) (Dobrescu et al. 1969: 446 as *Lasiosphaera gigantea*); Iași, in Long Valley (Botezatu 1962:149 as *Lycoperdon bovista*); Bihor: Oradea (Hazlinsky 1877:20 as *Globaria gigantea*); Durău Mountains in The Ceahlău Massif (Eliade 1965:264); Iași, in Dobrovăț Forest (Racoviță 1948: 29 as *Lycoperdon giganteum*); Bacău: Groși (ferma Groși Neamț) (Brândză & Solacolu 1932: 14); Fundătura Forest (Racoviță 1948:29 as *Lycoperdon giganteum*); Vaslui- Crășnița Forest (Chifu & Vițalariu 1971: 640 as *Calvatia maxima*); Cluj: Cluj-Napoca, in rich areas: the yard of the Metallurgical Factory (recorded by Pázmány 1981), in the timber warehouse of the Unirea Factory (recorded by Pázmány, leg. Szabo 1984) (Silaghi 1958: 27 as *Calvatia maxima*), Plopilor Valley and Fânațele Clujului (Silaghi 1966:218 as *Calvatia gigantea*), Turda (Fuss 1878:459 as *Lycoperdon giganteum*); Mureș: Chețani (in Herb. Pázmány 1950 leg. Antal 1989); Harghita: Polonița (leg. Lajber 1990-Herb. Pázmány), Rugănești (oral communication Misky); Alba, Blaj (Borza & Lupșa 1964: 150 as *Lycoperdon giganteum*); Sibiu: Mediaș (Fuss 1878:459 as *Lycoperdon giganteum*, according to Brandsch); Arad: Arad (Eliade according to Simonkai 1893), Arad-Ciala (Eliade according to Simonkai 1893); Alba: Alba Iulia (Eliade according to Cserni 1879, 1888); Sibiu, Șura Mare (leg. Zaharia 1993) (University of Agriculture and Veterinary Medicine Cluj-Napoca Herbarium); Covasna: Sf. Gheorghe (Eliade 1965: 264 according to Hollós 1904); Sibiu (Eliade 1965: 264 according to Fuss 1853), Șura Mare, Sibiu, Tălmaci (Eliade 1965: 264 according to Fuss 1878), Brașov-Satu Nou, Sibiu (Eliade 1965: 264 according to Fuss 1878); Hanu Conachi Tecuci) (Eliade 1965: 264 according to Brândză & Solacolu 1932: 14); Brașov-Tâmpa (Eliade 1965: 264 according to Alexandri 1934: 65); Focșani-Crâng, (Brândză et Solacolu 1932: 14), Perieni (Pázmány (1994-1995: 27-36); Ciucaș Mountain, in Berii Valley (Bănescu 1965: 168 as *Bovista gigantea*); Tulcea: Măcin Mountain-Culmea Pricopan [leg. Negrean 1989 in Herb. Mic. București (BUCM 112.317)], Cocoș Monastery [leg. Negrean 1983 in Herb. Mic. București (BUCM 76.274)], Nifon under „Le Jurnale" in Carpino-Tilietum [leg. Negrean 1983 in Herb. Mic. București (BUCM 76.239)]; Argeș: Pitești (Alexandri 1932: 65 as *Calvatia gigantea*); Tulcea: Babadag (Toma 1967: 132 as *Calvatia gigantea*); Ialomița: Urziceni (Eliade 1965: 264 according to Brândză et Solacolu 1932: 14); București: Mogoșoaia (Eliade 1965: 264 according to Alexandri 1934: 65-Herb. Myc. Rom. XIV. no: 697); Pasărea (Alexandri 1932: 31/65); Giurgiu:

Hobaia (Eliade 1965: 264 according to Brândză et Solacolu 1932); Ilfov: Râioasa Forest, [leg. Negrean 1983, in Herb. Mic. București (BUCM 75.872)]; București: Botanical Garden (Săvulescu, Eliade & Tadosescu 1965: 169 as *Bovista gigantea*); București: Pantelimon, Brănești (Eliade 1965: 264 according to Brândză & Solacolu 1932: 14); Giurgiu: Comana (Eliade 1965: 264 according to Brândză & Solacolu 1932: 14), Greaca, in Măgura Forest, in Quercetum frainetto (leg. Negrean 1983, in Herb. Mic. București); Dolj: Tâmburești (Eliade 1965: 264 according to Comes 1963); Constanța: Canaraua Fetii, in the thicket [leg. Vițalariu 1964, in Herb. Mic. București (BUCM 58. 511)].

The species is also indicated from Iași: Nițelea (Eliade 1965: 264 according to Popovici 1902); Haragaci (Lăpușna), Ciumai (Basarabia) (leg. C. Zahariadi) (Alexandri 1934: 65); Vâlcea: Căpățânii Mountains: Curmătura Comarnice, Cacova Mountain [Ioana Simion (Ciortan), 2010, 2013]; Hoghiz, Pădurea Bogata (ROSCI0137) Szas (2018: 33); Gurghiu Mountains, the Borsec area (Pál-Fám & al. 2018: 65); Ținutul Secuiesc without precise location (Pál-Fám & al. 2023:13); Sfântu Gheorghe (Farkas 2025: 161).

New distribution records. Mehedinți: Obârșia Cloșani (07.11.2010), 45°01'44.70"N/22°40'41.00"E, in pastures.

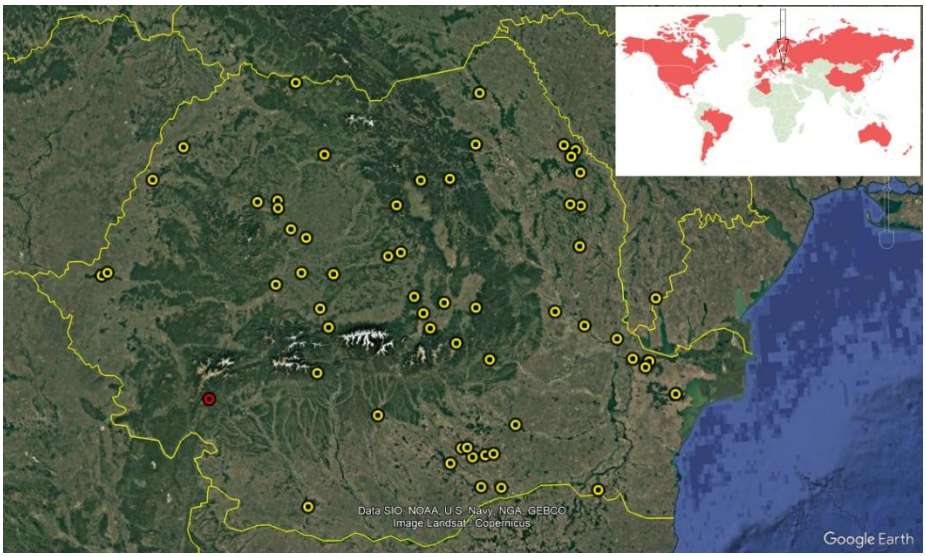


Fig. 5. *Calvatia gigantea*: Occurrence in Romania and in the world
(● - records obtained in the present study, ● - previously published records)

Edibility. Edible when young. According to Sălăgeanu & Sălăgeanu (1985: 294), edible with little nutritional value.

Conservation status. Proposed by Mikael Jeppson on the Fungal Red List (The Global Fungal Red List Initiative 2026) - This is a widespread species. It would likely qualify as Least Concern if there were no evidence for any rapid declines.

The identified species belong to the order Agaricales, subclass Agaricomycetidae, class Agaricomycetes, phylum Basidiomycota.

Four of them belong to the family Agaricaceae: *Chlorophyllum agaricoides*, *Montagnea arenaria*, *Mycenastrum corium*, *Tulostoma fimbriatum* (according to Index Fungorum), and *Calvatia gigantea* to the family Lycoperdaceae (according to Cannon & Kirk 2007, Index Fungorum), but according to the Global Fungal Red List initiative (2026), also from the family Agaricaceae. Regarding *Mycenastrum corium*, Cannon & Kirk (2007) classify it in the family Mycenastraceae Zeller 1948. Although molecular data places it in Agaricaceae (Kirk et al. 2008), Cannon & Kirk (2007) argue that more studies are needed.

All these species were previously classified in Gasteromycetes, which was a group of gasteroid fungi (with a basidioma whose hymenium is completely enclosed within the fruiting body), from the phylum Basidiomycota, which includes species of macromycetes with fruiting bodies (basidiomes) that are very diverse in shape (pear-shaped, spherical, tuber-like) and hypogeous or epigeous development. On the outside of the fruiting body there is an outer layer called peridium, and inside is the gleba. The basidia are whole (holobasidia), each producing from 4 to 12 basidiospores that have different shapes (cylindrical, globular, ovoid), with a thick, multi-layered wall and a smooth or rough surface, characteristics that vary depending on the genus; they are statismospores, which at maturity are released passively by the breaking or disintegration of the peridium and are dispersed by wind, rain, or insects, and even by mammals (wild boars) in the case of hypogeous basidioma.

They were placed in the class Gasteromycetes Fries (1821) („stomach fungi") (Alexopoulos et al. 1996) or in the order Gasteromycetales Rea [(Sălăgeanu & Sălăgeanu (1985)] because the basidiospores mature inside the basidiocarp. These historical classifications are now recognized as artificial because molecular phylogenetic studies have demonstrated that gasteroid fungi are polyphyletic and occur in numerous independently evolved lineages, since the species in the *Bovista*, *Calvatia*, *Lycoperdon*, *Geaster*, *Nidularia* genera, and *Phallus impudicus* are not closely related to each other. Because they are often studied as a group, it has been convenient to retain the generic (non-taxonomic) name „gasteroid fungi".

The artificial class Gasteromycetes include taxa lacking obvious morphological similarities with the hymenothecial ones in the gasteroid group (consisting of Tulostomataceae and Lycoperdaceae), as well as taxa very similar to their hymenothecial relatives in the secotioid group [consisting of *Agaricus*, *Coprinus* (monophyletic with the genera *Montagnea*, *Macrolepiota*, and *Chlorophyllum*) (Alexopoulos et al. 1996), *Cortinarius*, *Pholiota*, *Gastroboletus* (Thiers 1984)].

The relationship between secotioid fungi and agarics or boletes is well known (Smith 1973; Thiers 1984, Miller & Miller 1988). Secotioid species from the genus *Endoptychum* (*Chlorophyllum*) and *Agaricus* share common ecological and morphological characteristics; the secotioid forms are common decomposers, found in disturbed xeric regions (Alexopoulos et al. 1996). Analysis of rDNA sequences revealed that there are close relationships between secotioid forms, sequestrate fungi, and agaricoid forms. Examples include the *Coprinus comatus* species and the gasteroid forms *Montagnea* and *Podaxis* (Vilgalys et al., 1993 in Alexopoulos et al. 1996).

Based on morphological and ecological observations, Thiers (1984) proposed a hypothesis regarding the origin and phylogeny of secotioid: from a type of agaric or apothecial sporocarp with a fully exposed hymenium, there emerged an epigeous to

subepigeous secotioid type that has a hymenium at least partially protected, which, in turn, gave rise to the truly hypogeous sporocarp type, in which the hymenium or gleba is completely protected.

The theory proposed by Thiers in 1984 states that initially there was a natural selective process favoring those basidiocarps that offered some protection against moisture loss from hymenium. This is probably what happened of the species *Chlorophyllum agaricoides*, whose cap no longer fully expands and doesn't expose the hymenium (Figs 6, 7). As a result, pockets or spaces form in the hymenophore (Figs 7, 10), which would be effective in maintaining higher humidity and improving spore production.



Fig. 6. *Chlorophyllum agaricoides*
- the edge of the pileus does not separate from the stipe



Fig. 7. *Chlorophyllum agaricoides* - the edge of the pileus detaches from the stipe at maturity, pileus partially expanded, hymenophore not exposed

If the hymenophore has not been exposed, then there was no selective advantage in the forced discharge of basidiospores. The fact that no Homobasidiomycetes are known

to have retained forced spore discharge when the hymenium is closed argues in favor of this. Following the loss of active basidiospore discharge, the stalk/stipe no longer provided any selective advantage for the survival of the species. Thus, it gradually diminished until it disappeared. Hypogeous species with a true stem are very rare nowadays. However, an extension of the stipe in the form of a columella in the gleba has persisted much longer in evolution, and many of the current hypogeous species possess such a structure.

The species presented in this article are epigeous, the secotioid have a long percurrent columella (*Tulostoma fimbriatum* and *Montagnea arenaria*) (Figs 8, 9), and others (*Chlorophyllum agaricoides*) a short percurrent columella (Figs. 6, 7, 10).





Fig. 8. *Tulostoma fimbriatum*; Fig. 9. *Montagnea arenaria*
- long stipe in the form of a percurrent columella



Fig. 10. *Chlorophyllum agaricoides*
- convoluted, anastomosed gills, short stipe in the form of a percurrent columella

With the disappearance of the stipe, the basidiocarp lost any means by which it could be raised above the ground, thus becoming semihypogeous or hypogeous. Also, the peridium (epicutis) closed the hymenophore and the hymenium, thus resulting in the formation of a gasteroid-type basidiocarp (Figs 11, 12). The closing of the hymenophore and hymenium by the peridium ultimately led to the formation of a type of finely lacunose gleba, as seen in *Mycenastrum corium* and *Calvatia gigantea* species.

The dispersal of spores of secotioid fungi, intermediate in morphology between agaricoid and gasteroid fungi, no longer occurs with the help of air currents, but largely depends on spreading with the help of animals. The most important agents are small rodents and insects. Water probably plays a minor role, especially runoff and percolating waters, which can carry spores over a certain distance (Thiers 1984).



Fig. 11. *Mycenastrum corium*



Fig. 12. *Calvatia gigantea*

The main morphological and ecological characteristics of agaricoid, secotioid, and gasteroid fungi are compared in Table 1.

Table 1. The similarities and differences between agaricoid, secotioid, and gasteroid fungi

MORPHOLOGY		Agariciod fungi (ex. Agaricus sp.)	Secotioid fungi (*Chlorophyllum agaricoides*, *Montagnea arenaria*)	Gasteroid fungi (*Mycenastrum corium*, *Tulostoma fimbriatum, Calvatia gigantea*)
basidioma		epigeous, gymnocarpic, hemiangiocarpic	epigeous, hemiangiocarpic	hypogeous, epigeous, angiocarpic (cleistocarpic)
	pileus	well differentiated and usually expanding	pileus = shaped peridium, present but incompletely expanding or remaining closed in many forms	typically absent as a differentiated structure
	peridium	typically absent as a differentiated structure	typically absent as a differentiated structure	peridia = exoperidium and endoperidium
	stipe	usually present in the typical agaricoid form	present, often reduced or enclosed within the basidioma (percurrent columella)	absent in many taxa; present and well developed in some groups (ex. *Tulostoma*)
	columella	typically absent as a differentiated structure	columella (sterile tissue in the form of a columella can be percurrent or intercalated throughout the closed gleba)	columella
	sterile tissue	gills	convoluted and anastomosed gills	gleba/capilitium
basidiospore discharge		typically active (ballistospory)	active discharge reduced or lost; typically statismosporic	active discharge generally absent; statismosporic
subsequent dispersal		mainly air currents after active discharge	passive; mechanism varies among taxa	passive; wind, rain, mechanical disturbance, or animals, depending on the taxon

ECOLOGY	terricolous, lignicolous species, saprotrophic, rarely parasitic on plants (moss) or fungi, mycorrhizal (ectomycorrhizal, rarely mycorrhizal with orchids)	terricolous, saprotrophic species – common decomposers of organic matter, such as wood or needles/leaves, found in disturbed xeric regions (Alexopoulos et al., 1996), or they form mycorrhizae with cormophytes	mostly terrestrial species, saprotrophic, mycorrhizal

Conclusions

The species examined in this study illustrate different degrees of hymenophore enclosure and spore-discharge mechanisms and provide morphological examples that can be discussed in the context of the evolutionary model proposed by Thiers (1984).

This hypothesis is based on the forced expulsion of the spores. Thiers (1984) emphasized that this trait was acquired by an early ancestral type, which in turn passed it on to various current groups of Homobasidiomycetes. Otherwise, it would have been necessary for this trait to have appeared de novo in each of the different evolutionary lineages.

Supporting this theory is also the fact that currently, there are no known Homobasidiomycetes that have retained the forcible discharge of spores when the hymenium is enclosed.

In conclusion, there has been natural selection towards this type of basidiocarp, which provides protection against a dry and warm environment.It follows that gasteroid species, with statismospores, are more advanced than agaricoid ones in terms of resistance to adverse living conditions. The transition from active basidiospore discharge (ballistospory) to passive spore liberation and dispersal (statismospory) is associated with substantial modifications in fruiting-body morphology and spore-release mechanisms. Secotioid fruiting bodies exhibit morphological features intermediate between typical agaricoid and fully gasteroid forms. However, extant secotioid species should not be interpreted as direct evolutionary intermediates between extant agaricoid and gasteroid species, because secotioid and gasteroid morphologies have evolved independently in multiple fungal lineages.

Gasteromycetation has occurred independently in multiple lineages of Agaricomycetes. Hymenophore enclosure may provide protection against desiccation, and xeric conditions have been proposed as one selective factor favouring sequestrate fruiting-body forms in some lineages. However, gasteromycetation should not be interpreted as a universal response exclusively driven by moisture limitation.

The species presented, epigeous secotioid and gasteroid, are rare species: *Chlorophyllum agaricoides*, *Montagnea arenaria*, *Mycenastrum corium*, *Tulostoma fimbriatum*, except for *Calvatia gigantea* which is a widespread species. The global level, it would likely qualify as Least Concern (LC) if there were no evidence for any rapid declines (The Global Fungal Red List Initiative 2026).

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