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A PRELIMINARY STUDY OF THE FLORA AND TAXONOMY  
OF THE ORDER LYCOPERDALES (GASTEROMYCETES)  
OF ALBERTA AND NORTHWEST MONTANA

By

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B.Ed., B.Sc., University of Calgary, 1967, 1969.

Presented in partial fulfillment of the requirements

for the degree of

Master of Arts

UNIVERSITY OF MONTANA

1975

Approved by:

Orson K. Miller Jr.  
Chairman, Board of Examiners

Frank Stewart  
Dean, Graduate School

Aug 18, 1975  
Date

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## ABSTRACT

Askew, W. Blain, M.A., 1975. Botany

A Preliminary Study of the Flora and Taxonomy of the Order  
Lycoperdales (Gasteromycetes) of Alberta and Northwest Montana

Director: Orson K. Miller, Jr.

Gasteromycetes in the Order Lycoperdales were collected during four field seasons from 1971 to 1974, in Alberta and Northwest Montana. Thirty-three species in nine genera, including Geastrum, Radiigera, Calbovista, Mycenastrum, Calvatia, Bovista, Disciseda, Vascellum, and Lycoperdon, were identified. At least twenty new records of occurrence are reported for the study area.

Peridial tissue systems of species in the Mycenastraceae and Lycoperdaceae are newly described. Information on the development and morphology of tissues is presented which suggests a number of new relationships among the genera and species of the Lycoperdales. A complete description of all tissues of Disciseda defodioidis is reported for the first time.

Substrates and habitats are described for each species. In addition, new ecological information is presented, including observed fruiting periods, and sporophore development under field conditions.

Camera lucida drawings along with some black and white photographs of salient taxonomic features are included.



## ACKNOWLEDGMENTS

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The loan of specimens from the USDA National Fungus Collections, Beltsville, Maryland, made confirmations of many species possible and is greatly appreciated.

## CONTENTS

ABSTRACT . . . . .	ii
ACKNOWLEDGMENTS . . . . .	iii
LIST OF ILLUSTRATIONS . . . . .	vi
LIST OF PLATES . . . . .	vii
Chapter	
I. INTRODUCTION . . . . .	1
Scope of the Problem . . . . .	1
Review of the Modern Literature . . . . .	2
The Study Area . . . . .	4
Alpine Tundra . . . . .	4
Krummholz . . . . .	5
Low-Alpine and Foothills Forest . . . . .	5
Aspen Parklands . . . . .	5
Northern Coniferous Forest . . . . .	6
Transition Zones . . . . .	6
Habitats and Distribution . . . . .	7
II. MATERIALS AND METHODS . . . . .	9
III. TAXONOMY OF THE ORDER LYCOPERDALES . . . . .	12
Family I. Geastraceae . . . . .	13
<u>Geastrum</u> Persoon . . . . .	13
Family II. Mesophelliaceae . . . . .	27
<u>Radiigera</u> Zeller . . . . .	27
Family III. Mycenastraceae . . . . .	30
<u>Calbovista</u> Morse . . . . .	30
<u>Mycenastrum</u> Desvaux . . . . .	34
Family IV. Lycoperdaceae . . . . .	37
<u>Calvatia</u> Fries . . . . .	38
<u>Bovista</u> Persoon . . . . .	55
<u>Disciseda</u> Czerniaiev . . . . .	67
<u>Vascellum</u> Smarda . . . . .	74
<u>Lycoperdon</u> Tournefort ex Persoon . . . . .	77
IV. CONCLUSIONS . . . . .	100

ILLUSTRATIONS . . . . . 104

PLATES . . . . . 148

LITERATURE CITED . . . . . 156

## LIST OF ILLUSTRATIONS

### Figure

1.	The Study Area in the Pacific Northwest . . . . .	104
2.	Vegetation Regions in the Study Area . . . . .	106
3.	Cross-Sectional Illustrations of Features Characteristic of the Geastraceae, Mesophelliaceae, and Lycoperdaceae . . . . .	108
4.	Schematic Illustrations of Terminology Applying to <u>Geastrum</u> spp. . . . .	110
5.	Schematic Illustrations of Terminology Applying to Spore Ornamentation . . . . .	112
6.	Spores of <u>Geastrum</u> spp. and <u>Radiigera fuscogleba</u> . . . . .	114
7.	Spores of <u>Calbovista subsculpta</u> , <u>Mycenastrum</u> <u>corium</u> , and <u>Calvatia</u> spp. . . . .	116
8.	Spores of <u>Bovista</u> spp. and <u>Disciseda</u> spp. . . . .	118
9.	Spores of <u>Vascellum curtisii</u> and <u>Lycoperdon</u> spp. . . . .	120
10.	Basidia of <u>Geastrum</u> spp. and <u>Radiigera fuscogleba</u> . . . . .	122
11.	Basidia of <u>Mycenastrum corium</u> , <u>Calvatia fumosa</u> , and <u>Bovista</u> spp. . . . .	124
12.	Basidia of <u>Disciseda defodioidis</u> and <u>Lycoperdon</u> spp. . . . .	126
13.	Capillitium of <u>Geastrum</u> spp. and <u>Radiigera</u> <u>fuscogleba</u> . . . . .	128
14.	Capillitium of <u>Calbovista subsculpta</u> , <u>Mycenastrum</u> <u>corium</u> , and <u>Calvatia</u> spp. . . . .	130
15.	Capillitium of <u>Calvatia</u> spp. . . . .	132
16.	Capillitium of <u>Bovista</u> spp. . . . .	134
17.	Complete Capillitial Units of <u>Bovista echinella</u> . . . . .	136
18.	Capillitium of <u>Disciseda</u> spp. and <u>Lycoperdon</u> spp. . . . .	138
19.	Peridial Cells of <u>Calbovista subsculpta</u> and <u>Calvatia</u> spp. . . . .	140
20.	Peridial Cells of <u>Bovista</u> spp. and <u>Disciseda defodioidis</u> . . . . .	142
21.	Peridial Cells of <u>Vascellum curtisii</u> and <u>Lycoperdon</u> spp. . . . .	144
22.	Peridial Cells of <u>Lycoperdon</u> spp. . . . .	146

# LIST OF PLATES

## Plate

1. Capillitial Elements of Calbovista subsculpta  
and Mycenastrum corium . . . . . 148
2. Capillitial Elements of Bovista minor  
and B. pila . . . . . 150
3. Capillitial Elements of Bovista plumbea  
and B. tomentosa . . . . . 152
4. Geastrum pectinatum mature; endoperidial  
tissue of Calbovista subsculpta . . . . . 154

## CHAPTER I

### INTRODUCTION

#### Scope of the Problem

Until this study was begun, the Gasteromycete fungi had not been collected and studied to any significant extent in Alberta. Except for the Nidulariaceae (Brodie 1966-70), there are no published accounts of the Alberta species. Available data on the Gasteromycetes of the Pacific Northwestern States is incomplete. In the light of the unique and varied combinations of habitat and climate that exist in the area, these deficiencies leave a serious gap in the floristic knowledge of the North American fungi.

Published taxonomic accounts of the Gasteromycetes have traditionally been based on the gross morphology of the fruiting body and the microscopic character of spores and capillitium. Only very recently have attempts been made to use peridial cell characteristics as integral components of the species concepts. Most notably, Hanns Kreisel (1962, 1967), and Vincent Demoulin (1969, 1971, 1972) have established the use of these microscopic features as part of the taxonomic data on the Gasteromycetes.

It is therefore considered appropriate at this time to extend the use of all cellular structures of the sporophore in the taxonomic descriptions, and to increase the floristic knowledge of the

Gasteromycetes of the Pacific Northwest. The Order Lycoperdales, which contains most of the fungi commonly known as "puffballs", will form the topic of this thesis.

The following objectives were established for the study:

1. To compile a preliminary list of species in the Order Lycoperdales found in the study area and to chart their distribution and ecology as time and circumstances allow.
2. To determine the microscopic character of the peridia of the specimens collected, in addition to the traditionally described components of the fruiting bodies.
3. To follow the development of the sporophore in selected species.
4. To incorporate all observed data into revised taxonomic descriptions of the species.

#### Review of the Modern Literature

Many publications concerning the Lycoperdales have been produced since the beginning of the twentieth century, as papers, monographs, or as components of general works on the Gasteromycetes.

Major studies dealing with the Gasteromycetes in general include those for Eastern North America (Coker & Couch 1928), Ohio (Johnson 1929), Iowa (Kambly & Lee 1936), Australia and New Zealand (Cunningham 1942), Michigan (Smith 1951), Norway (Eckblad 1955), and Belgium (Demoulin 1969). All of those works are pertinent to this study as they contain data on many species of the Lycoperdales found in the study area.

Some genera have received comprehensive treatments, including Lycoperdon (Lohman 1927, Bowerman 1961), Geastrum (Longnecker 1927,

Long & Stouffer 1948, Dissing & Lange 1961), Radiigera (Zeller 1944), and Calvatia (Zeller & Smith 1964). These revisions are very useful references for Alberta and Montana. They present problems in taxonomy and nomenclature which can only be resolved by revisions of these genera on a worldwide basis.

Contributions to taxonomic and distribution data have been made in a number of shorter papers. Morten Lange (1948) described 11 species of the Lycoperdales from Greenland. Bowerman & Groves (1962) reported 19 from Northern Canada, and O. K. Miller, Jr. (1969) described 5 notable species from Alaska and the Yukon. Several of the species in these papers fruit in the alpine and northern regions of the area covered in this thesis.

Papers on general topics prove useful in studying the Lycoperdales in Alberta and Montana. Emended descriptions of a number of species of Disciseda by S. M. Zeller (1947) are not found in any other reference materials. Zeller's keys (1949) provide useful assistance in determining the placement of confusing or less common species, or genera seen for the first time. J. T. Palmer (1955) gives very detailed descriptive and general data for several species of Gaeastrum, including data on basidia that are not clearly reported elsewhere, and in his catalog to Gasteromycete literature (1968) furnishes useful lists of references to many species found in the study area.

Numerous other papers concerning individual species or techniques provide information useful in checking one's own observations, and give direction for further investigations.

Although the pre-1960 taxonomic literature is valuable to the



mycologist as reference material, almost all of it is based on characters of the fruiting body excluding the microscopic character of the peridia, and is therefore in need of revision. Such revisions began appearing after 1960 in Europe. Hanns Kreisel included a few microscopic peridial features in his local revision of the Lycoperdaceae (1962), and increased his use of them to form part of the species concepts in his revision of the genus Bovista (1967). Vincent Demoulin has used these characters as part of the species concepts for Lycoperdon in a number of papers since 1968, and in his revision of the genus which is still in preparation.

### The Study Area

The area selected for study (Fig. 1) includes the mountain and foothill regions of the Rocky Mountains from northern Montana to central Alberta, the Aspen Parkland region of central Alberta, the southern fringes of the Northern Coniferous Forest, and the associated transition zones. These areas contain diverse vegetation types (Fig. 2), and many different plant associations.

### Alpine Tundra

Small areas of unglaciated alpine tundra, beginning at approximately 8000 ft. altitude, are easily accessible in the Kananaskis region of southern Alberta. Patterned ground of lichen-covered rocks and boulders, dense moss mats, thin soil bearing many species of small herbs, and dwarf trees and shrubs characterize this biome. The flora, including the Gasteromycetes that were collected there, is similar to that generally reported for arctic tundra.

### Krummholz

This alpine biome supports a flora similar to that of the taiga regions of the arctic or subarctic, and in the study area exists at altitudes from approximately 7000 to 8000 feet. Broad expanses of open grassland dotted with stunted shrubs and coniferous trees are the common vegetation patterns.

### Low-Alpine and Foothills Forest

These areas contain a wide variety of conifer associations, and yield many species of Gasteromycete fungi. The most frequently encountered forest stands in northwestern Montana include Pinus ponderosa Dougl. (in dry habitats), Picea engelmannii Parry, Abies grandis (Dougl.) Lindl., Pseudotsuga menziesii (Mirb.) Franco, Larix occidentalis Nutt., Thuja plicata D. Donn, Tsuga heterophylla (Raf.) Sarg., and Abies lasiocarpa (Hook.) Nutt. Proceeding northward toward central Alberta, those species are replaced by Pinus contorta Dougl. (the major tree species), Picea glauca (Moench) Voss, Picea mariana (Mill.) B.S.P., Larix lyallii Parl., Larix laricina (Du Roi) K. Koch, with scattered occurrences of Populus spp., and Abies lasiocarpa remaining at higher altitudes. Sphagnum bogs are not uncommon in these areas.

### Aspen Parklands

The vegetation in the Aspen Parklands typically consists of scattered, sometimes large, groves of Populus tremuloides Michx., commonly with Symphoricarpos occidentalis Hook. and Rosa acicularis Lindl., and a wide variety of herbs. Several species of Salix grow

at the outer edges and in clearings within the groves, and in very wet places throughout the region. Most of the land is under agricultural cultivation, but where the natural state is observable the base vegetation is composed of grass species and many small herbs and shrubs.

Stands of Picea glauca occur along riverbanks and in wet areas of the Parklands; mixed stands of P. glauca and Populus tremuloides, often with some Betula papyrifera Marsh, occur in many low-lying wet or boggy places.

#### Northern Coniferous Forest

Only the southern fringes of this region, approaching the transitional state, exist in the study area. Larix laricina, Pinus contorta, Picea glauca, P. mariana, Betula papyrifera, Populus tremuloides, and Abies balsamea (L.) Mill. are the common tree species, often with several of them occurring together as "mixed woods". Sphagnum grows among the trees and in bogs in many places.

#### Transition Zones

The zones of transition exist along the boundaries between the vegetational regions (Fig. 2), where the vegetation typical of one region gradually disappears and that of the neighboring region gradually replaces it. This study provided insufficient data to show any such transitions among the fungi in the study area, except as they are associated with specific higher plants, substrates, or climatic conditions that exist in those zones.

### Habitats and Distribution

The data included here have been compiled from four seasons of fieldwork. During that time each habitat type in the study area was subjected to a variety of climatic conditions, which brought about the fruiting of many different Gasteromycetes. The Order Lycoperdales was found to be the most completely represented and the most commonly collected group.

Of the 6 families in the Lycoperdales (Zeller 1949), 4 were found to occur in the study area: Lycoperdaceae, Mycenastraceae, Mesopheliaceae, and Geastraceae. Among these, 9 genera including 33 species were collected.

As might be expected, areas with similar vegetation types and environmental factors possessed very similar Gasteromycete floras. Lycoperdon molle was collected in groves of Populus tremuloides in the Aspen Parklands and the Northern and Foothills Forests and their transition zones, and in small stands of Populus balsamifera L. in the Parkland-Prairie Grassland transition. Lycoperdon pusillum was found on semi-shaded moist soil, and L. polymorphum on open pasture soil throughout the area. Bovista plumbea was also common in all regions on exposed grassland of a variety of types. Calvatia fumosa and Calbovista subsculpta were collected on compacted soil at higher altitudes in the mountainous regions. Calvatia cyathiformis was found growing only in the Populus groves in the Aspen Parklands, as was Lycoperdon pedicellatum.

Many small open areas of grassland were found at various locations throughout the study area where, although the mean annual

precipitation was moderate, the light and sandy nature of the soil resulted in semi-arid conditions during the dry periods of the summer. Gasteromycetes characteristic of these areas include Calvatia bovista, Geastrum recolligens, G. minimum, Disciseda candida, D. defodioidis, and Vascellum curtisii. Tulostoma simulans Lloyd, an indicator of arid habitats, was also collected in many of these areas.

Lycoperdon perlatum, L. pyriforme, and L. umbrinum appeared to have no restrictions on their habitat and distribution. They were among the most commonly collected species, growing in all regions of the study area.

## CHAPTER II

### MATERIALS AND METHODS

Because fungi in the Order Lycoperdales remain intact well after maturity, it was possible to collect fresh, mature, and aged specimens of many of the species. When it was impossible to get fresh plants to the laboratory within a sufficiently short time to maintain their fresh condition, portions of them were killed and preserved in Newcomer's solution (Newcomer 1953), and the remainder dried. Fragile mature or aged specimens had to be transported from the field in containers with rigid compartments to avoid damage.

Peridial and glebal sections for microscopic study were made freehand, using elder pith and a sectioning razor. Sections of peridia were taken approximately midway between the apex of the fruiting body and the top of the sterile base, of fresh or preserved immature plants (when they were available), and of mature ones in order to observe the full range of character variation. To find fully formed basidia it was necessary to obtain specimens in the very early stages of the maturing process, when the color change was just beginning in the gleba. Capillitium and spores were measured and described from completely matured sporophores.

Portions of dried or mature dry tissues were revived for sectioning and mounting by immersing them in 95% ethyl alcohol and then soaking them in water. Mounts of all tissues were made in 3% KOH and

in Melzer's solution for microscopic examination. Spore ornamentation was studied by adding 0.5% or stronger aqueous methylene blue to the KOH mountant; 1% aqueous phloxine was added to stain glebal elements and hyaline tissues.

Microscopic observations were made using a Leitz SM-LUX microscope fitted with mounts for a camera lucida and a 35 mm. photographic camera. All drawings of microscopic features were made with the aid of a camera lucida.

Kornerup & Wanscher (1967) color designations as reported in the taxonomic descriptions here are in accordance with the directions for notation given by those authors. The plates of brown color variations illustrated in that book were sometimes found to be inadequate for parts of some specimens, in which cases no specific designation could be given.

Measurements of certain features, for which the size range is not significant, were determined as a range of maximums among all collections of the species (e.g. "up to 5-8 mm."). Spores were measured excluding their ornamentation. In instances when it was not possible to observe one or more features, they were omitted from the species description.

The data recorded here are those that were observed on the collections made by the author. Size and other features of the North American species may vary outside the ranges indicated here. Fruiting periods observed in the study area do not necessarily indicate the fruiting periods at other locations in the Pacific Northwest (Miller 1972).

Most of the specimens examined were from the author's own collections (prefixed "BA"). Specimens indicated by "BPI" were obtained on loan from the USDA National Fungus Collections, Beltsville, Maryland.



## CHAPTER III

### TAXONOMY OF THE ORDER LYCOPERDALES

The fruiting bodies of the plants in this order typically consist of 2-4 peridial layers surrounding a fertile gleba and sometimes a sterile subgleba beneath. The gleba becomes a mass of dry, powdery capillitium and spores at maturity. In most species the peridial layers dehisce in one of several ways to allow the spores to escape.

#### Key to the Families of Lycoperdales

1. Peridium of 3-4 layers, gleba with a distinct sterile pseudocolumella (Fig. 3i, ii, iii); opening stellately at maturity, or indehiscent ..... 2
1. Peridium of 2 layers (Fig. 3iv), gleba without a sterile pseudocolumella ..... 3
2. Outer peridia dehiscing stellately to elevate the endoperidium (spore case), (Fig. 4a) ..... Page 13. Geastraceae
2. Outer peridia indehiscent ..... Page 27. Mesophelliaceae
3. Capillitium of short discrete units with thornlike projections or short antler-like branches (Plates 2 & 3) ..... Page 30. Mycenastraceae
3. Capillitium not as above (Figs. 14c-18, Plates 2 & 3) ..... Page 37. Lycoperdaceae

Family I. Geastraceae

Geastrum is the only genus of this family that was found in the study area.

Geastrum Persoon

Syn. Meth. Fung. 131. 1801.

Unopened sporophore (button) globose, subglobose or slightly depressed, often with a long or short conic apical point, hypogeous to emergent. Peridium of 3 or 4 layers (Fig. 3 i, ii): exterior layer (universal mycelium) of loosely interwoven white mycelium, absent on some species; second layer (exoperidium) fibrous, thin and tough; third layer (mesoperidium) thick and fleshy, composed of pseudoparenchymatous tissue of enlarged cells; interior layer (endoperidium) very thin, tough, adherent to the gleba. Outer peridial layers dehiscing stellately at maturity to elevate the endoperidium which remains intact and acts as a spore case, sometimes supported by a short pedicel (Fig. 4a). Endoperidium opening by an apical pore, usually at the centre of a conic or tubular projection (peristome, Fig. 4a), which may be delimited by a ring of different color or texture than the spore case. Gleba with an obvious sterile pseudocolumella, from which the basidia-bearing hyphae and capillitial elements radiate toward the endoperidium; capillitium of long elements, seldom branched, with walls very much thickened. Basidia capitate, multi-spored (Fig. 10). Spores globose to subglobose, densely warted (Fig. 6).

Type Species: Geastrum coronatum Persoon.

Key to the Species of Geastrum

1. Rays hygroscopic (becoming extended when wet), smooth and silvery white on the exterior, becoming detached from the soil and blown about by wind in late maturity ..... Page 15. G. recolligens
1. Rays non-hygroscopic ..... 2
2. Peristome indeterminate, mouth fimbriate, rays saccate (Fig. 4f) ..... Page 16. G. fimbriatum
2. Peristome determinate, of different color or texture than the spore case, rays saccate or otherwise ..... 3
3. Peristome sulcate (Plate 4a), spore case and inner surface of rays covered with dark brown powdery material ..... Page 18. G. pectinatum
3. Peristome not sulcate, brown powdery material absent..... 4
4. Spore case sessile, rays often saccate, peristome determinate ..... Page 19. G. triplex
4. Spore case on a pedicel with a more or less distinct apophysis (Fig. 4a) ..... 5
5. Universal mycelium (Fig. 3i) not present, outer layer of rays separating from the rest except at the tips, spores 3.5-4.5  $\mu$  in diameter ..... Page 21. G. limbatum
5. Universal mycelium present with adherent debris, spores 4.5-5.5  $\mu$  in diameter ..... 6
6. Universal mycelium remaining adherent to the rays, spores with broad rounded warts (Fig. 5a), rays 8-23 mm. across the tips, spore case 3-9 mm. broad ..... Page 23. G. minimum
6. Universal mycelium remaining in the ground and joined to the rays at the tips (forficulate, Fig. 4g), spores with truncate warts (Fig. 5c), plants larger ..... Page 25. G. quadrifidum

Geastrum recolligens (Woodw. ex Relh. em. Sow.) Desvaux.

Journ. de Bot. 2: 102. 1809.

Figs. 6, 13.

Syn.: G. mammosum Chev. Fl. Paris. 359. 1836.

#### Mature Macroscopic Features

Spore case 0.6-1.5 cm. broad, depressed globose and often collapsed under pressure from the involuted rays (Fig. 4e), sessile; dull light grey to grey-brown.

Peristome slightly mammosose to short conic, ca. 1 mm. high, radially fibrillose and lighter in color than the spore case, sometimes obscure after maturity; mouth fimbriate, less than 0.5 or up to 2.0 mm. broad.

Rays 7-11, divided  $2/3$  to  $3/4$  of their radius, hygroscopic and involute to or over the spore case when dry, expanded diameter up to 3-4 cm. with the tips extended; exterior surface of exoperidium smooth and without adherent debris, light grey to silvery or almost white in age; mesoperidium remaining intact, smooth and entire upon drying and in age, becoming dull dark brown to nearly black.

Gleba very dark brown.

#### Mature Microscopic Features

Spores 4-5  $\mu$  diam., globose to slightly subglobose, densely covered with rounded warts ca. 0.5  $\mu$  long; yellow-brown to brown in KOH, brighter in Melzer's solution.

Capillitium moderately to heavily encrusted with debris, branching not evident (Fig. 13a); up to 5-8  $\mu$  diam., walls thickened so that the lumen appears as a thin line broadening in a few places; pale

yellow-brown in KOH, brighter in Melzer's solution.

#### Habitat and Distribution

On open dry sandy soil among short grasses, with many sporophores widely scattered over a large area. Fruiting period not observed.

Specimens examined: BA 263, Bittern Lake, Alberta; BA 347, Nose Hill, Calgary, Alberta; BA 354, Carbon, Alberta.

#### Discussion

This distinctive species was found in some places loosened from the soil and being blown about by the wind. It was collected close to Tulostoma simulans, which indicates the dry habitat conditions under which it grows. Only well-matured specimens were found; two of the collections made were undoubtedly overwintered.

This was the only hygroscopic species found in the study area.

Geastrum fimbriatum Fries. Syst. Myc. 3: 16. 1829. Fig. 6.

Syn.: G. rufescens Pers. em. Van Waveren. Med. Ned. Myc.  
Ver. 15: 118. 1926.

#### Mature Macroscopic Features

Spore case 0.9-2.0 cm. broad, globose to subglobose; nearly sessile or with a pedicel 1 mm. long or less and 4-8 mm. thick, usually laterally flattened, apophysis (Fig. 4a) more or less pronounced; brown to dark brown, (6-7)(E-F)(5-6).

Peristome raised or nearly conic, 1.5-3.0 mm. high, irregularly wrinkled and folded, indeterminate; mouth fimbriate, 1-4 mm. broad and often folded closed.

Rays 6-9, divided ca. 1/2 of their radius, recurved to shallowly

saccate with the tips usually strongly revolute (Fig. 4d), expanded diameter up to 2.5-5.0 cm. with the rays in their revolute position; universal mycelium remaining loosely adherent to the rays holding a small or large amount of debris, becoming detached in age; mesoperidium brown when dry, 7E(5-6).

Gleba dark brown.

#### Mature Microscopic Features

Spores 3.0-3.5(-4.0)  $\mu$  diam., globose, covered with truncate warts ca. 0.5  $\mu$  long; pale yellow-brown in KOH, brighter in Melzer's solution.

Capillitium lightly encrusted with debris in some portions, branching not evident; up to 7-9  $\mu$  diam., walls thickened so that the lumen appears as a thin line broadening in a few places; nearly hyaline or pale yellowish in KOH, pale yellowish in Melzer's solution.

#### Habitat and Distribution

On thick needle duff under Picea glauca on a wet river valley slope; sporophores growing in small groups. Buttons opening in late September.

Specimens examined: BA 346, 363, Camrose, Alberta.

#### Discussion

This species was found in one location only. No immature plants could be located during the two summers that the mature fruiting bodies were found.

Geastrum fimbriatum can be keyed to G. rufescens Persoon in much of the literature. Two collections from the Lloyd herbarium (BPI)

determined by Lloyd to be G. rufescens were examined and found to have spores and peristomes similar to those of G. fimbriatum. However, the spore cases of Lloyd's plants were supported on pedicels up to 2 mm. high with unmistakable smooth, saucer-shaped apophyses which have not been found described in any of the literature available.

Geastrum pectinatum Persoon. Syn. Meth. Fung. 132. 1801.

Figs. 6, 13; Plate 4a, b.

#### Mature Macroscopic Features

Spore case 1.1-2.3 cm. broad x 0.9-1.1 cm. high, depressed globose; pedicellate, pedicel 3-8 mm. long x 1-4 mm. thick and often laterally flattened, apophysis distinct, slightly enlarged and faintly to strongly sulcate; dark grey, covered with dark brown powdery material.

Peristome narrowly conic, up to 5 mm. high, strongly sulcate (Plate 4a) beneath a covering of dark brown powdery material; mouth less than 0.5 mm. broad.

Rays 4-8, divided unequally ca. 1/2 of their radius, recurved to vaulted (Fig. 4b, c), expanded diameter 4-8 cm. with the tips extended; universal mycelium remaining adherent to the rays and holding a large amount of debris; mesoperidium extending upward at the centre to form a sheath around the pedicel (Plate 4b) and shrinking away completely on drying, dull dark grey-brown beneath a covering of dark brown powdery material.

Gleba very dark brown.

### Mature Microscopic Features

Spores 4.0-5.5  $\mu$  diam., globose, covered with truncate warts 1.0-1.5  $\mu$  long; brown in KOH, dark brown in Melzer's solution.

Capillitium encrusted with debris in some portions, branching not evident (Fig. 13b); up to 6.0-9.5  $\mu$  diam. with walls thickened so that the lumen appears as a thin line; brown in KOH, dark brown in Melzer's solution.

### Habitat and Distribution

Emergent from thick needle duff under Picea glauca on wet river valley slopes; plants growing scattered over a wide area. Buttons opening in late September.

Specimens examined: BA 344, Camrose, Alberta.

### Discussion

The distinctive features of this fungus make it one of the most easily recognized species in the study area. Unopened buttons could not be located.

Geastrum triplex Junghuhn. Tijdschr. Natuurl. Gesch. et Physiol.

7: 287. 1840.

Figs. 6, 10, 13.

### Immature Features

Unopened button 1.8-3.5 cm. broad, globose or subglobose with a conic apical point up to 0.5-1.0 cm. long; surface without adherent debris, with a shallow pattern of fissures which often form scales; orange-brown to light brown, (5-6)C(5-7); hypogeous to emergent, with basal mycelium (Fig. 3i) extending to a mass of white mycelium just



beneath the surface of the substrate.

Mesoperidium staining pinkish-brown when cut or bruised, darkening to red-brown.

Basidia 11.0-14.5 x 5.5-9.5  $\mu$ , capitate (Fig. 10a), multi-spored with 5-8 usually observable.

#### Mature Macroscopic Features

Spore case 1.5-3.0 cm. broad, depressed globose, sessile; grey-brown to brown, 5D(3-5).

Peristome broadly conic, up to 2-3 mm. high, radially fibrillose, outlined by a circular zone lighter in color than the spore case and up to 1 cm. diam.; mouth fimbriate and sometimes lacerated, up to 4 mm. broad.

Rays 4-7, divided ca.  $\frac{3}{4}$  of their radius; usually saccate (Fig. 4f) with revolute tips, expanded diameter up to 7.5-11.0 cm. with the tips extended; exterior surface of exoperidium smooth; mesoperidium orange-brown, 5(B-C)(3-4), often split in a circle around the zones of ray reflex so that the central portion forms a "bowl" beneath the spore case.

Gleba dark brown, (5-6)F8.

#### Mature Microscopic Features

Spores 3.5-4.5  $\mu$  diam., globose, densely covered with truncate warts 1.0(-1.5)  $\mu$  long; light brown in KOH, rusty brown in Melzer's solution.

Capillitium heavily encrusted with debris, unbranched (Fig. 13c); up to 5.5-8.5  $\mu$  diam. with walls thickened so that the lumen appears as

a thin line; pale yellow-brown in KOH, rusty brown in Melzer's solution.

#### Habitat and Distribution

On soil rich in leaf litter or decayed wood under various conifers and Populus spp., growing in small scattered groups. Buttons forming in early July, opening from late August to mid-September.

Specimens examined: BA 281, 282, below Mission Falls, Lake Co., Montana; BA 348, Red Deer, Alberta; BA 366, Camrose, Alberta; C.G. Lloyd 5031 (BPI), Toledo, Ohio; C.G. Lloyd 5180 (BPI), Fort Dodge, Iowa.

#### Discussion

The "bowl" beneath the spore case, formed when the mesoperidium splits under tension, was found to be present on one or two specimens in most collections, but not consistently enough to be used as a key character. The species may be determined by the combination of the characters of the peristome, spores, and capillitium.

Geastrum limbatum Fries. Syst. Myc. 3: 15. 1829. Figs 6, 10.

#### Immature Features

Unopened button 2.5-3.5 cm. broad, globose or slightly depressed, with a conic apical point up to 5 mm. long; surface without adherent debris, more or less scaly, light brown (near 6E6); hypogeous to emergent, with a basal mycelium (Fig. 3i) extending to a dense mass of white mycelium just beneath the surface of the substrate.

Basidia 11-13 x 7.0-8.5  $\mu$ , capitate (Fig. 10b), multi-spored with

4-8 usually observable.

#### Mature Macroscopic Features

Spore case 1.2-2.5 cm. broad, globose to depressed globose; pedicellate, pedicel 0.5-3.0 mm. long x 3-6(-8) mm. thick and often laterally flattened, apophysis present but often indistinct; dull grey-brown, near 6E5.

Peristome slightly raised or broadly conic and up to 2 mm. high, outlined by a circular zone slightly lighter in color than the spore case and often not evident on old specimens; mouth fimbriate, 1-3 mm. broad.

Rays 5-10, divided ca. 1/2 of their radius and often secondarily divided, recurved to vaulted with the tips usually involute (Fig. 4), expanded diameter up to 8 cm. with the tips extended; exoperidium without adherent debris, outer layer separating from the inner layers over the central portion and remaining attached at the tips; mesoperidium light brown, 6D6, drying to very dark brown.

Gleba dark brown, (6-7)F(6-8).

#### Mature Microscopic Features

Spores 3.5-4.5  $\mu$  diam., globose, densely covered with truncate warts 0.5-1.0  $\mu$  long; light brown in KOH, bright yellow-brown in Melzer's solution.

Capillitium lightly encrusted with debris in places, seldom branched; up to 7-9  $\mu$  diam. with walls thickened so that the lumen appears as a thin line; light yellow-brown to brown in KOH, brighter in Melzer's solution.

## Habitat and Distribution

On soil and grassland debris, or on soil and sawdust, among herbs in forest clearings; growing singly or in groups of close sporophores, buttons often gregarious or caespitose; opening in late August.

Specimens examined: BA 26, below Jewel Basin, Flathead Co., Montana; BA 155, 183, 294, Ashley Lake, Flathead Co., Montana; C.G. Lloyd 22430 (BPI), Milwaukee, Wisconsin; C.G. Lloyd 22441 (BPI), Madison, Wisconsin.

## Discussion

The separation of the outer layer of the rays is perhaps the most striking feature of this fungus. A black colored form of Geastrum limbatum was described as a variety by E.E. Morse (1942), but this was not adhered to by some other authors (Long & Stouffer 1948). The black form is the common one reported from Europe.

Geastrum minimum Schweinitz. Syn. Fung. Carol. Schrift. Naturf.

Gesell. 1: 116. 1822.

Fig. 6.

## Mature Macroscopic Features

Spore case 3-9 mm. broad, globose to subglobose; pedicellate, pedicel very narrow, up to 1.0-1.5 mm. long, apophysis distinct; light brown, (5-6)D4, covered with very fine white particles which give a greyish appearance, becoming dark brown in age.

Peristome short-conic, ca. 0.5 mm. high, outlined by a zone of lighter color than the spore case, light colored zone delimited by a very narrow circular groove which may not be evident in age, radially

fibrillose; mouth fimbriate, less than 0.5 mm. broad.

Rays 5-9, more or less unequally divided  $1/3$  to  $1/2$  of their radius, plane to slightly recurved or vaulted (Fig. 4), expanded diameter 0.8-2.3 cm. with the tips extended; universal mycelium remaining adherent to the rays and holding a large amount of sand and debris; mesoperidium orange-brown upon drying, 6C(4-5).

Gleba dark brown, 7F8.

#### Mature Microscopic Features

Spores (4.0-)4.5-5.5  $\mu$  diam., globose to subglobose, seldom irregular, covered with broad rounded unequal warts ca. 0.5  $\mu$  long; brown in KOH, rusty brown in Melzer's solution.

Capillitium lightly encrusted with debris in a few places, seldom branched, often sinuous to crooked in the narrow portions; up to 5.5  $\mu$  diam. with walls thickened so that the lumen appears as a thin line broadening in a few places; pale yellow to yellow-brown in KOH, brighter in Melzer's solution.

#### Habitat and Distribution

On open dry sandy soil among grasses, growing singly and widely scattered. Buttons opening from early to mid-August.

Specimens examined: BA 264, 349, Bittern Lake, Alberta; BA 356, Camrose, Alberta.

#### Discussion

This is the smallest of the geasters, and is often hidden from view beneath the grass. This perhaps explains why it is not more commonly reported. No success was had in finding unopened buttons.

This species has many characteristics in common with Geastrum quadrifidum including color, peristome character, and the white particles on the spore case, but is easily separated on the basis of the spores and the character of the rays.

Geastrum quadrifidum Persoon. Syn. Meth. Fung. 133. 1801;

em. Persoon, Journ. de Bot. 2: 26. 1809.

Fig. 6.

#### Immature Features

Unopened button 1.2-2.0 cm. broad, globose to depressed globose; exterior layer a universal mycelium (Fig. 3i) which stains pink when handled or bruised, with adherent debris; exoperidium staining pink when cut or bruised; hypogeous to emergent.

#### Mature Macroscopic Features

Spore case 0.5-1.0 cm. broad x 0.7-1.5 cm. high, subglobose to somewhat oblong; pedicellate, pedicel 1-2 mm. long x 1-2 mm. thick, apophysis distinct; light grey-brown, near 6C(2-3), covered with very fine white particles, becoming dark brown to purple-brown in age.

Peristome slightly raised to broadly conic and up to 4 mm. high, radially fibrillose, outlined by a light colored zone which may be formed as a slightly elevated flat disc, sometimes delimited by a narrow groove or a small ridge; mouth fimbriate, 0.5-1.0(-2.5) mm. broad.

Rays 4(-6), divided  $\frac{2}{3}$  to  $\frac{3}{4}$  of their radius, recurved to vaulted (Fig. 4b, c), expanded diameter up to 3-4 cm. with the tips extended; universal mycelium separating from the centre of the rays and remaining cuplike in the ground, attached to the rays only at their

tips (fornicate, Fig. 4g), often with a pink tint when fresh; exoperidium smooth, white to cream and often with a pink tint when fresh; mesoperidium greyish orange, 5B3, to light brown, 6D4, becoming dark brown in age.

Gleba very dark brown to nearly black.

#### Mature Microscopic Features

Spores (3.5-)4.5-5.0(-5.5)  $\mu$  diam., globose to subglobose, densely covered with truncate warts 0.5(-1.0)  $\mu$  long; yellow-brown to dark brown in KOH, rusty brown to dark red-brown in Melzer's solution.

Capillitium lightly encrusted with debris in some portions, branching not evident; up to 6-8  $\mu$  diam. with walls thickened so that the lumen appears as a thin line; yellow-brown to dark brown in KOH, slightly darker in Melzer's solution.

#### Habitat and Distribution

On or emergent from needle duff under fir or spruce, growing separate and scattered. Buttons opening from early to late September.

Specimens examined: BA 298, Peterson Cr. Trail, Lake Co., Montana; BA 343, 345, Camrose, Alberta; BA 350, Lacombe, Alberta.

#### Discussion

The pink staining button was a constant feature of the specimens collected, and has not been seen on any other geasters. Although a number of buttons were found, they were not in a stage when basidia are intact.

Family II. Mesophelliaceae

Radiigera is the only genus of this family that was found in the study area, represented by R. fuscogleba as the only species collected.

Radiigera Zeller

Mycologia 36: 628. 1944.

Sporophore depressed globose, hypogeous to emergent. Peridium indehiscent, of three layers (Fig. 3iii): exterior layer (exoperidium) fibrous, thin and tough; second layer (mesoperidium) thick and fleshy, composed of pseudoparenchymatous tissue of enlarged cells; interior layer (endoperidium) very thin and fragile, adherent to the gleba. Gleba succulent, with a large sterile pseudocolumella (Fig. 3iii) from which the basidia-bearing hyphae and capillitial elements radiate toward the endoperidium; capillitium of long elements, seldom branched with walls very much thickened. Basidia capitate, multi-spored (Fig. 10c). Spores globose, densely warted (Fig. 6h).

Type Species: Radiigera fuscogleba Zeller.

Radiigera fuscogleba Zeller. Mycologia 36: 633. 1944.

Figs. 6, 10, 13.

Macroscopic Features

Sporophore 4.0-6.5 cm. broad x 3-4 cm. high when fresh, depressed globose; hypogeous, usually emergent before maturity.

Peridium 3-layered: exoperidium ca. 1 mm. thick, tough, white, staining pinkish brown and darkening to red-brown when cut or bruised, maturing and drying to various shades of brown or dark brown;



mesoperidium up to 4-6 mm. thick, tough, white, staining as the exoperidium when cut or bruised, drying to a thickness of 1 mm. or less; endoperidium very thin, adhering closely to the glebal mass at maturity.

Opening by the action of environmental forces, frequently remaining intact over winter.

Attached to the substrate by coarse white basal mycelium (Fig. 3iii) extending to a dense layer of white mycelium beneath the surface of the substrate.

Gleba soft and succulent, with a large pyriform pseudocolumella (Fig. 3iii) up to 1-2 cm. broad, maturing to a very compact mass but easily pulverized; white, maturing through light brown to very dark brown.

#### Microscopic Features

Basidia 11-18 x 6.5-8.5  $\mu$ , capitate (Fig. 10c), often lecythiform (Fig. 10c), multi-spored with 4-8 usually observable.

Spores (4.5-)5.0-5.5  $\mu$  diam., globose, densely covered with truncate warts 0.5-1.0  $\mu$  long; dark brown in KOH and in Melzer's solution.

Capillitium lightly to heavily encrusted with debris, without evident branching (Fig. 13d); up to 5.5  $\mu$  diam. with walls thickened so that the lumen appears as a thin line broadening in a few places; dark yellow-brown in KOH, rusty brown in Melzer's solution.

### Habitat and Distribution

Growing in wet soil rich in decomposed coniferous wood, with several sporophores arising separately from each underground mycelial mass; fruiting from late June to mid-July, maturing from early to mid-August.

Specimens examined: BA 151, 275, Yellow Bay, Lake Co., Montana. Also known from Glacier Nat. Park, Montana.

### Discussion

This species was found fruiting in the same location at the University of Montana Biological Station during four consecutive summers, and was collected in all stages of maturity. No regular manner of dehiscence was observed, therefore it was assumed that the plants depend on environmental forces to expose the gleba. They were often found eaten through by snails.

Radiigera atrogleba, also found in Montana (O.K. Miller 8971, 8985), differs from this species in having irregularly-shaped spores with very crowded, low, usually rounded warts, smooth capillitial elements, and gleba which becomes black at maturity.

Family III. Mycenastraceae

## Key to the Genera of Mycenastraceae

1. Exoperidium of long strands of inflated cells (Fig. 19b), peridia breaking up irregularly and falling away at maturity to expose the gleba ..... Page 30. Calbovista
1. Exoperidium of interwoven filaments of cylindric hyphae, endoperidium thick and dehiscing in an irregular stellate manner ..... Page 34. Mycenastrum

Calbovista Morse

Mycologia 27: 97. 1935.

Sporophore depressed globose to oval, turbinate, or pyriform with a short rooting basal constriction. Peridium of two layers: exoperidium of large, low, flattened or pyramidal warts with polygonal bases; endoperidium very thin, usually observed only at maturity on the sterile base. Peridia breaking up irregularly and falling away from the gleba, sterile bases long-persistent. Subgleba well developed, chambered. Capillitium of short discrete units with a conspicuous short main axis and numerous short antler-like secondary branches (Fig. 14a, Plate 1a, b, c). Spores globose to subglobose, warted (Fig. 7a).

Type Species: Calbovista subsculpta Morse.

Calbovista subsculpta Morse. Mycologia 27: 97. 1935.

Figs. 7, 14, 19; Plates 1, 4

#### Macroscopic Features

Sporophore 5-10 cm. broad x 4-10 cm. high, depressed globose to oval, turbinate, or nearly pyriform, usually with a basal constriction which is rooted a short distance into the substrate.

Exoperidium of polygonal warts, nearly pyramidal or flattened and very finely tufted at the centres, 0.7-2.5 cm. broad, 3-5 mm. thick becoming thinner toward the base; breaking up with the endoperidium and falling away over the glebal portion, remaining in small amounts on the sterile base; white when young, maturing to cream or very pale brown.

Endoperidium very thin, breaking up with the exoperidium and not usually separating from it over the glebal portion, remaining only on the sterile base; dull, dark brown.

Opening irregularly as the peridia dry and shrink to small separated pieces and fall away from the fertile portion of the sporophore.

Attached to the substrate by fibrous mycelium extending from the tip of the rooting base, holding a knot of dirt and debris.

Gleba powdery when mature, becoming dark brown (5-6)F8.

Subgleba very small or up to  $1/3$  of the sporophore height, chambered, chambers 1-3 per mm., becoming dark brownish yellow to brown at maturity. Sterile bases often persisting over winter.

## Microscopic Features

Exoperidium of long, branched strands of inflated globose to subglobose or oval cells (Fig. 19b) up to 30  $\mu$  broad, walls 0.5-1.5(-3.0)  $\mu$  thick, combined with numerous branched, septate filaments of cylindric hyphae 1-7(-10)  $\mu$  diam. with walls up to 0.5  $\mu$  thick; both cell types hyaline to brownish yellow in KOH, brighter in Melzer's solution.

Endoperidium merging gradually with the exoperidium, of closely interwoven filaments of cylindric hyphae, infrequently branched, septate and enlarged at the septa (Fig. 19a), 1.5-6.0  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline to pale yellow in KOH and in Melzer's solution.

Spores (3.5-)4.5-5.5  $\mu$  diam., globose to slightly subglobose, densely covered with small, hyaline, rounded warts less than 0.5  $\mu$  long, broken pedicels up to 6  $\mu$  long remaining; yellow-brown in KOH, brighter in Melzer's solution.

Basidia 7.0-14.5 x 5.5-7.0  $\mu$ , clavate to pyriform, 4-spored.

Capillitium of short discrete units with a distinct main axis and many short antler-like secondary branches which taper somewhat to blunt rounded tips (Fig. 14a, Plate 1a, b, c), main axes up to 10  $\mu$  diam. with walls up to 3  $\mu$  thick, unpitted; yellow-brown in KOH, rusty brown in Melzer's solution. Several free, inflated, globose to subglobose cells up to 30  $\mu$  broad with walls up to 1.5  $\mu$  thick are found in the outer regions of the mature gleba.

### Habitat and Distribution

Growing on compacted soil, often with a high clay content, along trails in the mountain regions of Montana from 3300 to 6500 ft. altitude, singly or in groups of 2-3 separate plants; fruiting from early July to early August.

Specimens examined: BA 212, Redmeadow Lake, Flathead Co., Montana; BA 285, 370, Fatty Creek Road, Lake Co., Montana. Specimens were also seen from Glacier Nat. Park, Montana, and from Athol, Idaho.

### Discussion

Calbovista subsculpta, the only known species in the genus, is easily recognized by the character of the capillitial elements, which is unique among the puffballs.

The inflated cells in the outer regions of the mature gleba, first described by O.K. Miller, Jr. (1969), were found to be consistent in the specimens examined. These cells appeared to originate in the exoperidial tissue, as the two peridial layers merge gradually and a few strands of the large exoperidial cells were observed to be growing through the endoperidium to its inner surface (Plate 4c). This feature has not been observed in any other Gasteromycete.

The enlarged joints of the endoperidial hyphae also appear to be unique.

Mycenastrum Desvaux

Ann. des Sci. Nat. Ser. II, 17: 143. 1842.

Sporophore globose to depressed globose, oval, or turbinate, with a thick rootlike basal attachment. Peridium of two layers: exoperidium soft and drying very thin, peeling away from the endoperidium at maturity; endoperidium thick and corky, dehiscing stellately from the top downward at maturity. Subgleba absent. Capillitium of short discrete units with a conspicuous short main axis and few secondary branches, with numerous short, thornlike projections (Fig. 14b, Plate 1d, e). Spores large, globose, covered with thick anastomosing reticulations which appear as dense warts (Fig. 7b).

Type Species: Mycenastrum corium (Guersent) Desvaux.

Mycenastrum corium (Guersent) Desvaux. Ann. des Sci. Nat. Ser. II,  
17: 147. 1842. Figs. 7, 11, 14; Plate 1.

## Macroscopic Features

Sporophore 6-12 cm. broad x 4-8 cm. high, globose to depressed globose, oval, or turbinate.

Exoperidium smooth and white when young, up to 5 mm. thick, soon separating to form flat-topped polygonal warts; at maturity shrinking to thin, angular, cream or pale brown areolae 1-2 cm. broad and coming away from the endoperidium in flakes, or wearing away slowly.

Mature endoperidium smooth, polished after long exposure, up to 3 mm. thick, corky and brittle; brown, 6(D-E)7, often darkening to purple-brown or blackish in age.

Opening by irregular stellate dehiscence of the endoperidium,

segments opening outward to become plane or nearly so, gleba dispersing completely.

Attached to the soil by a tapering, rootlike cord up to 2 cm. thick where it joins the peridium, breaking off readily to free the sporophore from the substrate.

Gleba cohesive but easily pulverized when mature, maturing through olive to dark brown, (6-8)(E-F)(7-8).

Subgleba absent.

#### Microscopic Features

Exoperidium of closely interwoven filaments of cylindric hyphae, highly branched, with abundant septa and clamp connections, 3.5-6.0(-8.5)  $\mu$  diam. with occasional broadened cylindric portions up to 15  $\mu$  diam., walls less than 0.5  $\mu$  thick; hyaline in KOH, yellow in Melzer's solution.

Exoperidium separated from the endoperidium by a very thin layer of more or less parallel long-cylindric hyphae, septate and clamped, 2.5-5.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick, pale yellow in KOH and somewhat darker in Melzer's solution.

Endoperidium of cylindric hyphae closely interwoven in a disorganized, contorted fashion, highly branched with abundant septa and clamps, 2.0-5.5(-8.0)  $\mu$  diam., walls less than 0.5  $\mu$  thick; nearly hyaline in outer portions and darkening gradually to yellow-brown near the interior in KOH, darker in Melzer's solution.

Spores (8.5-)9.5-12.5(-13.0)  $\mu$  diam., globose, surface covered with thick anastomosing reticulations of uneven height, up to 0.5  $\mu$  high, appearing as unequal warts at the cross-section, apedicellate;



yellow-brown in KOH, dark rusty brown in Melzer's solution.

Basidia 16.5-30.0 x 9.5-14.5  $\mu$ , pyriform to broadly clavate (Fig. 11a), 4-spored, clamps at the basal septa evident.

Capillitium of short discrete units with few secondary branches and abundant short, thornlike projections (Fig. 14b, Plate 1d, e), main axes up to 12-14  $\mu$  diam. with walls up to 1.5  $\mu$  thick, unpitted; pale yellow-brown in KOH, rusty brown in Melzer's solution.

#### Habitat and Distribution

On compacted pasture soil in open places, fruiting from the first week of July to the last week of August.

Specimens examined: BA 163, Camrose, Alberta; BA 234, Mile 69, Kananaskis Road, Alberta; BA 303, Lake Demay (Camrose), Alberta; BA 334, Camrose, Alberta. Specimens from central Montana were also examined.

#### Discussion

The only species in the genus, Mycenastrum corium is easily recognized by the physical properties of the endoperidium and by the spores and capillitium. The purple coloration of the gleba noted by Cunningham (1942) and Smith (1951) was not evident in these specimens, nor were the hyaline envelopes around the spores reported by Bowerman (1961). Lise Hansen (1962) described in detail the microscopic structure of the peridia with which the observations here agree. However, in the specimens examined during this study, it was not clear whether the thin layer of parallel hyphae in the mid-peridium belonged to the exoperidium or to the endoperidium.

The spore ornamentation observed at 1000x in methylene blue is not easily interpreted, appearing as irregular warts at the cross-section but as a network of lines on the spore surface. Upon viewing electron micrographs of fractured spores (Bronchart & Demoulin 1973), and scanning electron micrographs of the spore surface (Eckblad 1971), the reticulated nature of the ornamentation becomes clear.

#### Family IV. Lycoperdaceae

##### Key to the Genera of Lycoperdaceae

1. Peridia becoming very fragile at maturity, breaking up and falling away in pieces from the gleba at least over the top of the sporophore; plants often 10 cm. or more in height, but sometimes as little as 3 cm. high ..... Page 38. Calvatia
1. Endoperidium opening by an apical pore or an irregular tear, pore sometimes developing very late in maturity; plants usually less than 10 cm. high..... 2
2. Capillitium of discrete units, free of the endoperidium, arising from a more or less conspicuous main axis with secondary branches (Plates 2, 3), peridium usually papery thin but tough and persistent ..... Page 55. Bovista
2. Capillitium of long, infrequently to frequently branched elements attached to the endoperidium, peridium usually fragile and soon disintegrating through weathering ..... 3
3. Exoperidium consistently of loosely interwoven mycelium interspersed with abundant soil particles, plants usually less than 3 cm. broad and often detached from the substrate at maturity, always growing on soil ..... Page 67. Disciseda
3. Exoperidium consisting of tightly interwoven mycelium, soil particles if present merely adhering to the surface of the sporophore, plants growing on wood or on soil ..... 4

4. Diaphragm present as a thin layer between the subgleba and the gleba, mature capillitium hyaline in microscopic view with only a few colored strands, subgleba chambered ..... Page 74. Vascellum
4. Diaphragm absent, capillitium colored in microscopic view, subgleba chambered or compact-cottony ..... Page 77. Lycoperdon

Calvatia Fries

Summa Veg. Scand. 2: 442. 1849; em. Morgan, Journ. Cincinnati Soc. Nat. Hist. 12: 165. 1890.

Sporophore globose to depressed globose, oval, or pyriform, sometimes very large. Peridium of two layers: exoperidium smooth or variously ornamented, thick or thin; endoperidium usually very thin and not separating from the exoperidium; peridia breaking up irregularly and falling away from the gleba at maturity. Subgleba present or absent. Capillitium of long elements with frequent or infrequent branches, often fragile, attached to the endoperidium. Spores globose to subglobose, usually with short broken pedicels remaining, variously warted (Fig. 7).

Type Species: Calvatia craniiformis (Schweinitz) Fries.

Key to the Species of Calvatia

1. Endoperidium containing abundant, large, angular or rounded cells which are purple in KOH at maturity; gleba lilac to purple, subgleba compact-cottony ..... Page 40. C. fragilis
1. Endoperidium of filaments of cylindric hyphae; gleba brown or purple-brown, subgleba chambered or absent ..... 2

2. Exoperidium thick and hard, surface usually rimose to areolate, peridia dehiscing well after the gleba has matured; fruiting in spring or early summer at high altitudes, producing a foetid odor near maturity; globose to oval, less than 8 cm. broad ..... Page 42. C. fumosa
2. Exoperidium drying thin and fragile, peridia breaking up early in maturity; fruiting in summer or fall, odor not foetid; usually with a tapering or constricted base, if globose or oval then larger than 8 cm. .... 3
3. Spores globose, capillitium up to 6  $\mu$  diam.; gleba purple-brown, sporophore depressed globose or with a thick stemlike sterile base and an expanded top, up to 16 cm. high ..... Page 44. C. cyathiformis
3. Spores subglobose to oval, capillitium exceeding 6  $\mu$  diam.; gleba brown, sporophore with a tapering or constricted base, or globose to oval and large ..... 4
4. Capillitium with small rounded pits; subgleba very small or absent, plants 15 cm. or more in breadth, globose to oval; upper surface forming large polygonal areolae or scales 1.5 cm. broad or more near maturity ..... Page 46. C. booniana
4. Capillitium with at least some long-oval or slitlike pits; subgleba large, plants less than 15 cm. broad with a tapering or constricted base, upper surface of small areolae near maturity ..... 5
5. Spores with hyaline rounded warts (Fig. 5a), capillitium up to 13  $\mu$  diam. with many long slitlike pits, ends of elements tapering regularly; fruiting in dry, sandy soil at low altitudes ..... Page 49. C. bovista
5. Spores with truncate warts (Fig. 5c), capillitium up to 9  $\mu$  diam. with some long-oval and often slitlike pits, ends of elements usually protracted to narrow hyaline tips; fruiting in high alpine or arctic habitats ..... Page 52. C. tatrensis

Calvatia fragilis (Vittadini) Morgan. Journ. Cincinnati Soc. Nat.

Hist. 12: 168. 1890.

Figs. 7, 14, 19.

### Macroscopic Features

Sporophore 4.5 cm. broad x 5.0 cm. high, depressed globose with a short constricted base, plicate near the base.

Mature exoperidium smooth with a few minute granules, very thin and brittle, breaking up and flaking away from the endoperidium; metallic brown, 6E(5-6), some areas with a slight purplish tint.

Mature endoperidium smooth, ca. 1 mm. thick, brittle and breaking into small pieces; dark brownish purple, 8F5.

Opening as the peridia break up and fall away from the glebal portion of the sporophore.

Attached to the substrate by fine fibrous mycelium extending from the bottom of the basal constriction.

Gleba coherent but easily pulverized at maturity, powdery when old, mature color lilac to deep violet-purple, (9-10)F5.

Subgleba small, occupying only the narrow constricted base, compact-cottony and dark brown when mature with some purple-brown coloration near the edges.

### Microscopic Features

Mature exoperidium of tightly interwoven filaments of cylindric hyphae, branched, septate, 2.0-5.0(-5.5)  $\mu$  diam. with walls less than 0.5  $\mu$  thick; a few inflated, subglobose to oval cells up to 30  $\mu$  broad with walls less than 0.5  $\mu$  thick appearing among the tissue near the interior surface; both cell types hyaline in KOH, yellowish in

Melzer's solution.

Mature endoperidium of enlarged cells, angular to rounded or irregular (Fig. 19c), separated in the mount, up to 24(-45)  $\mu$  broad with walls ca. 0.5  $\mu$  thick, among septate cylindric hyphae 3.0-6.0(-9.5)  $\mu$  diam. with walls ca. 0.5  $\mu$  thick, fragmenting at the septa in the mount; lilac to purple or brownish-purple in KOH, dark brown in Melzer's solution.

Spores 5.5-6.5  $\mu$  diam., globose, densely covered with truncate warts ca. 0.5  $\mu$  long; pale lilac to purple in KOH, brown in Melzer's solution.

Capillitium of somewhat branched, septate elements, fragmenting in the mount, up to 6.5  $\mu$  diam., walls ca. 0.5  $\mu$  thick with very abundant small round pits (Fig. 14c); lilac in KOH, pale brownish yellow in Melzer's solution.

#### Habitat and Distribution

Growing on dry, sandy soil among grass and small herbs; fruiting in early August.

Specimens examined: BA 325, Bittern Lake, Alberta; C.G. Lloyd 6247 (BPI), Rooks Co., Kansas; C.G. Lloyd 20966 (BPI), Denver, Colorado.

#### Discussion

This fungus was recently given the name Calvatia cyathiformis f. fragilis (Zeller & Smith 1964). However, upon close examination, there was little resemblance found between this species and C. cyathiformis, neither the glebal tissues nor those of the peridia being

alike. The subgleba of C. fragilis consists of a small compacted mass of mycelial filaments and shows no development of chambers. The enlarged, often angular purple cells of the endoperidium are unique among the fungi collected.

The plants from the C.G. Lloyd collections were identical to the one described here.

Calvatia fumosa Zeller. Mycologia 39: 300. 1947. Figs. 7, 11, 14.

#### Macroscopic Features

Sporophore 3.5-9.0 cm. broad x 3.0-3.5 cm. high, globose to depressed globose or oval, producing an odor like that of decaying flesh toward maturity.

Exoperidium dull and smooth, entire or becoming rimose to areolate over the upper surface; cutis cream to grey, grey-brown or dark brown fading to a lighter shade toward the base, interior tissue white. Exoperidium and endoperidium not separable, together up to 4(-6) mm. thick, hard and persistent.

Opening as the peridia crack through and break up randomly in age.

Attached to the substrate by one or a few white mycelial cords which are easily detached from the sporophore.

Gleba powdery in age, maturing to dark brown, 6F(7-8).

Subgleba very small, or absent.

#### Microscopic Features

Spores 4.5-5.5  $\mu$  diam., globose, covered with nearly hyaline broad rounded warts ca. 0.5  $\mu$  long; pale yellow-brown in KOH,

brighter and somewhat darker in Melzer's solution.

Basidia 12.0-16.5(-20.0) x 6.0-7.0  $\mu$ , clavate (Fig. 11b), 4-spored.

Capillitium of somewhat branched, straight to sinuous elements with many small rounded bumps, fragmenting in the mount; up to 10-17  $\mu$  diam., walls up to 1  $\mu$  thick with small round pits in early maturity which later give rise to long, crooked, often forked slits (Fig. 14d); bright yellow-brown to brown in KOH, rusty brown in Melzer's solution.

#### Habitat and Distribution

On soil rich in coniferous litter, beside trails in the mountain regions at altitudes from 5800 to 7400 ft., near Picea engelmannii; fruiting from late June to early August.

Specimens examined: BA 73, Napa Lookout, Lake Co., Montana; BA 277, Jewel Basin Trail, Flathead Co., Montana; BA 290, Clayton Lake, Flathead Co., Montana; BA 312, Moraine Lake, Banff Nat. Park, Alberta. Specimens were also seen that were collected at the summit of the Highwood Pass, Kananaskis Road, Alberta.

#### Discussion

Calvatia fumosa is probably associated with Picea engelmannii since all specimens were found growing within the root region of that tree species. It can at once be recognized by the hard grey or grey-brown peridium, and by its strong offensive odor while maturing, which is unique among the puffballs.

Data from further collections are needed before an accurate



report can be made on the microscopic peridial characters.

Calvatia cyathiformis (Bosc) Morgan. Journ. Cincinnati Soc. Nat.

Hist. 12: 168. 1890.

Figs. 7, 15.

### Macroscopic Features

Sporophore up to 13 cm. broad in the upper portion, up to 16 cm. high, depressed globose to turbinate, or more often irregularly pyriform with an expanded depressed top on a cylindric to obconic sterile base up to 10 cm. broad; plicate to deeply furrowed beneath the expanded top.

Exoperidium compact-flocculent, becoming separated into small areolae 2-4 mm. broad, 0.5-1.0 mm. thick when fresh, drying very thin; breaking up with the endoperidium and falling away over the glebal portion, remaining as scattered small scales on the sterile base; white when young, maturing to creamy brown or brown.

Endoperidium remaining around the sterile base after maturity, smooth and shiny, light brown or grey-brown.

Opening as the peridia break up and fall away from the glebal portion of the sporophore.

Attached to the substrate by a broad, shallow knot of fibrous mycelium.

Mature gleba powdery, maturing through olive to dark purplish brown, (7-8)F(7-8).

Subgleba up to  $\frac{3}{4}$  of the sporophore height, convex on top, chambered, chambers 0.5-2.0 mm. broad; light lilac to purple just before maturity, then becoming dark purplish brown, (8-9)F(6-8),

sometimes with olive, yellowish, or pale brown portions. Sterile bases long-persistent.

#### Microscopic Features

Cutis of the exoperidium of loosely associated strands of inflated oval cells up to 30-40  $\mu$  broad, with walls irregularly thickened up to 3.5  $\mu$ , hyaline in KOH and yellow in Melzer's solution, arising from cylindric hyphae which extend out from the underlayer. underlayer of closely associated inflated cells up to 36  $\mu$  broad with walls less than 0.5  $\mu$  thick, among fewer cylindric hyphae 3.5-9.0  $\mu$  diam. with walls less than 0.5  $\mu$  thick; both cell types hyaline in KOH and yellow in Melzer's solution.

Endoperidium a very thin layer of interwoven filaments of cylindric hyphae, septate, branched, 2.0-3.5(-4.0)  $\mu$  diam. with walls up to 0.5  $\mu$  thick; hyaline in KOH when immature but darkening to yellow-brown at maturity, yellow in Melzer's solution when immature and maturing to rusty brown. Some disintegration of these cells is observed at maturity.

Spores 4.5-6.0  $\mu$  diam., globose, densely covered with truncate warts ca. 0.5  $\mu$  long; pale yellowish with a faint pink to lilac tint in KOH, rusty yellow-brown in Melzer's solution.

Basidia 15-18 x 7.5-9.0  $\mu$ , pyriform, 4-spored.

Capillitium of branched, infrequently septate elements (Fig. 15a) tapering very gradually to narrow rounded tips, often sinuous near the ends, fragmenting in the mount; up to 6  $\mu$  diam., walls ca. 0.5  $\mu$  thick with abundant small round pits; yellowish in KOH with a faint lilac tint, yellow-brown in Melzer's solution.

### Habitat and Distribution

Growing on soil among dense grasses under Populus tremuloides, within Aspen groves in the Parkland region; appearing either singly or in small scattered groups; fruiting from late August to late September.

Specimens examined: BA 133, Miquelon Lake, Alberta; BA 333, Lake Demay (Camrose), Alberta; BA 368, Camrose, Alberta.

### Discussion

The large sterile bases remain intact over winter, standing out prominently in the Aspen groves before being hidden by the spring growth. Calvatia cyathiformis has been reported from Wainwright, Alberta, by Bowerman & Groves (1962).

Calvatia booniana A.H. Smith. Lloydia 27: 164. 1964. Figs. 7, 15.

### Macroscopic Features

Sporophore 15-35 cm. broad x 10-15 cm. high, depressed globose to oval.

Exoperidium white and smooth when very young, soon separating to form flat polygonal plates 1.5-3.0 cm. broad and up to 6 mm. thick on the top and sides, remaining smoother and simply cracked near the base; creamy brown at maturity, 5(B-C)4, somewhat darker toward the base.

Endoperidium 1-2 mm. thick, breaking up with the exoperidium and not separating from it.

Opening as the peridia break up and fall away from the top

downward.

Attached to the substrate by a thick rhizomorph which breaks away when the sporophore is disturbed.

Mature gleba powdery, maturing through olive to brown, (6-7)(E-F)6.

Subgleba absent or extremely small, concolorous with the gleba and minutely chambered when present.

#### Microscopic Features

Exoperidium of interwoven filaments of cylindric hyphae, branched, septate, 2.0-14.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick, with a few slightly and irregularly swollen cells; hyaline in KOH and bright yellow in Melzer's solution.

Endoperidium of interwoven filaments of cylindric hyphae, branched, septate, 3-15  $\mu$  diam. with walls less than 0.5  $\mu$  thick, mixed with many enlarged oval to long-oval or clavate cells up to 23-30  $\mu$  broad with walls up to 1.0-2.5  $\mu$  thick. Both cell types yellow in KOH at maturity, yellow-brown to rusty brown in Melzer's solution.

Spores 4.5-6.0(-7.0)  $\times$  4.5-5.5  $\mu$ , globose to subglobose or broadly oval with scattered hyaline rounded warts up to ca. 0.5  $\mu$  long; yellow in KOH, yellow-brown to light rusty brown in Melzer's solution.

Capillitium of interwoven, branched, wavy to sinuous elements with thick septa, tapering slightly to blunt rounded or somewhat pointed tips, fragmenting in the mount most often at the septa; up to 8-10  $\mu$  diam., walls up to 2  $\mu$  thick with numerous small round pits which broaden toward the lumen (Fig. 15b), some not completely penetrating the wall; bright yellow-green in KOH, pigment diffusing

into the medium, rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing among grasses on soil, among widely scattered conifers or in open places; fruiting after heavy rains from mid-July to mid-August.

Specimens examined: BA 170, Lake Mary Ronan, Lake Co., Montana; BA 194, Camrose, Alberta; BA 335, New Norway, Alberta.

#### Discussion

This large puffball has often been misidentified as Calvatia gigantea in Alberta, but can be separated readily by the nature of the exoperidium, which in C. gigantea is smooth into maturity and then peels away in flakes or sheets. The exoperidial plates of C. booniana are usually stretched and separated by rapid expansion of the sporophore.

The warts that ornament the spores are hyaline and invisible in KOH and Melzer's solution, and become obscurely visible in 0.5% methylene blue. A concentrated solution of the stain, combined with an alcohol-water-3% KOH treatment before staining, was required to reveal their nature. These warts were not at all well developed in slightly immature specimens, or in those that were collected in young stages and matured in the laboratory, which can lead to misinterpretation and inaccurate identification of the species. The size range of the spores was extremely broad unless specimens had been collected when fully matured.

C. booniana is very difficult to distinguish from three closely

related species, C. lepidophora, C. pachyderma, and C. polygonia.

Blunt, rounded ("bullet-shaped") cell ends as described by Zeller and Smith (1964) were found along with rather sharply pointed ends, within the same specimen. The small capillitial pits broadening toward the lumen, a character of C. lepidophora (Zeller & Smith 1964), were found consistently in C. booniana. The same authors describe the spores of C. booniana as smooth, separating it from C. lepidophora largely on that character. The variation in the gross peridial features of C. booniana was found to be considerable, suggesting that minor differences are not sufficient to delimit a species character. Precise descriptions and more data on the character of all tissues are needed in order to conclusively separate these large species of Calvatia.

Calvatia bovista (Persoon) Kambly & Lee. Univ. Iowa Stud. Nat.

Hist. 17(4): 138. 1936.

Figs. 7, 15.

Syn.: C. caelata (Bulliard) Morgan. Journ. Cincinnati Soc. Nat. Hist. 12: 169. 1890.

C. utriformis (Bull. ex Pers.) Jaap. Verh. Bot. Ver. Prov. Brandenb. 59: 37. 1917.

### Macroscopic Features

Sporophore 6.0-8.5 cm. broad x 7.0 cm. high, turbinate to depressed globose, with a short rooting basal constriction ca. 13 mm. broad.

Mature dry exoperidium of thin areolae up to 6 mm. broad, many with depressed centres containing a small brown wart; cream to light brown.

Mature endoperidium smooth, thin and brittle, brown, remaining

as a rim around the sterile base.

Opening as the peridia break up and fall away from the fertile portion of the sporophore.

Attached to the substrate by fibrous mycelium extending from the basal constriction.

Mature gleba powdery, yellow-brown to dark brown, 7F8.

Subgleba up to  $1/3$  of the sporophore height, top portion concave, chambered, chambers 2-4 per mm.; dark brown at maturity with a definite purple tint. Sterile bases persistent after the upper portion has broken away and dispersed.

#### Microscopic Features

Exoperidium of closely associated, branched strands of inflated cells, subglobose to oval, long-oval or irregular, up to  $24\ \mu$  broad with walls up to  $0.5\text{--}1.5\ \mu$  thick, among fewer filaments of cylindric hyphae  $3\text{--}6\ \mu$  diam. with walls less than  $0.5\ \mu$  thick; all cell types hyaline in KOH, pale yellow in Melzer's solution.

Endoperidium of tightly interwoven filaments of cylindric hyphae, septate, somewhat branched,  $3\text{--}9\ \mu$  diam. with walls up to  $0.5\ \mu$  thick; pale yellow to brownish yellow in KOH, rusty brown in Melzer's solution.

Spores  $4.0\text{--}5.5(-6.5) \times 3.5\text{--}5.0\ \mu$ , subglobose to broadly oval, covered with small, hyaline, rounded to obtuse warts (Fig. 5) less than  $0.5\ \mu$  long, broken pedicels up to  $7\ \mu$  long remaining; yellowish in KOH, yellow-brown in Melzer's solution.

Capillitium of somewhat branched elements with few septa,

tapering very gradually to narrow rounded to pointed tips, fragmenting in the mount; up to 10.5-13.0  $\mu$  diam., walls 0.5-1.0  $\mu$  thick with many long slitlike pits (Fig. 15c); yellowish in KOH, yellow-brown in Melzer's solution.

#### Habitat and Distribution

Growing singly on open grassland, in dry habitats; fruiting period not observed.

Specimens examined: BA 319, Wildhorse Island, Lake Co., Montana; BA 341, Nose Hill, Calgary, Alberta.

#### Discussion

This species is found in most of the older literature as Calvatia caelata. A.H. Smith (1951) cited the International Rules in upholding the name ascribed by Kambly & Lee. It is reported under the name C. utriformis by European mycologists.

Two single-specimen collections were made, both very mature and probably overwintered. However, the tissue revived well, and is expected to be consistent with the character of fresher material.

The spores are described in some of the literature as smooth, or "perfectly smooth" (Cunningham 1942), as they do appear in common mounting media. When stained with methylene blue however, the small warts described here became evident.



Calvatia tatrensis Hollos. Die Gasteromyceten Ungarns. 90. 1904.

Figs. 7, 15, 19.

### Macroscopic Features

Sporophore 4.5-8.0 cm. broad x 5.0-7.0 cm. high, subglobose to turbinate with a pointed base, deeply plicate toward the base.

Exoperidium smooth and white when young, ca. 2 mm. thick, becoming separated by random cracks into small areolae over the upper surface, thin and continuous with fine brown spines on the sides; breaking up with the endoperidium on top and peeling or flaking away from it on the sides; maturing to cinnamon brown, 6D6.

Mature endoperidium thin, smooth and shiny, golden brown, 5D(5-6); a small amount remaining around the margin of the sterile base after maturity.

Opening as the peridia break up and fall away from the fertile portion of the sporophore.

Attached to the substrate by an extensive network of fibrous mycelium extending from the base, which holds a knot of dirt and debris.

Gleba powdery at maturity, dark brown, (5-6)F(6-7).

Subgleba up to 1/2 of the sporophore height and extending as a thin layer a short distance up the sides, concave on top, chambered, chambers 3-5 per mm.; brown to grey-brown at maturity with a purplish tint near the bottom and sides.

### Microscopic Features

Exoperidium of branched filaments of cylindric and enlarged or inflated hyphae (Fig. 19d); cylindric hyphae from 3  $\mu$  up to diameters approaching those of the enlarged cells, walls less than 0.5  $\mu$  thick; enlarged and inflated cells oval to long-oval or irregular, up to 45  $\mu$  broad with walls less than 0.5  $\mu$  thick; both cell types hyaline in KOH, brownish yellow in Melzer's solution.

Endoperidium a very thin layer of tightly interwoven, septate, seldom branched filaments of cylindric hyphae, 1.5-5.5  $\mu$  diam. with walls up to 0.5  $\mu$  thick; yellow-brown in KOH, rusty brown in Melzer's solution.

Spores 4.5-6.5  $\mu$  diam., globose to slightly subglobose, densely covered with truncate warts ca. 0.5  $\mu$  long, a few up to 1  $\mu$ ; numerous pedicels up to 18  $\mu$  long floating free in the mount; yellow-brown in KOH, rusty yellow-brown in Melzer's solution.

Capillitium of septate, branched elements tapering to rounded or somewhat pointed tips, many of the ends protracted to short, narrow, pale or hyaline tips (Fig. 15d); often with sinuous portions, lightly to heavily encrusted with debris, fragmenting in the mount; irregular diameter up to 9  $\mu$ , walls 0.5-1.0  $\mu$  thick with numerous round, oval, long-oval or slitlike pits; yellow-brown to brown in KOH, rusty brown in Melzer's solution.

### Habitat and Distribution

On alpine tundra soil, 8400 ft. altitude, fruiting in early August.

Specimens examined: BA 195, 304, Plateau Mtn., Mile 51,  
Kananaskis Road, Alberta.

#### Discussion

Calvatia tatrensis has been reported as an arctic and alpine species, with the exception of the collections reported by Zeller and Smith (1964), and it appears to be limited to high alpine habitats in the study area.

The spore ornamentation as seen in methylene blue agrees with the scanning electron micrographs published by F.-E. Eckblad (1971) and described by the same author earlier (1955). Pits in the capillitium walls seem to change character with the age of the element, being round near the tips and becoming elongated toward the older, central portions.

Bovista Persoon

Syn. Meth. Fung. 136. 1801.

Sporophore globose, subglobose or depressed, epigeous or hypogeous, sometimes freed from the substrate by minor environmental forces. Peridium of two layers: exoperidium thin, separating partially or completely from the endoperidium at maturity; endoperidium thin, opening at maturity by an apical pore or slit. Subgleba very small and compact-cottony, or absent. Capillitium of discrete units with a conspicuous main axis and numerous secondary branches (Fig. 17, Plates 2, 3). Spores globose to subglobose or oval with small hyaline warts, with or without persistent long pedicels (Fig. 8).

Type Species: Bovista plumbea Persoon.

Key to the Species of Bovista

1. Fruiting bodies 8-18 mm. broad, hypogeous, often emergent at maturity, exoperidium of loosely interwoven mycelium interspersed with soil particles ..... Page 56. B. minor
1. Fruiting bodies larger (or if small not over 7 mm. broad), exoperidium fleshy or membranous, of tightly interwoven mycelium ..... 2
2. Spores without persistent long pedicels, globose (Fig. 8b), sporophore opening by a slit or a torn aperture ..... Page 58. B. pila
2. Spores with persistent long pedicels (Fig. 8c-e), globose or oval, sporophore opening by a rounded pore ..... 3
3. Endoperidium grey at maturity, exoperidium becoming loosened and breaking away in sheets or pieces ..... Page 60. B. plumbea
3. Endoperidium a variation of brown at maturity, exoperidium not breaking away in large pieces ..... 4

4. Capillitium with long, gradually tapering secondary branches (Fig. 17), plants not more than 7 mm. broad, exoperidium remaining as small thin areolae ..... Page 63. B. echinella
4. Capillitium with short, sharply tapering secondary branches (Plate 3c, d), plants larger, exoperidium falling away completely near maturity ..... Page 65. B. tomentosa

Bovista minor Morgan. Journ. Cincinnati Soc. Nat. Hist. 14: 147.

1892.

Figs. 8, 16; Plate 2.

### Macroscopic Features

Sporophore 0.8-1.8 cm. broad, globose to subglobose or somewhat irregular, growing submerged but emergent at or near maturity.

Exoperidium a white felty layer of loosely woven mycelium, wearing away as the sporophore emerges from the soil, some specimens retaining a small pad combined with soil particles at the base.

Endoperidium smooth or marked with the impressions of soil particles, very thin and fragile; dark reddish brown, 8E5, faded to greyish where exposed above the ground.

Opening by a smooth rounded apical pore, 1-2 mm. in diameter.

Attached by fibrous mycelium to a dense cottony mycelial layer beneath the soil, which extends to and over the surface in places.

Gleba cohesive but easily pulverized at maturity, dark brown, 7E6, with a slight reddish tint.

Subgleba absent.

### Microscopic Features

Spores 4.0-5.0 x 3.5-4.0  $\mu$ , oval, covered with hyaline, rounded to obtuse warts (Fig. 5) less than 0.5  $\mu$  long, with persistent pedicels

up to 15  $\mu$  long; yellow-brown in KOH, rusty yellow-brown in Melzer's solution.

Capillitium of discrete units with a conspicuous main axis and numerous secondary branches tapering to pointed tips (Plate 2a, b), pseudosepta frequent; main axes up to 24  $\mu$  diam., walls up to 6  $\mu$  thick with frequent small funnel-shaped pits (Fig. 16a); yellow-brown in KOH, with a violet tint in some specimens, dark rusty brown in Melzer's solution.

#### Habitat and Distribution

On moist, shaded, humic soil at the outer edge of an Aspen grove, close groups of several fruiting bodies attached to each conspicuous mycelial mass beneath the soil; fruiting from late August to early September.

Specimens examined: BA 247, Camrose, Alberta.

#### Discussion

Bovista minor is commonly listed as a "rare" species. However, it is possible that it is simply not found because of its subterranean growth habit, and the fact that the fragile endoperidium is destroyed by weathering soon after it emerges from the ground.

The peridia were impregnated with soil particles to the extent that it was impossible to produce successful microscopic sections of them. Growth habit and glebal characters are sufficiently diagnostic to determine the species.

Bovista pila Berkeley & Curtis. Grevillea 2: 49. 1873.

Figs. 8, 11, 20; Plate 2.

#### Macroscopic Features

Sporophore 3.0-4.5 cm. broad x 2.5-3.5 cm. high, globose, depressed globose, or oval.

Exoperidium smooth and white, maturing to a thin, cream to brown layer which wears away slowly from the endoperidium, sometimes becoming fibrillose in appearance before disappearing.

Endoperidium maturing smooth and shiny, often metallic in appearance, very thin but persistent; brown to coppery, or silver to silver-purple.

Opening by a roughly torn pore or broad slit at the apex, varying in size and becoming enlarged in age.

Attached to the substrate by a short rooting cord ca. 3 mm. in diameter which breaks off readily allowing minor forces to free the sporophore from its place of growth.

Mature gleba cohesive but easily pulverized, maturing through olive to dark brown, (6-8)F6.

Subgleba absent.

#### Microscopic Features

Exoperidium of branched, septate, cylindric hyphae 3.5-8.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick, combined with an abundance of enlarged globose to angular cells (Fig. 20a) up to 30-40  $\mu$  broad with walls less than 0.5  $\mu$  thick; hyaline in KOH and nearly hyaline in Melzer's solution. Cutis a loosened extension of the cylindric hyphae

from this layer.

Endoperidium of tightly interwoven filaments of cylindric hyphae, infrequently branched, 2.5-4.5(-5.0)  $\mu$  diam. with walls ca. 1  $\mu$  thick; hyaline in KOH when immature, dark brown when mature; dextrinoid in Melzer's solution when immature, dark rusty brown at maturity.

Spores 4.5-5.0  $\mu$  diam., globose, densely covered with very small, hyaline, obtuse warts less than 0.5  $\mu$  long, short broken pedicels remaining on most; brown in KOH, dark rusty brown in Melzer's solution.

Basidia 9.0-16.5 x 8.0-10.0  $\mu$ , pyriform to short broadly clavate (Fig. 11c), 4-spored.

Capillitium of discrete units with a conspicuous main axis and many secondary branches (Plate 2c, d), somewhat encrusted with debris in many specimens, main axis up to 11.5-14.0  $\mu$  diam., walls up to 3.0-3.5  $\mu$  thick with no pits evident; dark brown in KOH, dark rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing singly or in small scattered groups, on soil among thin pasture grass in relatively moist places; fruiting from late July to late August.

Specimens examined: BA 200, Island Lake, Lincoln Co., Montana; BA 257, Mulhurst, Alberta.

#### Discussion

The largest of the Bovistas found in the study area, B. pila was commonly found lying loose upon the ground, often blown about by



the wind. The microscopic features of the peridial layers are very similar to those of B. plumbea, but the two are easily separated on the basis of their other characters.

Bovista plumbea Persoon. Syn. Meth. Fung. 137. 1801.

Figs. 8, 11, 16, 20; Plate 3.

#### Macroscopic Features

Sporophore 1.5-3.5(-4.5) cm. broad x 1.0-3.0 cm. high, globose to depressed globose, often plicate near the point of attachment.

Exoperidium smooth, ca. 1 mm thick when immature, dull white to cream, sometimes with small darker areolae which separate to expose white tissue between; maturing to a papery thin and brittle layer, dull cream to very pale brown (or red-brown where in contact with soil), the inner lining grey; usually loose around the spore case and breaking away in large or small pieces, often with a small patch remaining attached around the base; sometimes totally persistent long after maturity.

Mature endoperidium smooth, resilient but tough and persistent, dull blue-grey, 20D2, becoming dark brown or purple-brown in age, with irregular shallow cracks over the surface.

Opening by a small apical pore which often gives rise to an irregular slit which may extend across the top of the endoperidium; occasionally no opening develops at all. Pore usually outlined by a small zone of lighter color.

Attached to the substrate by a shallow basal knot of mycelium and dirt, 5-10 mm. broad. Sporophore sometimes loosened from its

attachment and rolling free, but often remaining rather firmly fastened in its place.

Mature gleba cohesive but easily pulverized, maturing through olive to dark brown, 6F8.

Subgleba absent.

#### Microscopic Features

Exoperidium of branched, septate, cylindric hyphae 4.5–8.0  $\mu$  diam. with walls less than 0.5  $\mu$  thick, with abundant enlarged globose to oval or angular cells (Fig. 20b) up to 38(–43)  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline in KOH, pale yellow in Melzer's solution. Cutis a loosened extension of the cylindric hyphae from this layer.

Endoperidium of interwoven filaments of cylindric hyphae, infrequently branched, 3.5–5.5  $\mu$  diam. with walls ca. 1  $\mu$  thick, light brownish yellow in KOH, brown in Melzer's solution, dextrinoid when immature; becoming 2–4  $\mu$  diam. and paler in color where merging with the exoperidium.

Spores 5.5–7.0(–8.0) x 4.5–5.5(–6.5)  $\mu$ , oval, covered with small, hyaline, obtuse warts ca. 0.5  $\mu$  long, with persistent pedicels up to 17–18.5  $\mu$  long; yellow-brown in KOH, dark rusty brown in Melzer's solution, dextrinoid when very immature.

Basidia 12.0–18.0 x 8.0–9.5  $\mu$ , clavate to pyriform (Fig. 11d), 4-spored with sterigmata arising from slightly below the apical crown.

Capillitium of discrete units with a conspicuous main axis and many secondary branches (Plate 3a), main axes up to 20–22  $\mu$  diam. with

walls up to 3.5-5.0  $\mu$  thick, unpitted (Fig. 16b); dark yellow-brown in KOH, dark rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing singly or in small groups, often with many sporophores scattered over a large area, on soil among grasses in open areas, in pastures, recreational areas, and in old car trails; fruiting from late June to late August.

Specimens examined: BA 138, Camrose, Alberta; BA 150, Bigfork, Flathead Co., Montana; BA 168, Miquelon Lake, Alberta; BA 186, Echo Lake, Flathead Co., Montana; BA 215, Cowley, Alberta; BA 238, Mile 131, Kananaskis Road, Alberta; BA 258, Mulhurst, Alberta; BA 265, Finley Point, Lake Co., Montana.

#### Discussion

This is one of the commonest puffball species in the study area, and is often found during the spring, after overwintering. It is readily identified by its oval, long-pedicellate spores (Fig. 8c) and the color of the endoperidium. The form and occurrence of the apical opening were not found to be constant species characters, nor was the habit of the sporophore becoming loosened from the substrate and tumbling about. As often, it remained firmly attached to its place of growth, and in many instances overwintered there.

Spore measurements are given only for well-matured specimens because immature fruiting bodies contain small, immature spores. The dextrinoid reaction of the fresh spores and endoperidium appeared to occur only at a specific level of maturity and disappeared rapidly

during maturation, therefore it was not useful in identifying specimens.

The spore ornamentation appears as small echinulations when mounted in KOH or Melzer's solution. When stained with concentrated methylene blue however, the small obtuse warts became clearly visible. Gregory & Nixon (1950) published electron micrographs showing such warts on Bovista plumbea spores.

Bovista echinella Patouillard. Bull. Soc. Myc. France 7: 165. 1891.

Figs. 8, 16, 17.

#### Macroscopic Features

Sporophore 4-7 mm. broad, globose.

Exoperidium white, remaining white at maturity and separating to form very tiny areolae, which remain over the upper portion of the sporophore after maturity.

Endoperidium smooth, very thin and flaccid, dull dark brown, 6F(7-8).

Opening by a round apical pore up to 1 mm. broad, slightly mambose and fimbriate.

Attached to the substrate by a small amount of persistent fine fibrous mycelium which holds a small pad of dirt to the base of the sporophore.

Mature gleba cottony, brown, 6(E-F)7.

Subgleba absent or very tiny, compact-cottony when present and slightly lighter in color than the gleba.

### Microscopic Features

Spores variable in size and shape, 4.0-5.5(-6.5) x 4.0-5.0 (-6.0)  $\mu$ , globose to subglobose, sometimes oval, with small, hyaline, rounded to obtuse warts (Fig. 5) less than 0.5  $\mu$  long, persistent pedicels 4.0-11.4  $\mu$  long; brownish yellow in KOH, yellow-brown in Melzer's solution.

Capillitium of intertwined discrete units with an obscure main axis and long secondary branches which taper very gradually to narrow rounded tips (Fig. 17), very few thick septa, numerous pseudosepta (Fig. 16c); main axes up to 6.5  $\mu$  diam., walls 1.0-1.5  $\mu$  thick without evident pits; yellow-brown to dark brown in KOH, rusty brown in Melzer's solution.

### Habitat and Distribution

On dry sandy soil among short grass, growing singly and scattered or in close groups of 2 or 3 sporophores; fruiting in mid-August.

Specimens examined: BA 364, Camrose, Alberta.

### Discussion

This species has often been placed in the genus Bovistella Morgan, a genus erected on some rather unstable characters, and one that has been much disputed and revised since its conception in 1892. Hanns Kreisel, in his monograph of Bovista (1967), distinguished Bovistella partly on the basis of its chambered subgleba, and therefore put this species into the genus Bovista.

The capillitium examined was not pitted, and had abundant pseudosepta with infrequent true septa. On the basis of these

characters, this species is not consistent with B. echinella as described by Kreisel. However, it was described in some detail by Coker & Couch (1928), Eckblad (1955), Lange (1948), and Smith (1951), all of whom are in agreement with the observations made here. Coker and Couch reported that they had seen Patouillard's specimens, and made no mention of a pitted capillitium.

Bovista tomentosa (Vittadini) Quelet. Champ. Jura 3: 445. 1875.

Figs. 8, 16; Plate 3.

#### Macroscopic Features

Sporophore 0.7-1.2 cm. broad, globose to subglobose or slightly depressed.

Exoperidium not observed.

Endoperidium smooth, very thin and flaccid but persisting over winter, dark reddish brown and shiny after maturity, 7F(6-8), becoming grey-brown to grey or silvery in age.

Opening by a small rounded or slitlike apical pore 1-3 mm. broad, becoming only slightly enlarged and irregularly lobed in age.

Attached to the substrate by a small amount of fine fibrous mycelium which holds a small knot of dirt to the base of the sporophore.

Mature gleba easily pulverized, dark brown with a slight reddish tint, (7-8)F(7-8).

Subgleba absent.

### Microscopic Features

Spores 4.5-5.0(-5.5) x 4.0-4.5  $\mu$ , nearly globose to broadly oval, with small, hyaline, rounded to obtuse warts less than 0.5  $\mu$  long, persistent pedicels 5-14  $\mu$  long; light brownish yellow in KOH, rusty brown in Melzer's solution.

Capillitium of discrete units with a conspicuous main axis and ca. 8-14 short secondary branches, tapering rapidly to narrow rounded tips (Plate 3c, d), with more or less frequent pseudosepta (Fig. 16d); main axes up to 14.0-16.5  $\mu$  diam., walls up to 5  $\mu$  thick with frequent small round pits which are more numerous in narrower portions; yellow-brown to dark brown in KOH, dark rusty brown in Melzer's solution.

### Habitat and Distribution

On dry sandy soil among long grasses and Rosa acicularis, growing singly and scattered; fruiting period not observed.

Specimens examined: BA 279, 327, 328, Bittern Lake, Alberta.

### Discussion

This species was found at one location only, in mature and in overwintered conditions. The exoperidium was not present on any of the specimens collected.

The mature sporophores are easily confused with those of Bovista minor. The slightly larger spores, and thinner capillitial elements with fewer secondary branches may be used to distinguish the species after they have matured.

Disciseda Czerniaiev

Bull. Soc. Imp. Nat. Moscou 18: 153. 1845.

Sporophore globose, subglobose, depressed or oval, growing partly or entirely submerged in the soil, often subsequently detached and lying loose on the surface of the ground. Peridium of two layers: exoperidium of loosely woven mycelium interspersed with soil particles, becoming brittle at maturity and remaining only around the lower portion of the spore case; endoperidium tough and persistent, opening by an apical pore or a basal pore, apical pore sometimes formed with the assistance of windblown sand. Capillitial elements without a definite main axis, fragile, branched, sinuous to spiralled; true capillitium sometimes absent, being replaced by hyaline paracapillitium (Kreisel 1962). Pseudocolumella and subgleba absent. Spores variously warted, usually with short broken pedicels (Fig. 8f-h) remaining.

Type Species: Disciseda collabescens Czerniaiev.

Key to the Species of Disciseda

1. Sporophore hypogeous and remaining so at maturity unless exposed by erosion, apical pore flush with the soil surface; true capillitium absent, endoperidium gelatinous when moist, cream to white after exposure ..... Page 68. D. defodiodis
1. Sporophore epigeous at least at maturity, true capillitium present, endoperidium membranous, grey or brown..... 2
2. Spores 3.5-5.0  $\mu$  diam. with short, rounded warts (Fig. 8g) ..... Page 70. D. candida
2. Spores 6.0-8.5  $\mu$  diam. with truncate or obtuse warts up to 1.5  $\mu$  long (Fig. 8h) ..... Page 72. D. bovista



Disciseda defodioidis (Lloyd) Zeller. Mycologia 39: 308. 1947.

Figs. 8, 12, 18, 20.

### Macroscopic Features

Sporophore 0.8-1.7 cm. broad x 1.0-3.0 cm. high, subglobose to oval; hypogeous, the top flush with the surface of the soil, with a thickened white mycelial cord extending from the base into the soil.

Exoperidium of loosely woven white mycelium interspersed with much sand, thin, fragile when moist, coming away from the endoperidium in small pieces where exposed above ground, or eroding away slowly.

Endoperidium smooth, thin, pliant when moist but becoming brittle and fragile when dry; greyish yellow to brownish orange (4-6)(B-C)4, becoming cream to white when exposed and dry.

Opening by a more or less regular apical pore formed as the exposed top dries and cracks around the line of soil contact, or is eroded by windblown sand.

Mature gleba loose and fragile with a spider web-like consistency, greyish yellow to light brownish orange, (4-5)(B-C)(4-5).

Subgleba absent.

### Microscopic Features

Exoperidium of very loosely interwoven branched filaments of cylindric hyphae, with abundant septa and clamp connections (Fig. 20d); 2.0-3.5  $\mu$  diam. with many short enlarged portions within hyphae and at filament ends, walls less than 0.5  $\mu$  thick; hyaline in KOH, pale yellow in Melzer's solution.

Endoperidium of partially gelatinized hyphae; fragments with

abundant septa and clamp connections (Fig. 20c), 2.5-5.5  $\mu$  diam., walls less than 0.5  $\mu$  thick; subhyaline in KOH, pale yellow in Melzer's solution.

Spores 3.5-6.0 x 3.0-5.0  $\mu$ , globose to subglobose, oval, or angular, with very small, hyaline, rounded warts less than 0.5  $\mu$  high; subhyaline in KOH, pale yellow in Melzer's solution.

Basidia 18-25 x 5-8  $\mu$ , clavate or irregular (Fig. 12a), often constricted at the outer ends, 4-spored.

True capillitium not formed. Paracapillitium of branched elements with numerous septa and clamp connections (Fig. 18a), up to 4.5-6.0  $\mu$  diam. with frequent small rounded bumps, walls less than 0.5  $\mu$  thick, many portions collapsed; hyaline in KOH, very pale yellow in Melzer's solution.

#### Habitat and Distribution

Growing singly and scattered on sandy soil, on open dry grasslands, fruiting from early May to early July.

Specimens examined: BA 262, 324, Bittern Lake, Alberta; BA 355, Carbon, Alberta; C.G. Lloyd 22360 (BPI), Cody, Wyoming; C.G. Lloyd 22361 (BPI), Cody, Wyoming (Type); C.G. Lloyd 22362 (BPI), Kulm, North Dakota.

#### Discussion

Previous reports of this species were found only in publications of Lloyd (1913), and Zeller (1947). It is easily passed by in the field, since only a tiny portion of the sporophore appears above the ground. In some instances however, wind erosion frees the entire

plant before the apical pore forms, and it is found lying loose on the ground, either unopened or randomly split.

True capillitium was not observed at any stage of maturity. The paracapillitium collapses and disintegrates slowly in age.

The spores appear smooth in common mounting media. Only after staining with a concentrated solution of methylene blue are the very low, rounded warts made visible.

Disciseda candida (Schweinitz) Cunningham. Proc. Linn. Soc. New South Wales 52: 238. 1927. Figs. 8, 18.

#### Macroscopic Features

Sporophore 0.8-1.5 cm. broad x 0.8-1.3 cm. high when mature and dry, subglobose to depressed globose.

Exoperidium of loosely woven mycelium combined with much soil, remaining at maturity as a brittle cup around the lower half of the endoperidium, or merely a small pad at the base; color that of the soil.

Mature endoperidium smooth, dull light grey, covered with fine granules which wear away slowly; tough and persistent, surface becoming reticulated by shallow cracks in age.

Opening by a slightly mambose pore, 0.5-2.0 mm. in diameter.

Mature gleba becoming pulverulent when disturbed, dark reddish brown, (7-8)E7.

Subgleba absent.

### Microscopic Features

Spores 3.5-5.0  $\mu$  diam., globose to somewhat irregular or infrequently angular, covered with rounded warts less than 0.5  $\mu$  long; pale brownish yellow in KOH, bright yellow-brown in Melzer's solution.

Capillitium of long, branched, septate, sinuous to spiralled elements (Fig. 18b), fragile and fragmenting in the mount, up to 5.5  $\mu$  diam., walls ca. 0.5  $\mu$  thick with numerous obscure small round pits; faintly lilac in KOH, light yellow-brown in Melzer's solution.

### Habitat and Distribution

Growing singly or in groups of several separate fruiting bodies, on well-drained sandy soil among short or grazed grass in open places; fruiting period not observed.

Specimens examined: BA 338, Camrose, Alberta; BA 339, Lacombe, Alberta; BA 351, Cowley, Alberta.

### Discussion

Recently matured specimens were collected in late August in all locations. Although fruiting was not observed, it would be expected to occur during late July or early August. Several specimens that had overwintered were observed to have undergone very little deterioration.

This species has long been attributed to Lloyd, however Eckblad (1955) stated that "Lloyd did not validly publish the name and the species should be ascribed to Cunningham". Kreisel (1962) also credited it to Cunningham.

Disciseda candida has essentially the same exterior features as D. bovista, and the two are not readily separated in the field.

D. candida is recognized by its smaller, less distinctly warted spores.

Since all specimens collected were mature and lying loose on the ground, neither the method of attachment nor details of immature glebal and peridial tissues were observed. Coker & Couch (1928) gave a complete description of the circumcissal dehiscence of the exoperidium and the inversion of the sporophore near maturity, indicating that the pore forms at the base. Cunningham (1942) described a non-pitted capillitium as a character of the genus, whereas Coker & Couch included a drawing of pitted capillitial elements. The capillitium in the specimens examined had very indistinct pale spots in the walls when seen in KOH, which became visible as definite pits in methylene blue and in phloxine.

This species is reported as D. circumcissa (B.& C.) Hollos in some of the literature.

Disciseda bovista (Klotzsch) Hennings. Hedwigia 42: 128. 1903.

Figs. 8, 18.

#### Macroscopic Features

Sporophore 0.9-2.0 cm. broad x 0.8-1.5 cm. high when mature and dry, depressed globose.

Exoperidium of loosely woven mycelium combined with soil, drying to a brittle cup surrounding the lower half of the endoperidium, becoming broken away to leave a small pad at the base; color that of the soil.

Endoperidium smooth, dull, pale grey to grey-brown becoming whitish when weathered; tough, persisting over winter.

Opening by a slightly mambose pore up to 3 mm. in diameter.

Mature gleba compact but easily broken up and pulverized, light brown, 7D7, to brown, 6E(6-8), with a slight reddish tint.

Subgleba absent.

#### Microscopic Features

Spores (5.0-)6.0-8.5  $\mu$  diam., globose to subglobose, densely covered with large, truncate or obtuse warts (Fig. 5) up to 1.5  $\mu$  long and often curved; yellow-brown in KOH, somewhat brighter in Melzer's solution.

Capillitium of somewhat branched, infrequently septate, crooked to obviously spiralled elements (Fig. 18c), fragmenting extensively in the mount, up to 6  $\mu$  diam., walls up to 0.5  $\mu$  thick with small and obscure but numerous pits; nearly hyaline with a faint lilac tint in KOH, yellow in Melzer's solution.

#### Habitat and Distribution

Growing singly and scattered, on well drained sandy soil among short grass; fruiting period not observed.

Specimens examined: BA 357, Camrose, Alberta.

#### Discussion

Only one collection site for this species was found, and a large number of fruiting bodies were obtained in two collecting seasons. The cuplike remains of the exoperidium were basal with respect to the position of the specimens on the ground at the time they were collected however it could not be determined if they actually grew with this orientation.

Disciseda bovista is reported as D. subterranea Coker & Couch or D. debreceniensis Hollos in some of the literature. It is easily distinguished by its large spores with obvious long, often bent warts, which are well illustrated by the scanning electron micrographs published by F.-E. Eckblad (1971).

Vascellum Smarda

Flora CSR, ser. B, vol. 1: 304. 1958.

Sporophore globose to depressed globose, often with a constricted base, epigeous. Peridium of two layers: exoperidium thin, covered with small, sharp, white spines; endoperidium thin but tough, opening at maturity by a round to oval apical pore. Gleba separated from the chambered subgleba by a thin but distinct membranous diaphragm. Capillitium of long, hyaline, septate elements with thin walls (paracapillitium), attached to the endoperidium, true capillitium scanty or absent. Spores globose, warted, apedicellate or with small broken pedicels remaining (Fig. 9a).

Type Species: Vascellum pratense (Pers. em. Quel.) Kreisel.

Syn.: V. depressum (Bon.) Smarda.

Vascellum curtisii (Berkeley) Kreisel. Feddes Repert. 68: 86. 1963.

Figs. 9, 21.

Syn.: Lycoperdon curtisii Berkeley. Grevillea 2: 50. 1873.

#### Macroscopic Features

Sporophore 0.6-2.0 cm. broad x 0.5-1.2 cm. high, globose to depressed globose.

Exoperidium densely covered with slender spines up to 1 mm. long, curved and united at their tips, mixed with fine granules; falling away slowly in small patches or at random from the top downward, remaining on the underside of the sporophore well after maturity; white when young, remaining white to cream at maturity.

Endoperidium smooth, thin but persistent and usually remaining over winter; dull pale brown (near 5C4) to pale brownish grey.

Opening by a round or oval apical pore 1-4 mm. broad.

Attached to the substrate by fine fibrous mycelium which holds a small knot of debris to the base.

Gleba cottony when mature, with a more or less distinct pseudocolumella, separated from the subgleba by a distinct thin diaphragm; light brown, brown, or clay brown, (5-6)E(6-7).

Subgleba usually very small but sometimes up to 1/3 of the sporophore height, chambered, chambers 3-6 per mm.; mature color pale purple-brown (near 6D4) to purple-brown, (7-8)E5.

#### Microscopic Features

Exoperidium spines and granules composed of branched strands of inflated cells (Fig. 21a), arising from a thin basal layer of inflated,



oval to long-oval or irregular cells up to 22-50  $\mu$  broad with walls less than 0.5  $\mu$  thick, among fewer cylindric hyphae 3-6  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline in KOH, pale yellow in Melzer's solution.

Endoperidium of closely interwoven filaments of cylindric hyphae, branched, more or less septate, 2.0-5.5  $\mu$  diam., walls thin or thickened up to 2  $\mu$ ; hyaline to yellowish in KOH, yellow-brown in Melzer's solution.

Spores (3.0-)3.5-4.0(-4.5)  $\mu$  diam., globose, densely covered with small, hyaline, rounded warts less than 0.5  $\mu$  long; pale yellow to brownish yellow in KOH, yellow-brown in Melzer's solution.

True capillitium present only as a few tapering filaments near the endoperidium. Paracapillitium of branched, septate elements encrusted more or less heavily with debris, a few portions collapsed, up to 5.5-7.5  $\mu$  diam., walls up to 0.5  $\mu$  thick with no pits evident; hyaline in KOH, pale yellow in Melzer's solution.

#### Habitat and Distribution

Growing separately and scattered, or in small dense clusters on well drained sandy soil among short grass; fruiting in late August and early September.

Specimens examined: BA 250, Lake Demay (Camrose), Alberta; BA 254, Camrose, Alberta; BA 340, Driedmeat Lake, Alberta. Specimens were also seen from Jefferson Nat. Forest, Virginia.

## Discussion

The name Vascellum curtisii was proposed for this species by Hanns Kreisel (1963), on the basis of the thin diaphragm which separates the gleba from the subgleba, and the presence of paracapillitium which replaces true capillitium almost entirely. It is recognized by the spines and granules on the exoperidium, and the small, purple tinted, chambered subgleba, as well as the diaphragm and paracapillitium.

### Lycoperdon Tournefort ex Persoon

Syn Meth. Fung. 140. 1801.

Sporophore globose to depressed globose, oval, turbinate or pyriform, epigeous. Peridium of two layers: exoperidium thin, smooth or variously ornamented; endoperidium very thin, opening at maturity by an apical pore. Gleba with or without a pseudocolumella, subgleba chambered, compact-cottony, or absent. Capillitium of long elements tapering gradually toward the ends, with frequent or infrequent branches, attached to the endoperidium. Spores globose to oval, variously warted (Fig. 9), with short broken pedicels, or occasionally with persistent long pedicels.

Type Species: Lycoperdon perlatum Persoon.

Key to the Species of Lycoperdon

1. Exoperidium smooth, compressed-flocculent,  
subgleba compact-cottony or absent ..... 2
1. Exoperidium ornamented with some form of warts,  
spines, granules, or combinations of them,  
subgleba chambered ..... 3
2. Plants 2 cm. broad or less, subgleba  
absent ..... Page 79. L. pusillum
2. Plants larger, with a compact-cottony  
subgleba ..... Page 81. L. polymorphum
3. Exoperidium with scattered small, hard, sharp,  
warts which are colored from the beginning of  
growth, mature subgleba white or  
nearly so ..... Page 84. L. pyriforme
3. Exoperidium white when young, mature subgleba  
colored ..... 4
4. Exoperidium of small soft granules only,  
subgleba very small ..... Page 87. L. lividum
4. Exoperidium with at least some spines or  
elongated warts, subgleba  $1/3$  of the  
sporophore height or more ..... 5
5. Exoperidium of persistent filiform spines  
among fine granules ..... Page 89. L. umbrinum
5. Exoperidium of thickened deciduous spines,  
often combined with granules ..... 6
6. Exoperidial spines narrowly conic, falling  
away to leave pale round spots among a continuous  
reticulum of small warts and granules ..... Page 92. L. perlatum
6. Not as above ..... 7
7. Exoperidium of spines and large, soft granules  
which are easily rubbed off, spores with distinct  
truncate warts ca. 1  $\mu$  long ..... Page 94. L. molle
7. Exoperidium densely covered with long narrow  
spines up to 2.5 mm. long on polygonal bases,  
spores with indistinct rounded warts and  
persistent long pedicels ..... Page 97. L. pedicellatum

Lycoperdon pusillum Persoon. Journ. de Bot. 2: 17. 1809.

Figs. 9, 21.

### Macroscopic Features

Sporophore 0.6-1.7 cm. broad x 0.6-1.0 cm. high, globose to depressed globose, sometimes plicate beneath, usually with a very narrow, short, rooting cord.

Exoperidium smooth, compressed-flocculent, separating into very thin and small areolae at maturity and wearing away very slowly; white when young, white to cream at maturity.

Endoperidium thin and fragile, smooth, golden brown to light brown at maturity, (5-6)(C-D)(5-6).

Opening by a round apical pore 1-3 mm. broad, becoming ragged or torn in age.

Attached to the substrate by a thickened rooting cord with fine mycelium extending from it, usually holding a knot of dirt to the base of the sporophore.

Gleba cottony at maturity, brown to dark brown, (6-7)(E-F)7.

Subgleba absent.

### Microscopic Features

Exoperidium basal layer of inflated subglobose to oval or irregular cells up to 36-48(-60)  $\mu$  broad with walls less than 0.5  $\mu$  thick, among fewer short filaments of cylindric hyphae from 3  $\mu$  up to the diameter of the smaller inflated cells, walls less than 0.5  $\mu$  thick; hyaline in KOH, pale yellow in Melzer's solution. Cutis of closely interwoven filaments of cylindric hyphae (Fig. 21b),

extensively branched and septate, 2-6  $\mu$  diam. with walls unevenly thickened up to 2  $\mu$  at maturity, with very few enlarged cells 11-15  $\mu$  broad; hyaline in KOH, brownish yellow in Melzer's solution.

Endoperidium of tightly interwoven filaments of cylindric hyphae, branched, septate, 1.5-6.0  $\mu$  diam. with walls ca. 0.5  $\mu$  thick; pale brown in KOH, rusty brown in Melzer's solution.

Spores 3.5-4.5(-5.0)  $\mu$  diam., globose, covered with hyaline rounded warts less than 0.5  $\mu$  long; pale brownish yellow in KOH, bright yellow-brown in Melzer's solution.

Capillitium of more or less frequently branched, infrequently septate elements with numerous sinuous portions; irregular diameter up to 6  $\mu$ , walls ca. 0.5  $\mu$  thick with extremely numerous small round pits; concolorous with the spores.

#### Habitat and Distribution

Growing singly and scattered, often numerous, in either open habitats or within conifer stands, on soil among grasses; fruiting from mid-July to mid-August.

Specimens examined: BA 181, Ashley Lake, Flathead Co., Montana; BA 210, Echo Lake, Flathead Co., Montana; BA 246, Jasper, Alberta; BA 300, Lake Louise, Alberta.

#### Discussion

Lycoperdon pusillum is separated from L. polymorphum by the absence of a subgleba. The spores appear smooth in KOH and in Melzer's solution, but when stained with methylene blue they were seen to possess very small rounded warts (Fig. 9b).

This species is known as Bovista pusilla by European mycologists.

Lycoperdon polymorphum Vittadini. Monographia Lycoperdineorum.

39. 1842.

Figs. 9, 12, 18, 21.

#### Macroscopic Features

Sporophore 1.0-5.5 cm. broad x 1.0-5.0 cm. high, globose to depressed globose or pyriform, often plicate to deeply folded near the point of attachment.

Exoperidium smooth, compressed-flocculent, separating at maturity to form thin small areolae ca. 1 mm. broad, or granular particles, flaking off or simply wearing away slowly; white when young, white to cream or pale brown at maturity.

Mature endoperidium smooth, very thin and more or less fragile, golden brown to brown, (5-6)(C-D)(6-7).

Opening by a rounded apical pore 3-5 mm. broad, becoming enlarged and sometimes ragged in age, infrequently becoming irregularly torn over the top of the sporophore before the pore forms.

Attached to the substrate by a small mass of fibrous mycelium which sometimes forms a thin rooting cord, usually holding a knot of dirt and debris to the base of the sporophore.

Mature gleba cottony to powdery, yellow-brown or brown to dark brown, (5-6)(E-F)(6-8).

Subgleba very small or up to 1/3 of the sporophore height, compact-cottony, slightly lighter in color than the gleba.

### Microscopic Features

Exoperidium basal layer of inflated subglobose to angular or irregular cells up to 30-38(-45)  $\mu$  broad, walls less than 0.5  $\mu$  thick, among fewer short filaments of cylindric hyphae 1.5-8.0  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline in KOH, pale yellow in Melzer's solution. Cutis of tightly woven cylindric hyphae (Fig. 21c), extensively branched and septate, 2-8  $\mu$  diam. with walls thickened up to 2  $\mu$  at maturity, combined with frequent enlarged cells 9-21  $\mu$  broad with walls up to 2  $\mu$  thick at maturity; hyaline to yellow in KOH, yellow to rusty yellow-brown in Melzer's solution.

Endoperidium of interwoven filaments of cylindric hyphae, infrequently branched, with numerous septa, 1.5-5.5  $\mu$  diam. with walls ca. 0.5  $\mu$  thick; yellow-brown in KOH, rusty brown in Melzer's solution.

Spores 3.5-4.5(-5.0)  $\mu$  diam., globose, covered with hyaline, rounded warts less than 0.5  $\mu$  long; pale brownish yellow to bright yellow in KOH, rusty yellow-brown in Melzer's solution.

Basidia 9-12 x 6-8  $\mu$ , pyriform (Fig. 12b), 4-spored.

Capillitium of branched or highly branched elements with few septa, sinuous in the thinner portions; up to 5.0-6.0(-7.5)  $\mu$  diam., walls up to 0.5-1.0  $\mu$  thick with extremely abundant small round pits (Fig. 18d); nearly concolorous with the spores.

### Habitat and Distribution

Growing singly and scattered, often numerous, infrequently in caespitose groups of 2 or 3; on open pastures, hilltops, and forest

clearings, on soil among grasses; fruiting from mid-August to mid-September.

Specimens examined: BA 167, 251, Miquelon Lake, Alberta; BA 217, Cowley, Alberta; BA 226, Mile 69, Kananaskis Road, Alberta; BA 241, Wetaskiwin, Alberta; BA 332, 365, Camrose, Alberta; BA 342, Nose Hill, Calgary, Alberta; E.E. Morse M-16C (BPI), Pacific Grove, California (labelled L. cepaeforme Bull.); W.H. Long 2039 (BPI), Denton, Texas; W.H. Long 7872 (BPI), Kaibab Nat. Forest, Arizona.

#### Discussion

This species is included in the genus Bovista by Kreisel (1967).

Lycoperdon polymorphum is a very variable species. It has been published as L. cepaeforme Bull., L. ericetorum Pers., or as varieties of those, and as L. polymorphum. The usual basis for differentiation of this taxon is the size of the sporophore and the amount of subgleba present. These variations however are not accompanied by any cellular differences. The European workers consider them all to be synonyms of L. polymorphum.

I found no "cells" or chambers in the subgleba, but merely spaces within the network of hyphal filaments that might be misinterpreted as tiny chambers.



Lycoperdon pyriforme Schaeffer ex Persoon. Syn. Meth. Fung. 148.

1801.

Figs. 9, 12, 22.

#### Macroscopic Features

Sporophore 1-4 cm. broad x 1.5-5.0 cm. high, pyriform to depressed globose with a short cylindric stem, sometimes clavate or turbinate and laterally flattened by mutual pressure; lower portion smooth, plicate, or irregularly wrinkled to deeply folded when caespitose.

Exoperidium thin, continuous when young with very small dark warts which are hard and sharp, near maturity separating over the top of the sporophore into small persistent areolae, becoming brittle and flaking off or wearing away slowly over the top of the sporophore; colored from the beginning of growth and darkening somewhat toward maturity, mature color variable, from creamy brown through shades of orange-brown and brown to brownish red, usually paler toward the base.

Endoperidium becoming exposed on top in late maturity, thin and usually brittle, breaking up readily; cream to golden brown, 6D8.

Opening by a rounded apical pore 2-3 mm. broad, or merely by a small irregular slit, very slow to form and becoming much enlarged in age.

Attached to the substrate by an extensive network of coarse white mycelial cords (rhizomorphs) extending from the base of the sporophore.

Gleba of tough consistency when immature, cottony at maturity with a large pseudocolumella, maturing very slowly; becoming yellow-

brown to brown, 5(E-F)(7-8) to 6E(5-7), often with a pink or reddish orange tint in early stages.

Subgleba up to 1/2 of the sporophore height, chambered, chambers 4-8 per mm.; white, remaining white or cream at maturity.

#### Microscopic Features

Exoperidium cutis and warts of enlarged angular cells (Fig. 22a), often with short pointed projections, up to 35-50  $\mu$  broad with walls up to 2.0-3.5  $\mu$  thick; hyaline to yellowish in KOH, yellow-brown to dark rusty brown in Melzer's solution. Underlayer composed of enlarged subglobose to oval or irregular cells up to 24  $\mu$  broad with walls less than 0.5  $\mu$  thick, combined with fewer cylindric hyphae 2.0-5.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline in KOH, yellowish in Melzer's solution.

Endoperidium of closely interwoven filaments of cylindric hyphae with frequent branches, septate, 1.5-6.0  $\mu$  diam., walls less than 0.5  $\mu$  thick, merging with the exoperidium tissue; hyaline to pale yellow in KOH, bright rusty brown in Melzer's solution, dextrinoid in immature stages.

Spores 3.5-4.5(-5.5)  $\mu$  diam., globose, with small, hyaline, rounded to pointed warts (Fig. 5) less than 0.5  $\mu$  long; yellowish in KOH, yellow-brown in Melzer's solution.

Basidia 8.0-14.5 x 5.0-7.0  $\mu$ , pyriform (Fig. 12c), 4-spored.

Capillitium of elements with frequent sinuous portions, infrequently branched, with few septa; up to 4.0-6.5  $\mu$  diam. with walls up to 1-2  $\mu$  thick, unpitted; yellow-brown to dark brown in KOH, rusty brown in Melzer's solution.

## Habitat and Distribution

Growing in large gregarious to caespitose groups, less frequently in 2's or 3's, seldom single; most often on decaying wood, sometimes on clay soil containing layers of dead moss; fruiting from mid-July to late August.

Specimens examined: BA 109, Blue Bay Cr., Lake Co., Montana; BA 166, Lake Demay (Camrose), Alberta; BA 172, 203, 205, 206, 207, 213, Hungry Horse Res., Flathead Co., Montana; BA 202, Ashley Lake, Flathead Co., Montana; BA 221, Bull Lake, Lincoln Co., Montana; BA 223, Honeymoon Lake, Jasper Nat. Park, Alberta; BA 224, Hinton, Alberta; BA 229, 236, Mile 112, Kananaskis Road, Alberta; BA 244, Alsike, Alberta; BA 255, Camrose, Alberta; BA 337, Lacombe, Alberta.

## Discussion

This unmistakable fungus is very common in the study area, occurring in all but the most arid habitats. It is readily distinguished by the tiny-chambered subgleba, which remains white after maturity. The spores must be stained so that the small hyaline warts may be seen, as illustrated by the electron micrographs published by Bronchart & Demoulin (1971).

Lycoperdon lividum Persoon. Journ. de Bot. 2: 18. 1809.

Figs. 9, 18.

Syn.: L. spadiceum Persoon. Journ. de Bot. 2: 20. 1809.

#### Macroscopic Features

Sporophore 1.4-1.8 cm. broad x 1.3-2.0 cm. high, subglobose to depressed globose with a short, narrow, pointed basal constriction.

Mature exoperidium a very thin layer covered with fine granules, wearing away slowly over the top of the sporophore and remaining well after maturity on the lower half; light brown to yellow-brown, near 5E7.

Mature endoperidium very thin but tough and persistent, smooth and shiny where exposed, slightly lighter in color than the exoperidium.

Opening by a rounded apical pore ca. 2 mm. broad, becoming enlarged and ragged in age.

Attached to the substrate by a small amount of fibrous mycelium extending from the basal constriction, which is rooted in the soil.

Mature gleba cottony, pseudocolumella not evident, dark yellow-brown (near 5E8) or reddish brown (near 7F6).

Subgleba very small, occupying only the basal constriction, chambered, chambers 2-8 per mm.; mature color brown, with a more or less distinct purple tint.

#### Microscopic Features

Spores 3.5-4.5(-5.0)  $\mu$  diam., globose to slightly subglobose, covered with small, hyaline, rounded to pointed warts less than

0.5  $\mu$  long; pale brownish yellow in KOH, bright yellow-brown in Melzer's solution.

Capillitium of infrequently branched and seldom septate elements, lightly encrusted with debris in some places, with many sinuous portions and small rounded bumps; diameter often irregular, up to 5.5-8.0  $\mu$ , walls 0.5-1.0  $\mu$  thick with numerous small round pits (Fig. 18e); brown in KOH and often with a purplish tint, rusty brown in Melzer's solution. A few branched, septate elements of paracapillitium present among the capillitium.

#### Habitat and Distribution

Growing singly in diverse habitats: on low-altitude dry sandy grassland, in a dense birch-fir forest at 3600 ft., and on alpine tundra at 8400 ft. Fruiting period not observed.

Specimens examined: BA 305, Peterson Cr. Trail, Lake Co., Montana; BA 306, Plateau Mtn., Mile 51, Kananaskis Road, Alberta; BA 326, Bittern Lake, Alberta.

#### Discussion

The granular exoperidium separates this species from those that are close to it in other respects. All collections were in a very mature condition and no accurate observations could be made on the peridial tissue.

This species is commonly called Lycoperdon spadiceum, with L. lividum listed as a synonym. However, Demoulin (1970) determined Persoon's two species to be identical, with the name L. lividum having precedence.

Lycoperdon umbrinum Persoon. Syn. Meth. Fung. 147. 1801.

Figs. 9, 12, 22.

### Macroscopic Features

Sporophore 1.5-4.5 cm. broad x 1.5-4.0 cm. high, globose to depressed globose with a short pointed base, or more often pyriform, lower portion often plicate.

Exoperidium a very thin layer covered more or less densely with filiform spines 0.25-1.0 mm. long, erect or curved and often united at their tips, firmly attached, mixed with dense small granules; usually separating into small areolae, wearing away very slowly; mature color brown to dark brown, (5-7)E(6-7), spines often darker or with darker tips; infrequently bright yellow with brown spines.

Endoperidium smooth and shiny where exposed, very thin but tough; brown to golden brown, (5-6)(C-D)(6-7), infrequently bright yellow to brownish yellow.

Opening by a rounded apical pore 2-4 mm. broad, becoming enlarged and somewhat ragged in age.

Loosely attached to the substrate by a mass of fine white fibrous mycelium, sometimes with a few thickened threads present, holding a knot of debris to the base of the sporophore.

Gleba cottony when mature, often with a pseudocolumella that is obvious just at maturity and not evident afterward; brown or dark brown, (5-7)(E-F)(5-7), sometimes with a slight purplish or reddish tint.

Subgleba up to 1/2 of the sporophore height, chambered,

chambers 1-4 per mm.; mature color slightly lighter than that of the gleba, (6-7)E5, usually with a definite purple tint, sometimes with zones of purple or lilac.

#### Microscopic Features

Exoperidium a very thin layer of inflated subglobose to oval cells up to 24-36  $\mu$  broad with walls less than 0.5  $\mu$  thick, among fewer filaments of cylindric hyphae 1-3  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline to yellow in KOH, yellow to yellow-brown in Melzer's solution. Spines and granules of long strands of inflated cells arising from the basal layer (Fig. 22b), cells subglobose to oval or irregular, up to 30-38  $\mu$  broad, walls thickening at maturity to 1.5-3.0  $\mu$  and often with an undulate inner surface; hyaline to yellow or pale brown in KOH, bright yellow to brown in Melzer's solution.

Endoperidium of closely interwoven filaments of cylindric hyphae, branched, with frequent and sometimes close septa, 1.5-5.0(-7.5)  $\mu$  diam. with walls ca. 0.5  $\mu$  thick; yellow to pale brown in KOH, rusty brown to reddish brown in Melzer's solution.

Spores (4.0-)4.5-5.0(-5.5)  $\mu$  diam., globose, densely covered with hyaline, obtuse to truncate warts 0.5-1.0  $\mu$  long, short broken pedicels remaining on most with many long pedicels floating free in the mount; yellow-brown in KOH, sometimes with a slight pinkish tint, rusty yellow-brown in Melzer's solution.

Basidia 11.0-17.0 x 7.0-8.5  $\mu$ , pyriform (Fig. 12d), 4-spored.

Capillitium of branched elements, sometimes septate at the point of branching, with frequent sinuous portions; diameter often irregular and up to 5.0-8.5  $\mu$ , walls 0.5-1.5  $\mu$  thick with numerous small round

pits; yellow-brown to dark brown in KOH, bright yellow-brown to dark rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing singly or in small scattered groups, on a wide variety of substrates: grassed soil in forest clearings, pasture soil, coniferous needle duff, decaying wood, and decaying cedar bark; fruiting from early July to late August.

Specimens examined: BA 188, Yellow Bay, Lake Co., Montana; BA 197, 214, Kootenay Falls, Lincoln Co., Montana; BA 220, Lower Mission Falls, Lake Co., Montana; BA 227, 231, Hinton, Alberta; BA 230, Honeymoon Lake, Jasper Nat. Park, Alberta; BA 235, Mile 70, Kananaskis Road, Alberta; BA 237, Mile 131, Kananaskis Road, Alberta.

#### Discussion

This is a common species throughout the study area, distinguished by the brittle, persistent, hairlike spines which are often quite dense and give the upper surface a woolly appearance. Although the endoperidium is rather tough, it was not found to survive the winter without severe deterioration.

Lycoperdon umbrinum has been divided into a number of species and varieties in past years, often on the basis of colors and other minor variations. The specimens included here show some differences in the colors of the various parts and in the extent of the spinulose covering, but there are essentially no differences histologically.



Lycoperdon perlatum Persoon. Syn. Meth. Fung. 145. 1801.

Figs 9, 18.

### Macroscopic Features

Sporophore 1-4 cm. broad x 1.5-4.5 cm. high, pyriform.

Exoperidium thin, covered with upright narrow conic spines ca. 0.5-1.5 mm. long at the top of the sporophore and becoming smaller toward the base, each surrounded by low warts and granules; conic spines falling away at maturity to leave pale round spots, remaining warts and granules wearing away slowly; white when young, maturing to cream, light brown, 6(D-E)(6-7), or greyish, 5C3.

Endoperidium smooth, thin, fragile or persistent, dull yellow-brown to golden brown.

Opening by a round apical pore 2-5 mm. diam., becoming slightly enlarged and torn in age.

Attached to the substrate firmly by a mass of fine fibrous mycelium extending from the sporophore base.

Gleba cottony when mature with a poorly developed pseudocolumella, maturing through olive to yellow-brown, clay brown or brown, (5-6)(D-E)(5-8).

Subgleba up to  $\frac{2}{3}$  of the sporophore height, chambered, chambers 1-4 per mm.; mature color pale brown with a violet tint, often with greenish zones.

### Microscopic Features

Exoperidium of closely associated inflated cells among fewer filaments of cylindric hyphae: inflated cells subglobose to oval,

long-oval or irregular, up to 25-50  $\mu$  broad with walls less than 0.5  $\mu$  thick, extending outwards to form the warts and spines; cylindric hyphae 2.0-6.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline to yellowish in KOH, yellow to brownish yellow in Melzer's solution.

Endoperidium a thin layer of closely interwoven filaments of cylindric hyphae, branched, septate, sometimes sinuous to S-shaped or looped, 1.5-6.0(-9.0)  $\mu$  diam., walls thin in early stages and thickening at maturity to 2.5  $\mu$ , sometimes thickened so that the lumen appears as a thin line: hyaline to yellow in KOH, rusty yellow-brown to brown in Melzer's solution.

Spores 3.5-4.5(-5.0)  $\mu$  diam., globose, covered with hyaline, rounded to pointed warts up to 0.5  $\mu$  long; pale yellowish in KOH, yellow-brown in Melzer's solution.

Basidia 9.5-15.0 x 5.5-7.0  $\mu$ , clavate to pyriform, 4-spored.

Capillitium of infrequently branched elements, narrower portions often sinuous, up to 6  $\mu$  diam., walls up to 1  $\mu$  thick with several large round pits up to 2  $\mu$  broad (Fig. 18f), sometimes with more numerous small round pits; pale brown to brown in KOH, rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing singly and scattered or in small groups, on coniferous duff, decaying wood, and a variety of humic soil types; fruiting from early July to late August.

Specimens examined: BA 154, Yellow Bay, Lake Co., Montana; BA 180, Ashley Lake, Flathead Co., Montana; BA 204, 209, Island

Lake, Lincoln Co., Montana; BA 218, Mile 120, Kananaskis Road, Alberta; BA 225, Mile 59, Kananaskis Road, Alberta; BA 228, Edson, Alberta; BA 240, Carrot Creek, Alberta; BA 243, Pembina River Prov. Park, Alberta.

### Discussion

This was a very common puffball in the study area, occurring in nearly all habitats and at altitudes up to 6000 feet. The ornamentation of the exoperidium distinguishes the species when the plant has matured under normal conditions. If, however, it was rainsoaked during its development, the exoperidium was observed to form into irregular pyramidal warts and peel from the endoperidium in large pieces or in sheets, making identification rather difficult.

Lycoperdon molle Persoon. Syn. Meth. Fung. 150. 1801.

Fig. 9.

### Macroscopic Features

Sporophore 3-9 cm. broad x 4-13 cm. high, turbinate to pyriform, or with an elongated cylindric to obconic sterile base and an expanded top, often plicate beneath the expanded top or toward the point of attachment.

Exoperidium with more or less abundant soft granules up to 1.5 mm. broad, among soft thick spines up to 1.5 mm. long, usually accompanied by finer granules and spines; spines and granules of both types very loosely attached and easily rubbed off, wearing away early in maturity or often before; white when young, maturing to yellow-brown, 5C(4-6), to brown, 6D6.

Endoperidium smooth, thin and very fragile, concolorous with the exoperidium or very slightly lighter.

Opening by a small rounded apical pore or by a small slit, which soon becomes an enlarged ragged hole or tear.

Attached to the substrate by a mass of fine fibrous mycelium which extends from a broad basal area, holding a knot of soil and debris to the base of the sporophore.

Gleba cottony when mature, fragile, maturing through olive to dark brown, 7F(7-8) with a definite purple tint, seldom reddish.

Subgleba up to  $\frac{3}{4}$  of the sporophore height, chambered, chambers 0.3-1.5 mm. broad; slightly lighter in color than the gleba at maturity, with a definite purple tint, often with yellowish or greenish zones.

#### Microscopic Features

Exoperidium a thin layer of inflated subglobose to irregular cells up to 30  $\mu$  broad, walls less than 0.5  $\mu$  thick but becoming 2.0-3.5  $\mu$  thick near the surface at maturity, combined with fewer filaments of cylindric hyphae 3-6  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline to pale yellow in KOH, yellow in Melzer's solution. Spines and granules composed of branched strands of inflated cells arising from the basal layer, subglobose to irregular or often pyriform, up to 30-45  $\mu$  broad with walls up to 2.0-3.5  $\mu$  thick; yellowish in KOH, yellow to yellow-brown in Melzer's solution.

Endoperidium of loosely interwoven cylindric hyphae, septate, seldom branched, 1.5-5.0  $\mu$  diam. with walls up to 0.5  $\mu$  thick; hyaline to yellowish in KOH, yellow to yellow-brown in Melzer's solution.

Spores 4.5-5.5  $\mu$  diam., globose, densely covered with large truncate warts ca. 1  $\mu$  long, most with a short broken pedicel, many long pedicels floating free in the mount; pale yellow-brown in KOH, brighter in Melzer's solution.

Capillitium of somewhat branched elements with frequent sinuous portions, sometimes encrusted with debris in places, up to 5.0-6.5  $\mu$  diam., walls 0.5-1.0  $\mu$  thick with more or less frequent small round pits which may become short slits in age; brown in KOH and often with a slight purple tint, rusty brown in Melzer's solution.

#### Habitat and Distribution

Growing singly on soil, buried decayed wood, or leaf mold soil under Populus; fruiting from mid-August to mid-September.

Specimens examined: BA 242, Pembina River Prov. Park, Alberta; BA 248, 259, 330, Camrose, Alberta; BA 252, Miquelon Lake, Alberta; BPI #F5921, Uinta Co., Wyoming.

#### Discussion

This species is similar in many respects to Lycoperdon umbrinum, and may be found in some of the literature as L. atropurpureum, L. umbrinum, or varieties of L. umbrinum.

L. molle may be distinguished from L. umbrinum by the large, soft, deciduous spines and granules on the exoperidium, the large truncate warts on the spores, and by the larger fruiting bodies with large sterile bases.

Lycoperdon pedicellatum Peck. New York State Mus. Rep. 26: 73. 1874.

Figs. 9, 12.

#### Macroscopic Features

Sporophore 2.5-4.5 cm. broad x 2.0-4.0 cm. high, pyriform to depressed globose or oval, often with a short, narrow basal constriction, usually plicate below the expanded top or near the point of attachment.

Exoperidium of dense, pointed, pyramidal warts in early stages of growth which split to form a covering of narrow pointed spines up to 2.5 mm. long, shorter toward the base, united at their tips in 4's and 5's; falling away from the endoperidium at maturity from the fruiting body apex downward; white when young, maturing to light brown, 5C(5-6).

Endoperidium with small shallow indentations where exoperidium spines have fallen away, thin and very fragile, mature color light brown to golden brown, 5(C-D)(5-6).

Opening by a rounded apical pore ca 4 mm. broad, soon becoming enlarged and torn.

Attached to the substrate by white fibrous mycelium containing a few thickened threads.

Gleba cottony at maturity, without a pseudocolumella, dark yellow-brown to brown, (5-6)E(7-8).

Subgleba  $1/3$  to  $1/2$  of the sporophore height, fragile, chambered, chambers 1-3 per mm.; maturing to brownish yellow, 5(D-E)(6-8), often with a greenish tint.

## Microscopic Features

Exoperidium basal layer of inflated subglobose to oval cells up to 24-30  $\mu$  broad with walls less than 0.5  $\mu$  thick, hyaline in KOH, yellow in Melzer's solution. Spines of closely associated, long, branched strands of inflated globose to oval or irregular cells with intermittent cylindric cells, up to 24-34  $\mu$  broad with walls up to 0.5-1.5  $\mu$  thick, combined with numerous filaments of branched, septate, cylindric hyphae 2.5-7.5  $\mu$  diam. with walls less than 0.5  $\mu$  thick; hyaline to pale yellowish in KOH, yellow to brownish yellow in Melzer's solution.

Endoperidium of more or less loosely interwoven, sinuous to contorted filaments of cylindric hyphae, branched, septate, 1.5-5.0  $\mu$  diam., walls up to 0.5  $\mu$  thick; hyaline to yellowish in KOH, yellow to dark rusty brown in Melzer's solution.

Spores 4.0-5.0 x 3.5-4.5  $\mu$ , subglobose to broadly oval, covered with small, hyaline, rounded to obtuse warts up to 0.5  $\mu$  long, persistent pedicels 14-40  $\mu$  long; pale brownish yellow in KOH, rusty yellow-brown in Melzer's solution.

Basidia 9.0-15.0 x 4.5-7.5  $\mu$ , broadly clavate to pyriform (Fig. 12e), 4-spored.

Capillitium of infrequently branched elements, a few lightly encrusted with debris, up to 8  $\mu$  diam., walls 0.5-1.0  $\mu$  thick with more or less abundant small round pits; yellow-brown in KOH, rusty brown in Melzer's solution.

### Habitat and Distribution

Growing singly and scattered, sometimes in small clusters, less frequently caespitose, on decaying wood or on leaf mold soil under Populus; fruiting from early August to mid-September.

Specimens examined: BA 249, Camrose, Alberta; BA 331, Camrose, Alberta. Numerous other observations were made in the same region.

### Discussion

The spore ornamentation was difficult to interpret, even after staining in concentrated methylene blue. The warts appeared to be inserted a short distance into the outer region of the spore wall, however this was possibly an illusion created by changes in the focus of the microscope. They appeared as illustrated in Fig. 9i at 1000x, focused at the equator of the spore.

This fungus is distinguished by the long exoperidial spines, and by the long persistent pedicels on the spores.



## CHAPTER IV

### CONCLUSIONS

Distribution records for the Alberta species listed here have not been previously reported, with the exception of Calvatia cyathiformis. This is the first organized study, to the author's knowledge, of the Lycoperdales in Alberta.

The approach to the study of the Gasteromycetes used here has revealed many new and interesting features of the cellular morphology of the puffballs, and raised some questions concerning their relationships. In the species studied, all spores were found to be ornamented with some form of wart (with the exception of the reticulated spores of Mycenastrum corium), although some are hyaline and small, and not visible in the common mounting media. "Echinulations" were not found on any of the spores.

Disciseda defodioidis, a little-known species, has been previously reported only from North Dakota and Wyoming (Lloyd 1913, Zeller 1947), and only briefly described. The descriptions of the peridia, basidia, and the descriptive details of the spores and capillitium, are reported in this thesis for the first time.

There are no published descriptions of the peridial tissue of Calvatia fragilis, which clearly separates that species from C. cyathiformis. There was little distinction found between the tissues of Calbovista subsculpta and the species of Calvatia (except for the

capillitial elements), which leaves little support for maintaining Calbovista as a genus outside the Lycoperdaceae. The same can be said for Mycenastrum, since it shows no greater character variation from the type species for Calvatia than does C. fragilis or C. fumosa, and has a capillitium similar to that of Bovista, which is considered by all mycologists to be a legitimate member of the Lycoperdaceae.

The peridial tissues, capillitium, and subgleba of Lycoperdon pusillum and L. polymorphum were found to bear a close resemblance to those of species of Bovista, a fact used by Kreisel (1967) in support of his inclusion of those species in the genus Bovista. That comparison encourages one to support Kreisel's concept, but further investigation of the developmental characters is necessary before definite conclusions can be drawn.

On the basis of the data collected to date there appears to be sufficient peridial cell differences to distinguish Lycoperdon umbrinum from L. molle, two species that are very close and often confusing. A number of other species of both Calvatia and Lycoperdon can readily be separated using peridial cell characters described here in conjunction with traditional features.

Vascellum curtisii shows essentially no differences in tissue types from Lycoperdon spp., but is separated on the basis of its diaphragm and capillitium (paracapillitium). Although this is considered a developmental difference and therefore a phylogenetic one, it is difficult to reason that this should be used to erect a new genus when features such as presence or absence of subgleba, or of clamped hyphae, or development of the exoperidial extensions (warts or spines)

are not seen to have the same significance.

There was a remarkable similarity found between Radiigera fuscogleba and Geastrum spp. The only difference that was evident was the lack of dehiscence in Radiigera, which is a minor feature in view of the many characters that may be used for comparison. It seems likely that Radiigera should be placed in the Geastraceae along with Geastrum. A separate study has been initiated in this regard.

The families and genera in the order Lycoperdales that are used here are those outlined by Zeller (1949). The taxonomic scheme presented by Dring (1973), based on developmental characters in an attempt to produce a phylogenetic ordering, achieves a similar outline of taxa. Keys based on this system are of limited usefulness, since they are not at all well adapted to the identification of plants, which should be the primary purpose of a key. Yet another scheme was proposed by R. L. Shaffer (1975), who combined a number of orders throughout the Basidiomycetes. There, the Tulostomataceae, Calostomataceae, Sclerodermataceae, and Astraeaceae were included in the Lycoperdales, on the basis of their mature character rather than their development. This system would probably not be as easily used to identify plants as Zeller's, and would require more complex keys, lacking the preliminary separation of orders.

It is evident from the findings of this study that future investigations of the taxonomy of Gasteromycetes must have their scope extended to include in their criteria the complete fruiting body and its development, both macroscopically and microscopically. The development of techniques in pure culture growth of fruiting bodies,

and in chemotaxonomy, will no doubt provide much useful data as well, for purposes of confirmation of species. With this in mind, it is probably unwise to adapt traditional criteria for naming "new" species at this time without utilizing all modern investigative methods on the taxa now described.

Worldwide stabilization of species concepts and other taxonomic criteria are needed at this time when there is such a great potential for international communication and cooperation. Complete revisions of Geastrum and Disciseda are imperative before good regional work can be done with them. As well, a second look should be taken at certain genera (such as Vascellum) in the Lycoperdaceae, and at some species within genera (such as Calvatia booniana).

Figure 1. The study area in the Pacific Northwest (shaded).

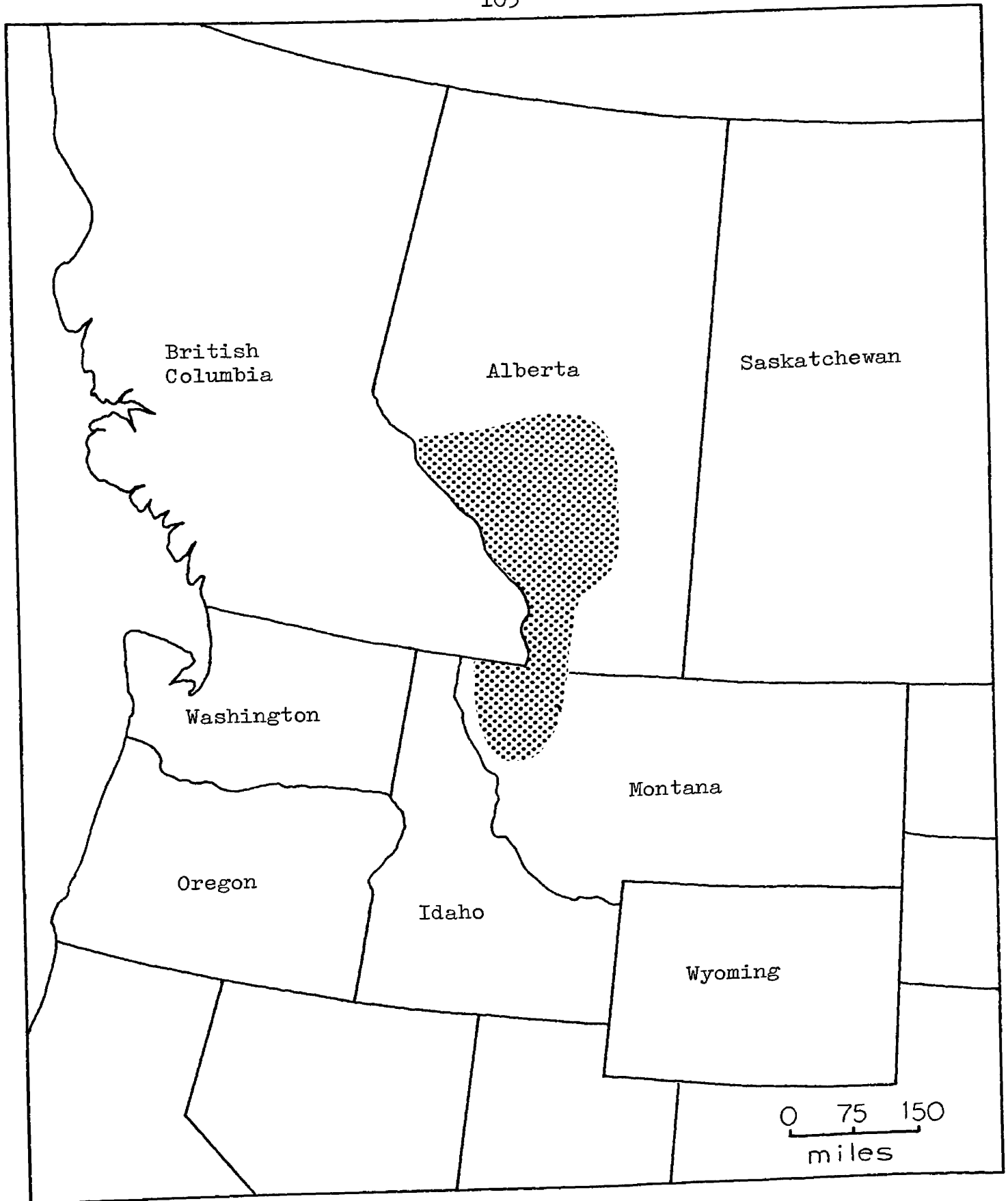


Figure 2. Vegetation regions in the study area:  
(1) Northern Coniferous Forest, (2) Montane and Foothills Forest,  
(3) Aspen Parklands, (4) Prairie Grasslands.

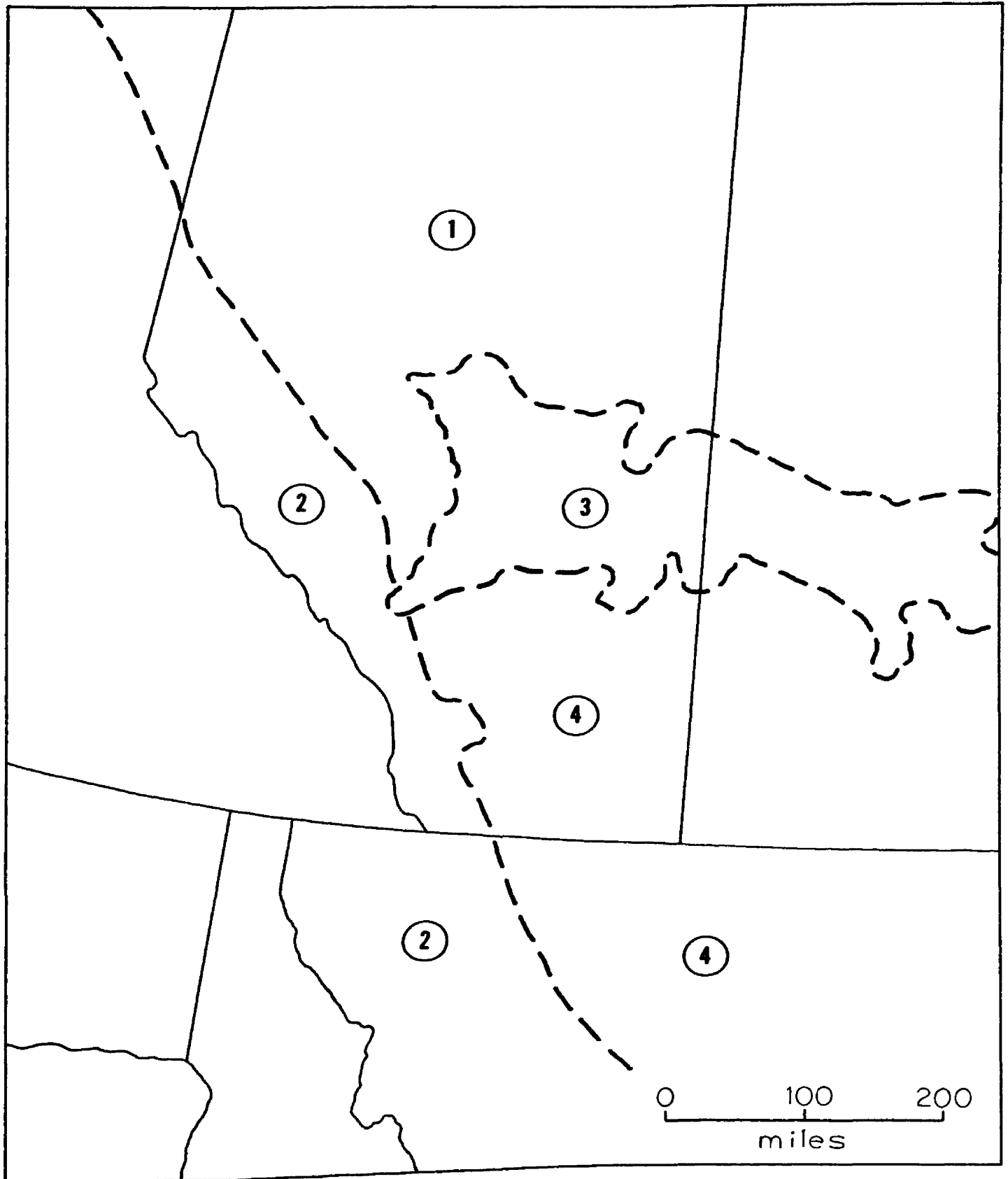
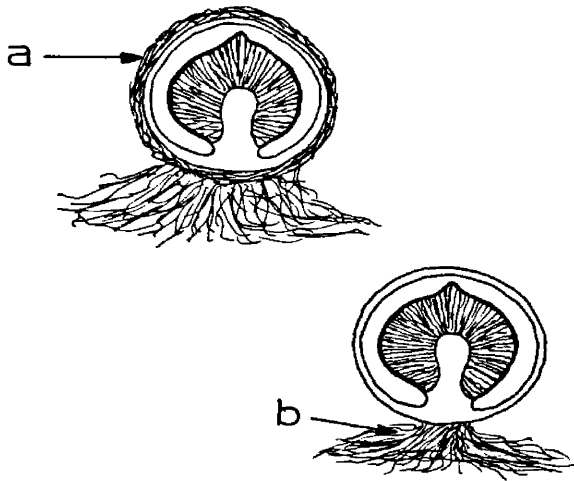
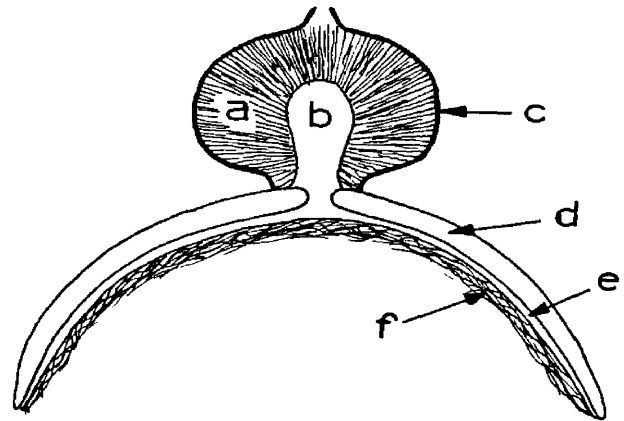




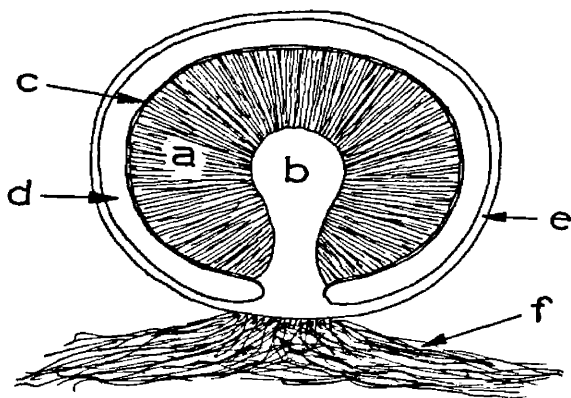
Figure 3. Cross-sectional illustrations of features characteristic of (i) and (ii) Geastraceae, (iii) Mesophelliaceae, and (iv) Lycoperdaceae.



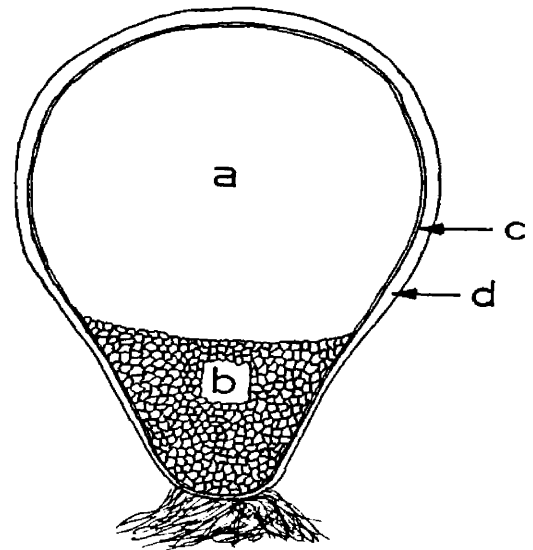
(i) Geastrum sp., c.s. button:  
(a) universal mycelium, (b) basal mycelium.



(ii) Geastrum sp., mature: (a) gleba, (b) pseudocolumella, (c) endoperidium, (d) mesoperidium, (e) exoperidium, (f) universal mycelium.

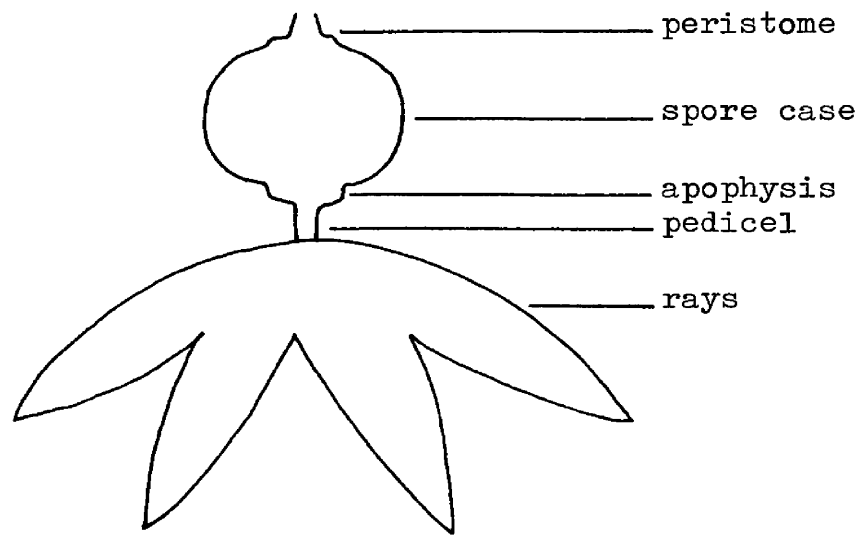


(iii) Radiigera sp., c.s.:  
(a) gleba, (b) pseudocolumella,  
(c) endoperidium, (d) mesoperidium,  
(e) exoperidium, (f) basal mycelium.



(iv) Lycoperdon sp., c.s.:  
(a) gleba, (b) subgleba, (c) endoperidium, (d) exoperidium.

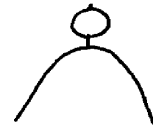
Figure 4. Schematic illustrations of terminology applying to Geastrum spp.



a. external features



b. recurved rays



c. vaulted rays



d. revolute rays



e. involute rays

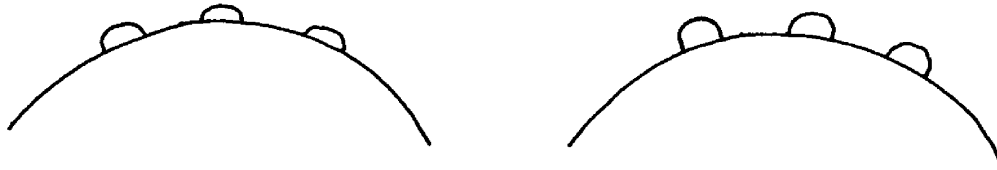


f. saccate rays,  
sessile spore case



g. fornicate rays

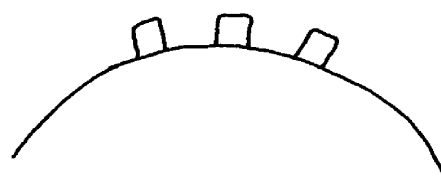
Figure 5. Schematic illustrations of terminology applying to spore ornamentation.



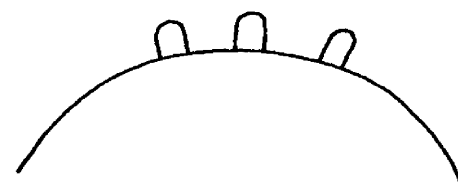
a. rounded warts



b. pointed warts

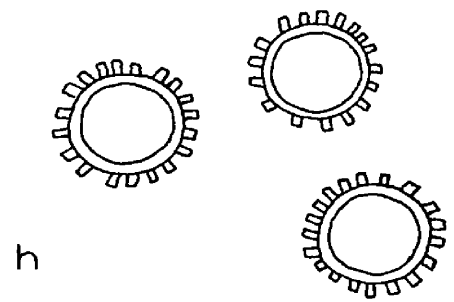
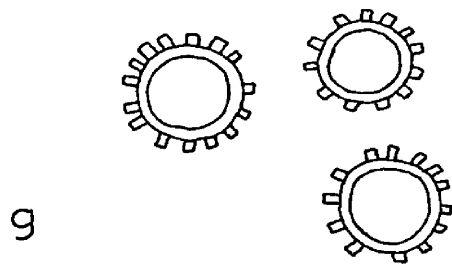
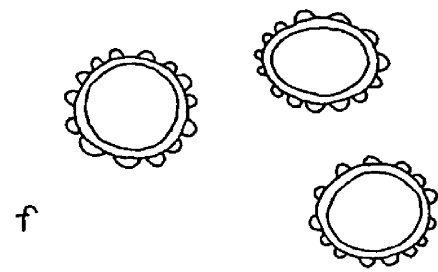
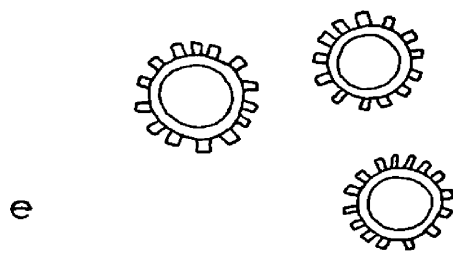
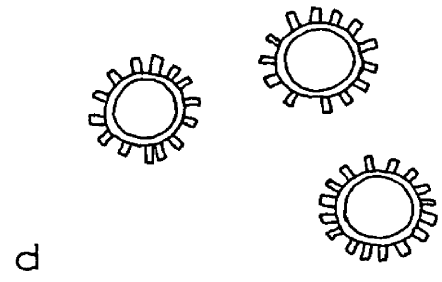
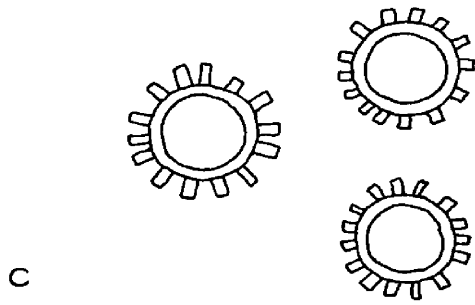
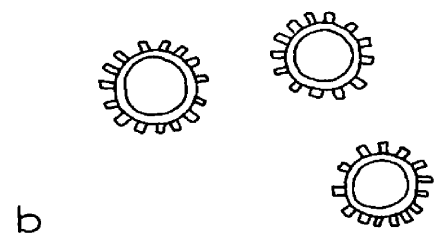
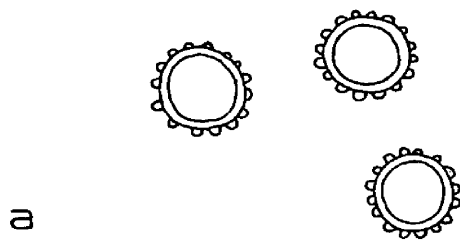


c. truncate warts



d. obtuse warts

Figure 6. Spores: (a) Geastrum recolligens, (b) G. fimbriatum,  
(c) G. pectinatum, (d) G. triplex, (e) G. limbatum, (f) G. minimum,  
(g) G. quadrifidum, (h) Radiigera fuscogleba.



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Figure 7. Spores: (a) Calbovista subsculpta, (b) Mycenastrum corium, (c) Calvatia fragilis, (d) C. fumosa, (e) C. cyathiformis, (f) C. booniana, (g) C. bovista, (h) C. tatrensis.

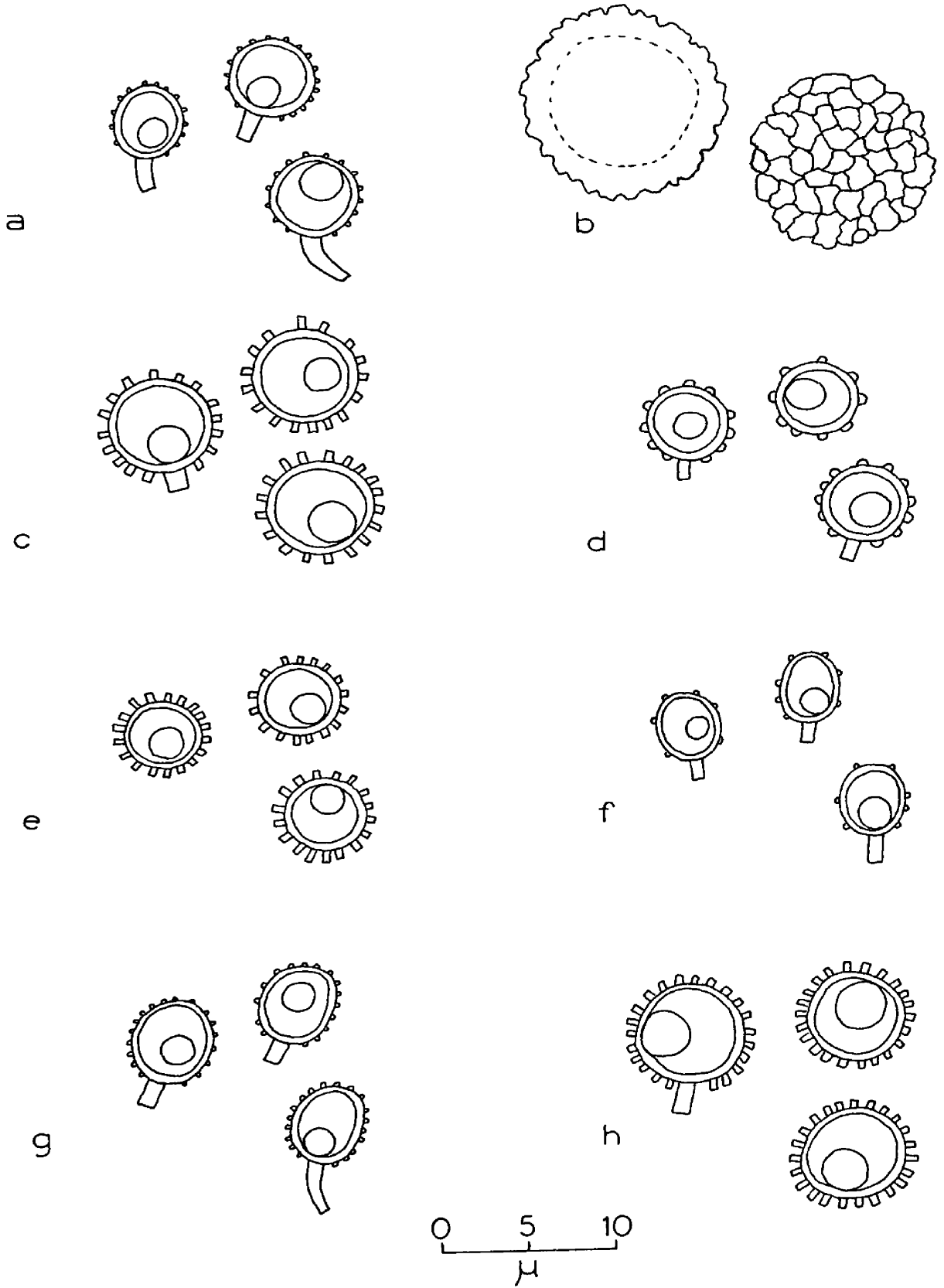


Figure 8. Spores: (a) Bovista minor, (b) B. pila,  
(c) B. plumbea, (d) B. echinella, (e) B. tomentosa, (f) Disciseda  
defodiodis, (g) D. candida, (h) D. bovista.

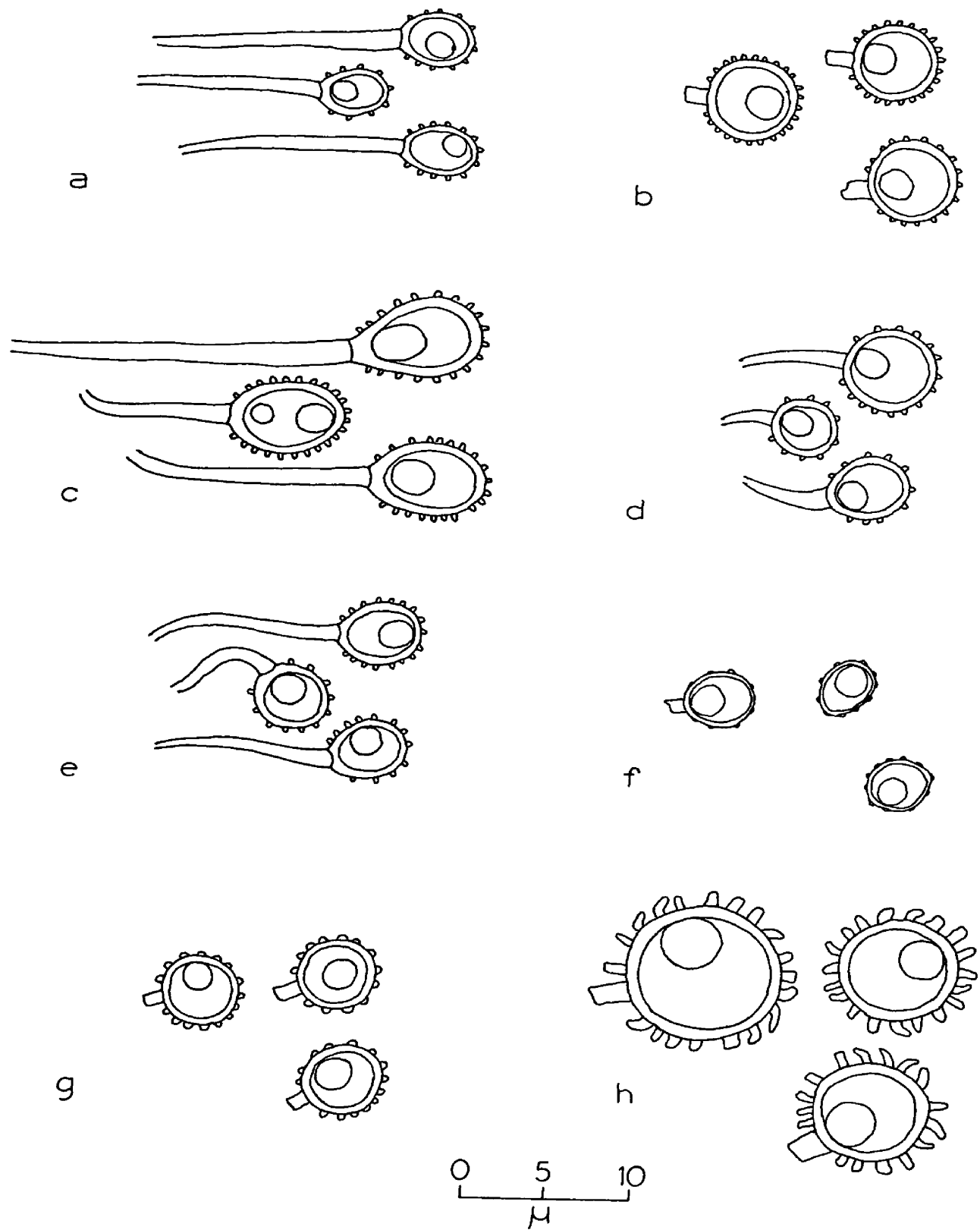


Figure 9. Spores: (a) Vascellum curtisii, (b) Lycoperdon pusillum, (c) L. polymorphum, (d) L. pyriforme, (e) L. lividum, (f) L. umbrinum, (g) L. perlatum, (h) L. molle, (i) L. pedicellatum.

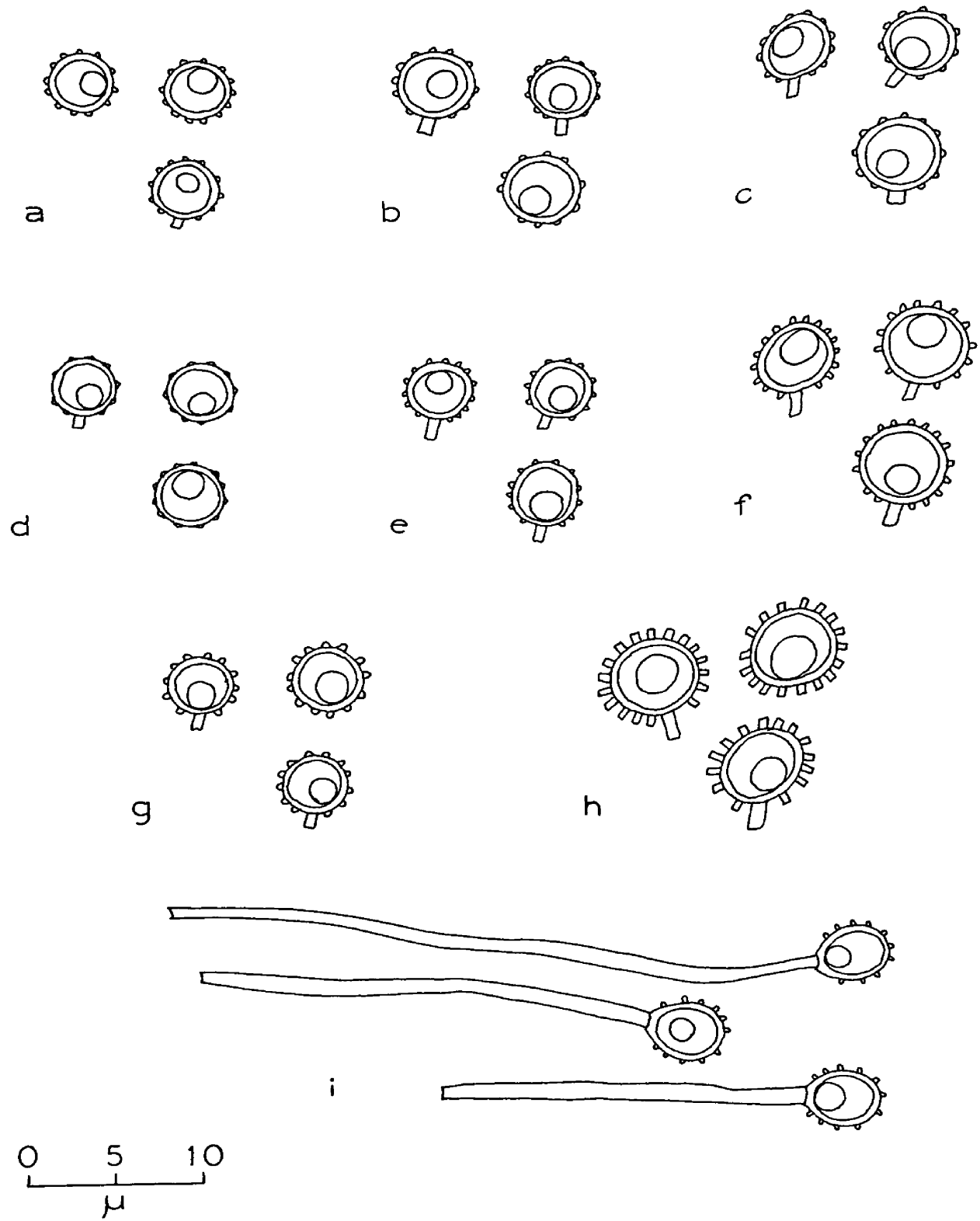


Figure 10. Basidia: (a) Geastrum triplex, (b) G. limbatum,  
(c) Radiigera fuscogleba.

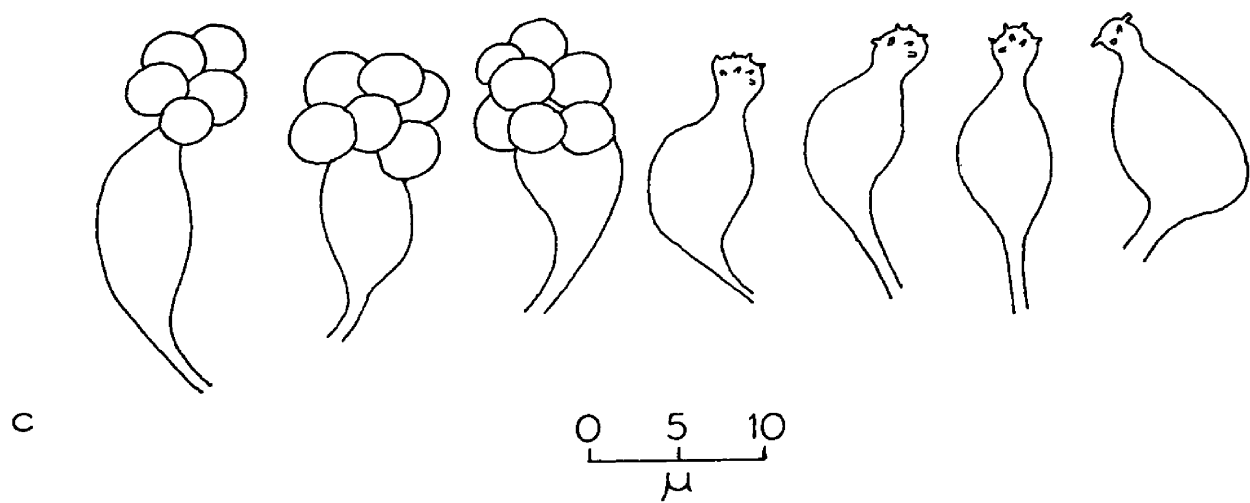
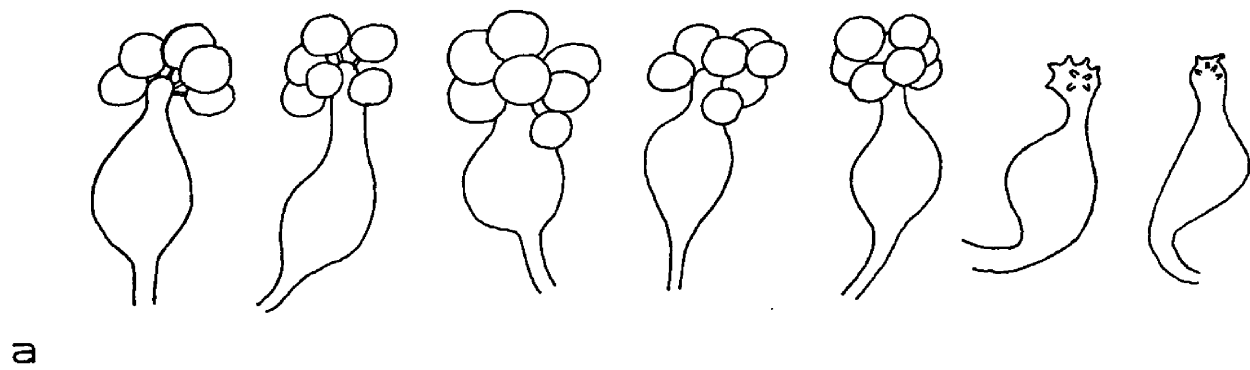
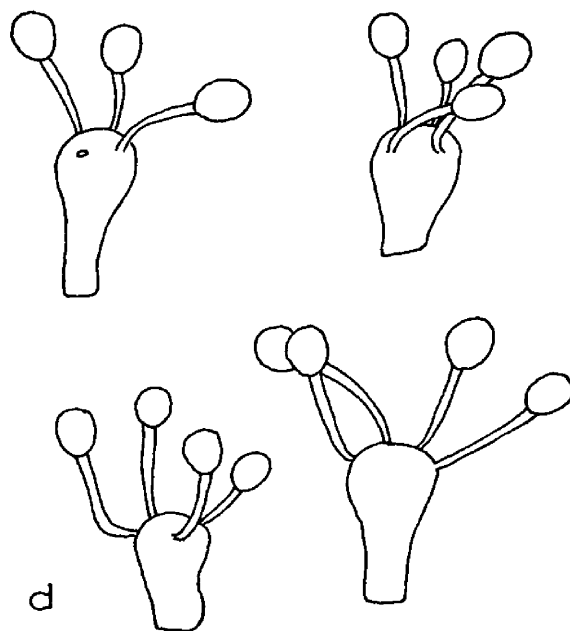
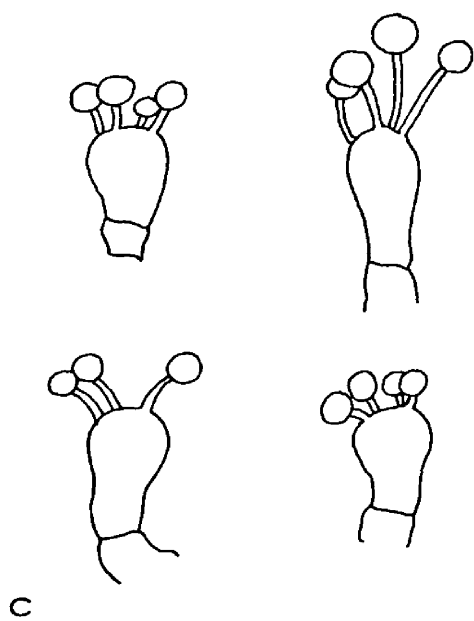
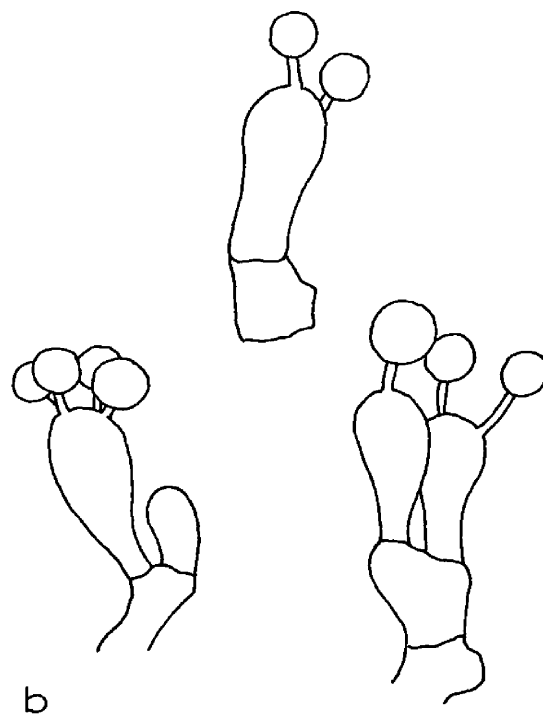
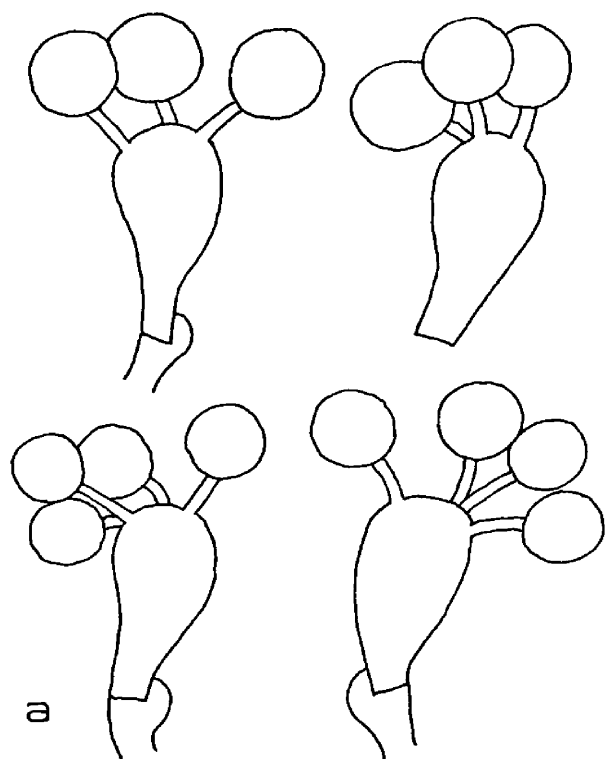




Figure 11. Basidia: (a) Mycenastrum corium, (b) Calvatia fumosa, (c) Bovista pila, (d) B. plumbea.



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Figure 12. Basidia: (a) Disciseda defodiodis, (b) Lycoperdon polymorphum, (c) L. pyriforme, (d) L. umbrinum, (e) L. pedicellatum.

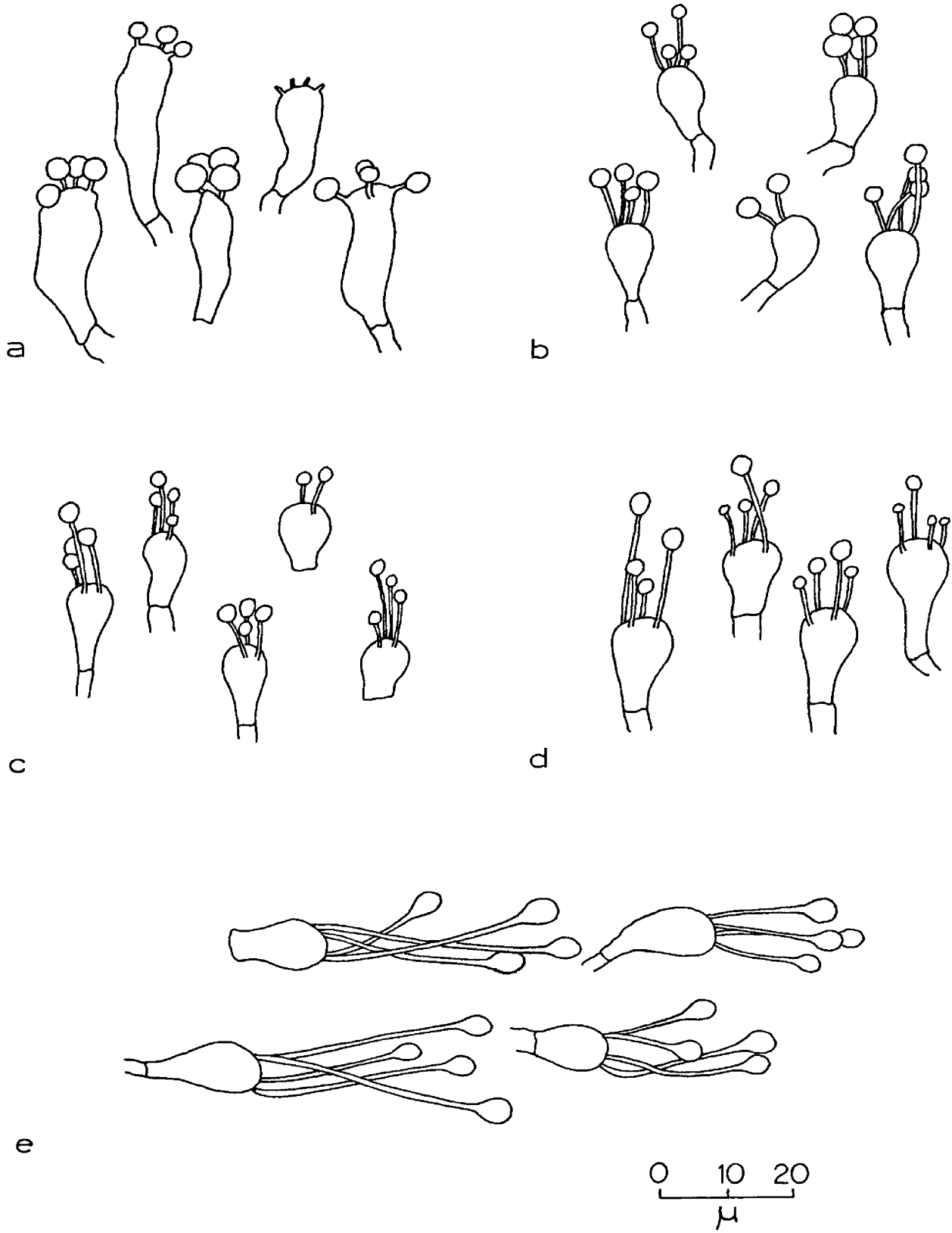
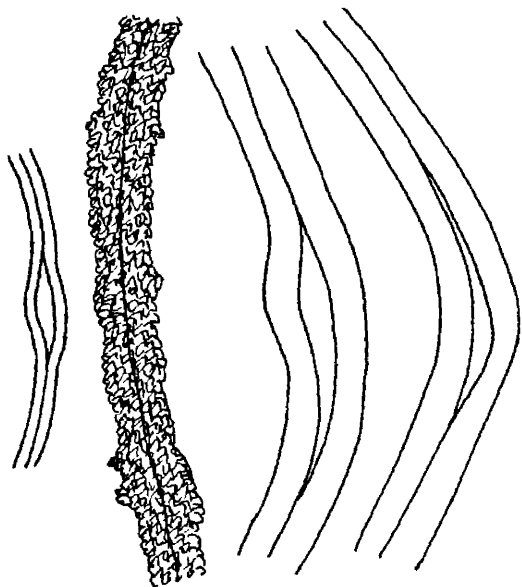
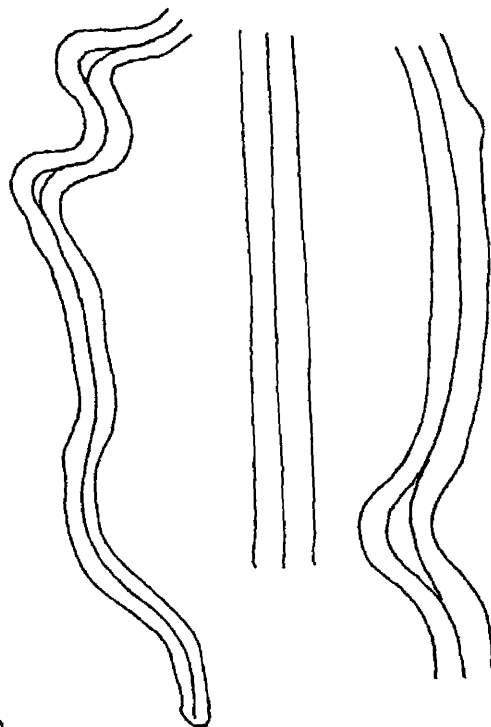


Figure 13. Capillitium: (a) Geastrum recolligens,  
(b) G. pectinatum, (c) G. triplex, (d) Radiigera fuscogleba.

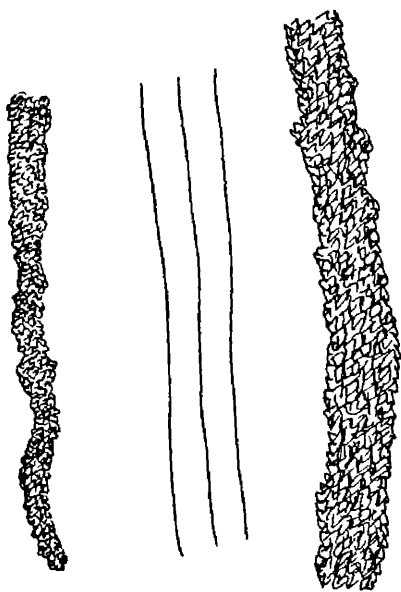
a



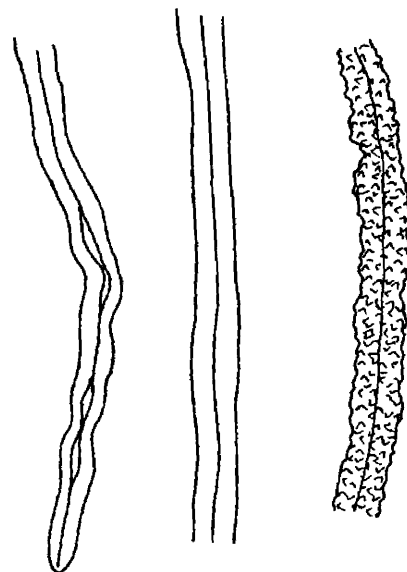
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c

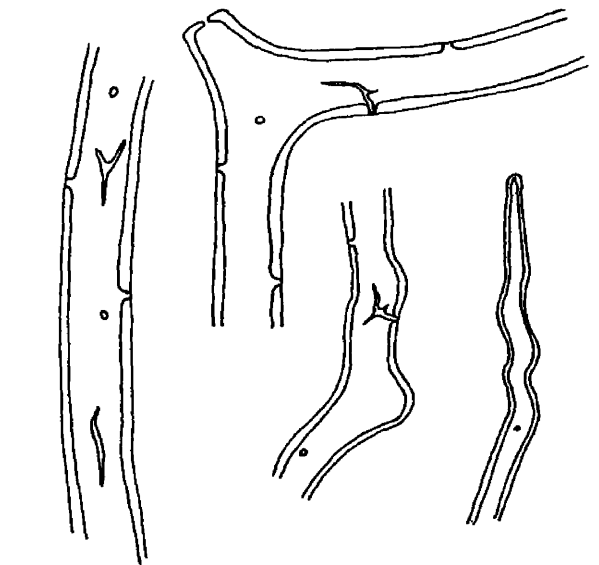
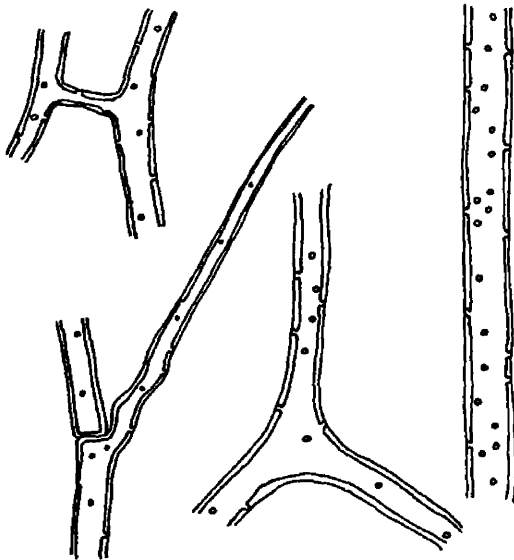
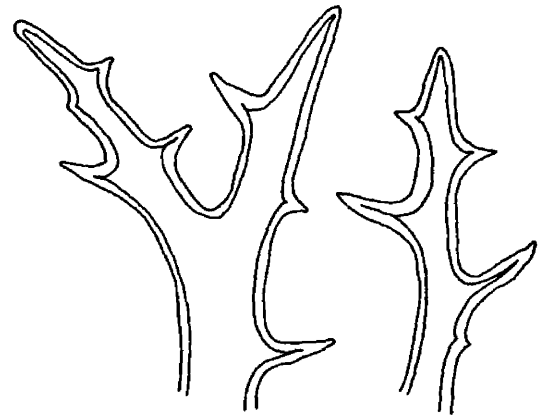
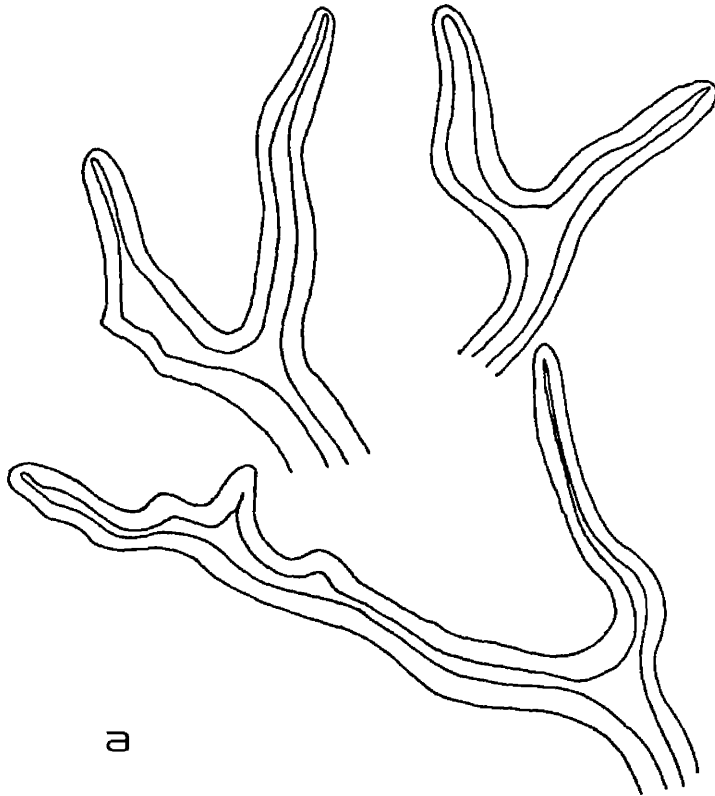


d



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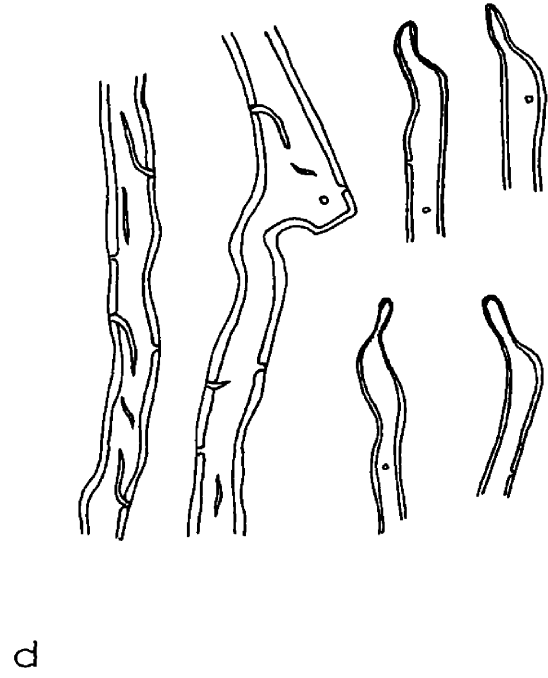
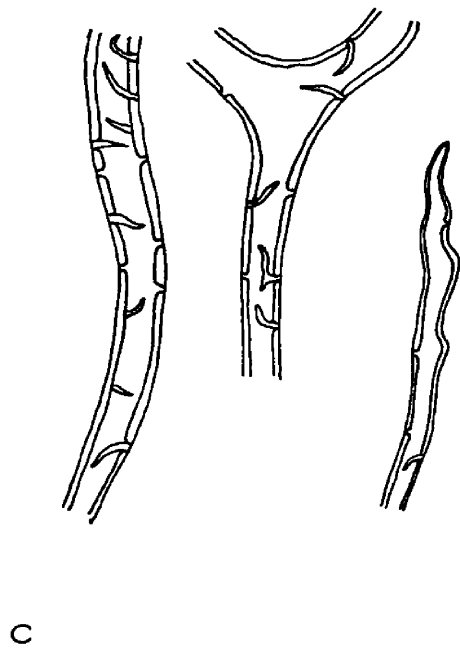
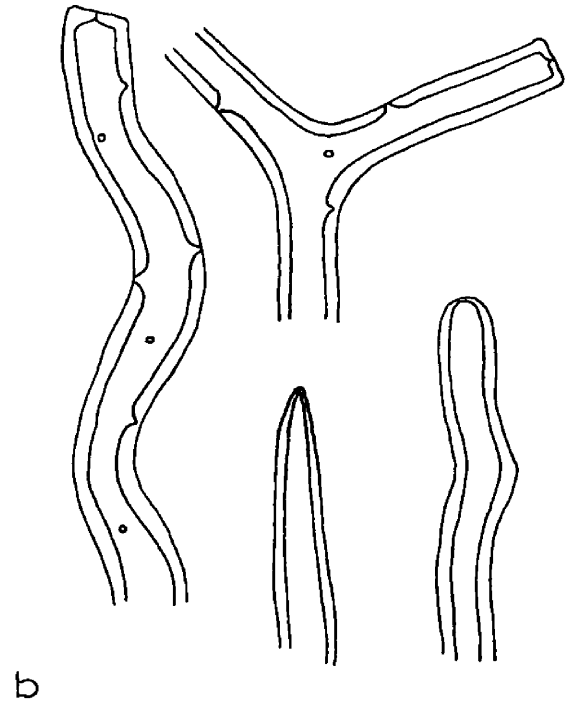
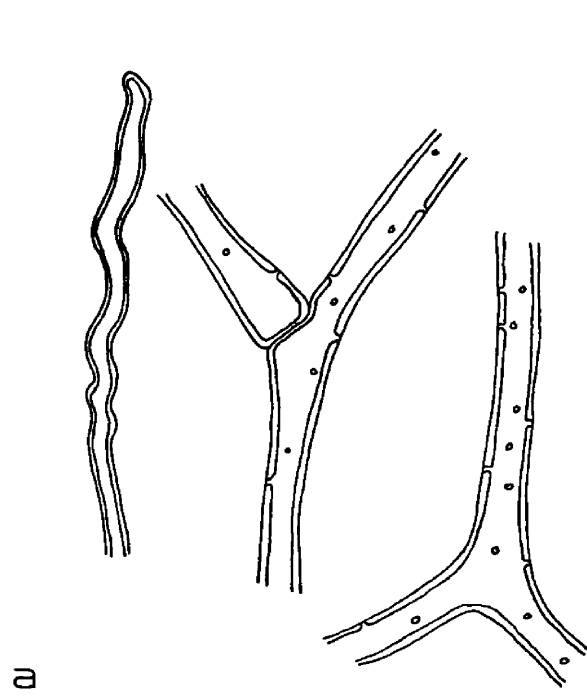
Figure 14. Capillitium: (a) Calbovista subsculpta,  
(b) Mycenastrum corium, (c) Calvatia fragilis, (d) C. fumosa.



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μ

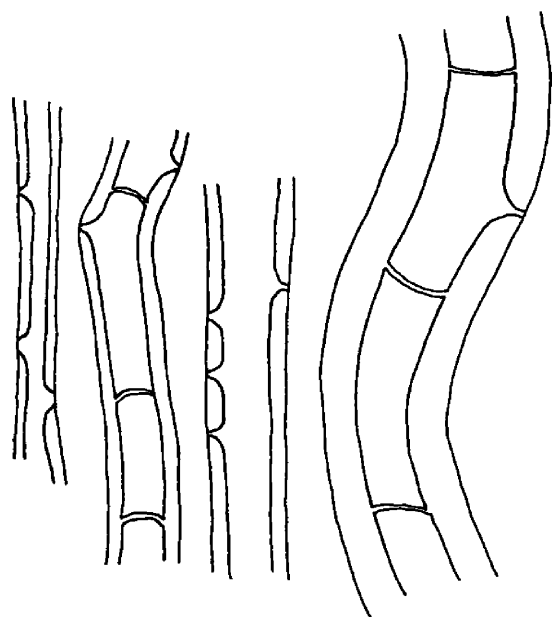


Figure 15. Capillitium. (a) Calvatia cyathiformis,  
(b) C. booniana, (c) C. bovista, (d) C. tatrensis.

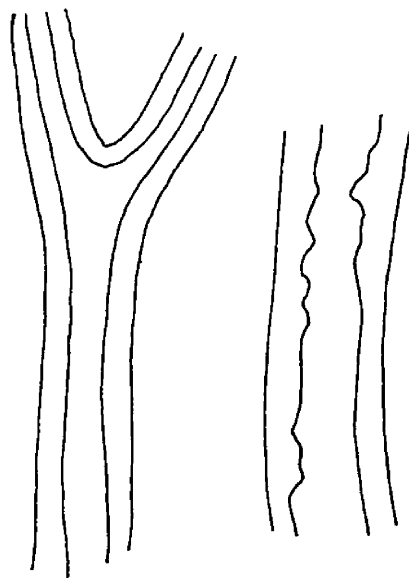


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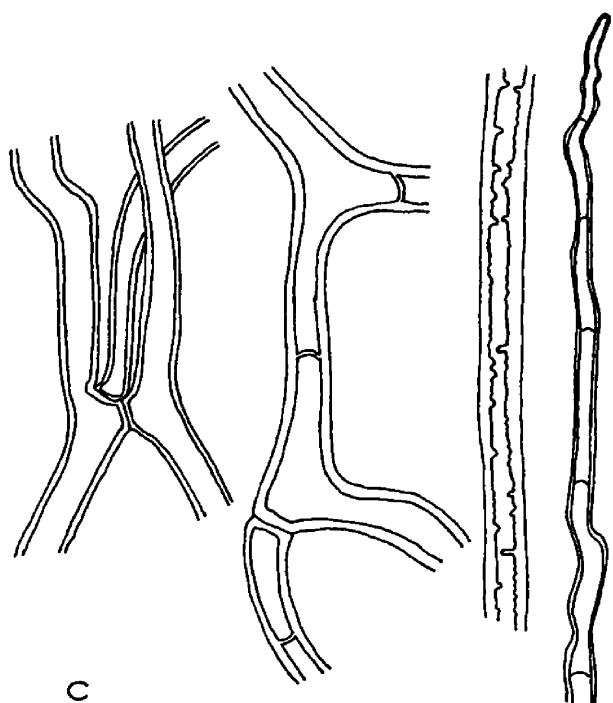
Figure 16. Capillitium: (a) Bovista minor, (b) B. plumbea,  
(c) B. echinella, (d) B. tomentosa.



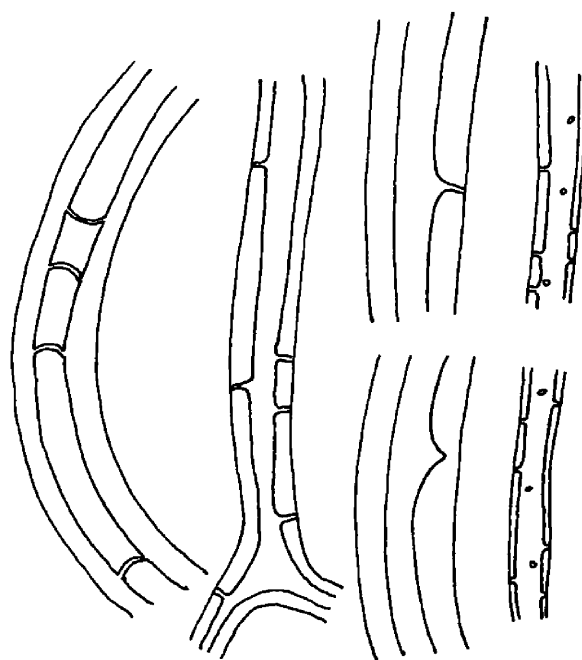
a



b



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d

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Figure 17. Complete capillitial units of Bovista  
echinella, x120.

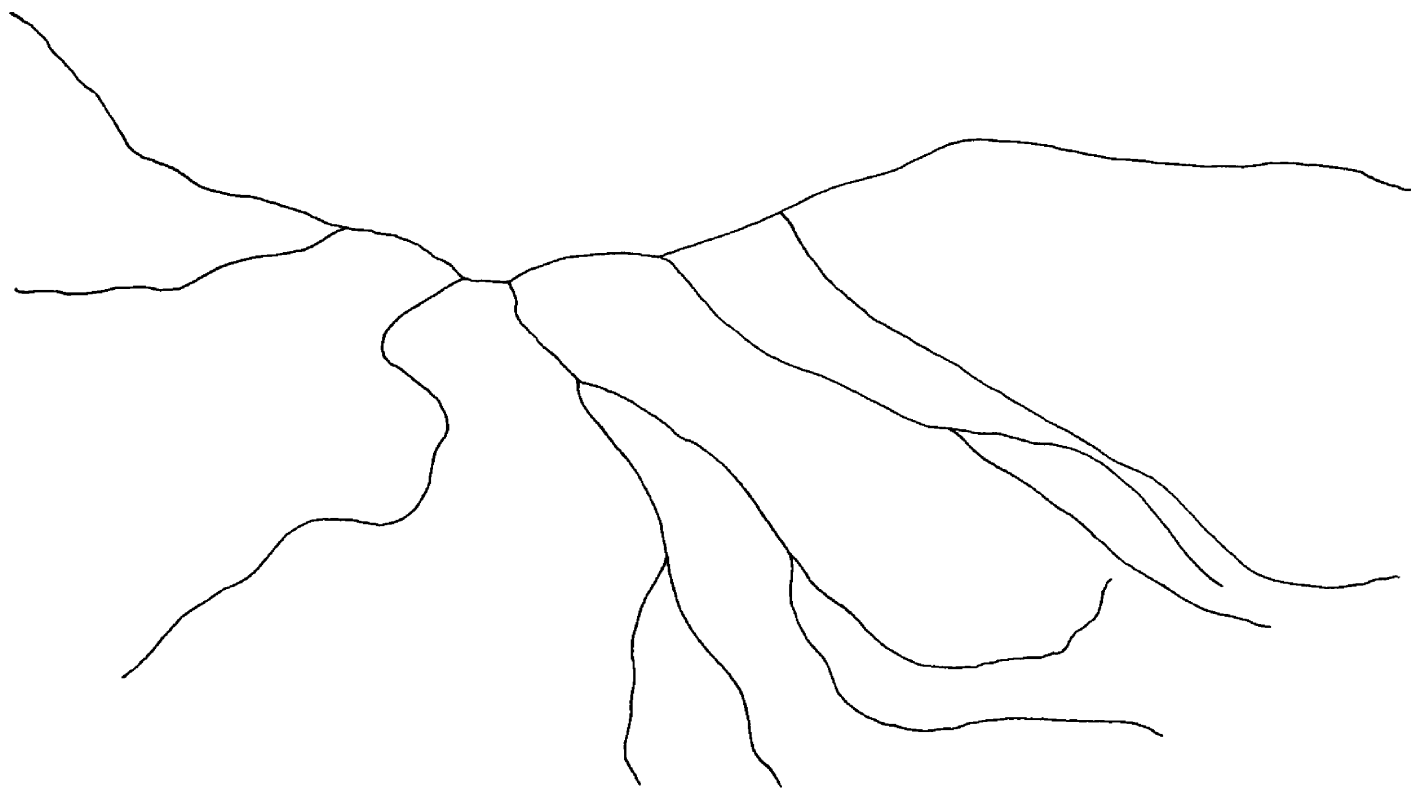
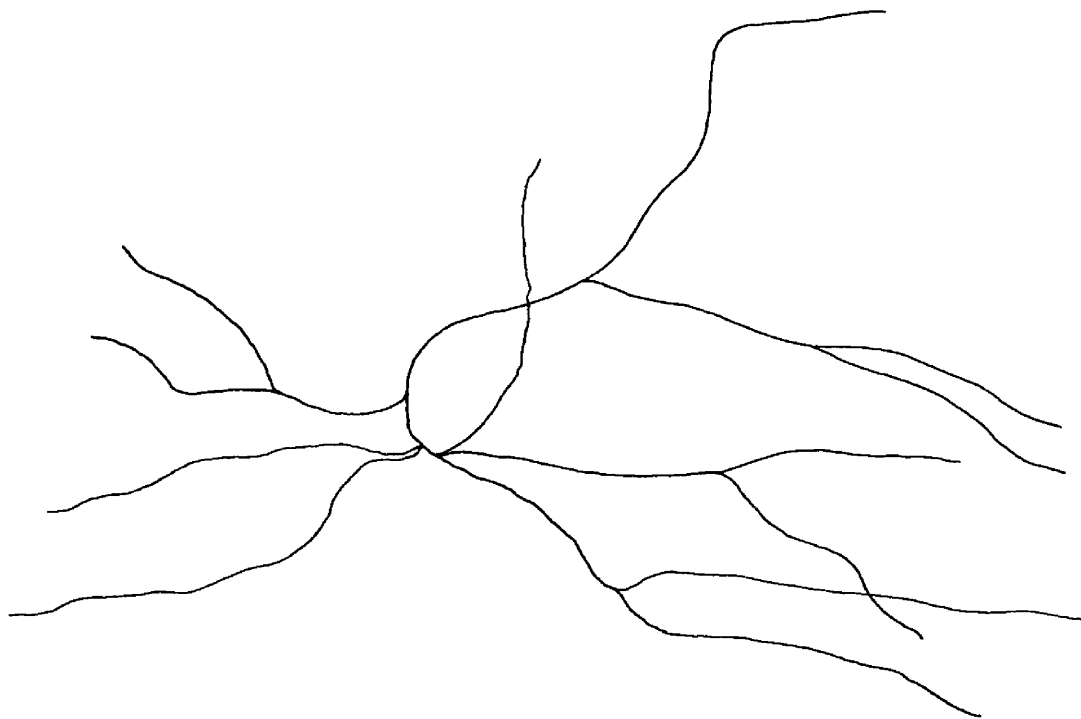


Figure 18. Capillitium: (a) Disciseda defodiodis,  
(b) D. candida, (c) D. bovista, (d) Lycoperdon polymorphum,  
(e) L. lividum, (f) L. perlatum.

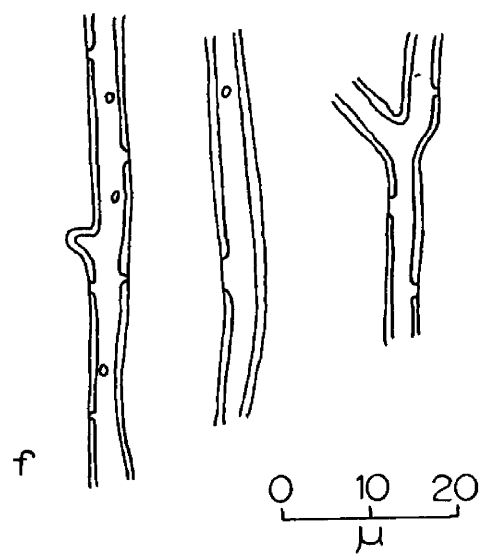
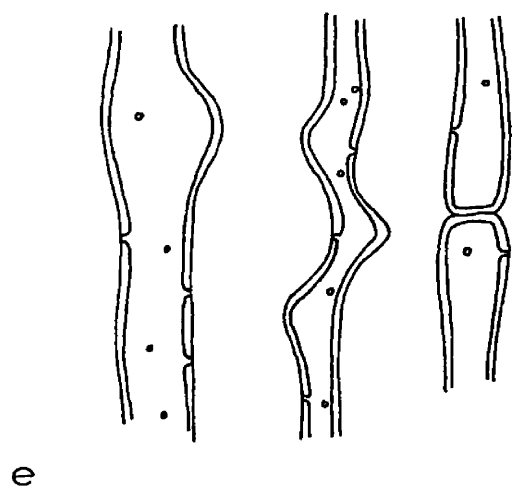
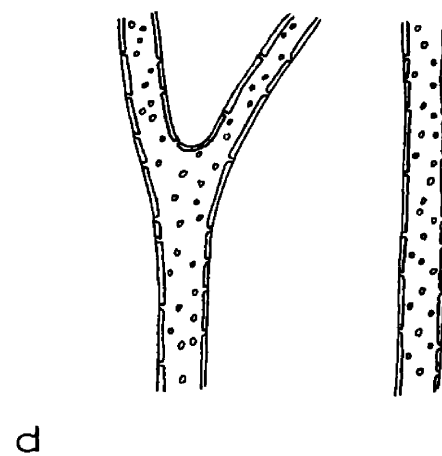
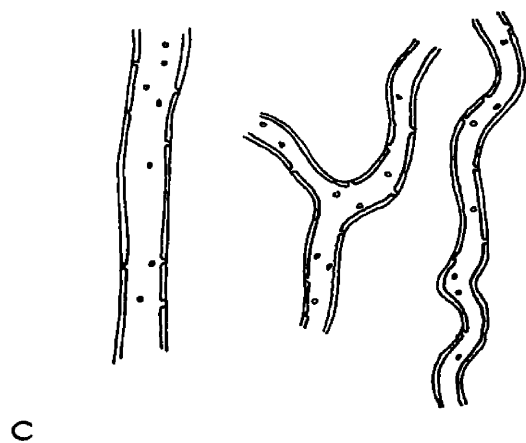
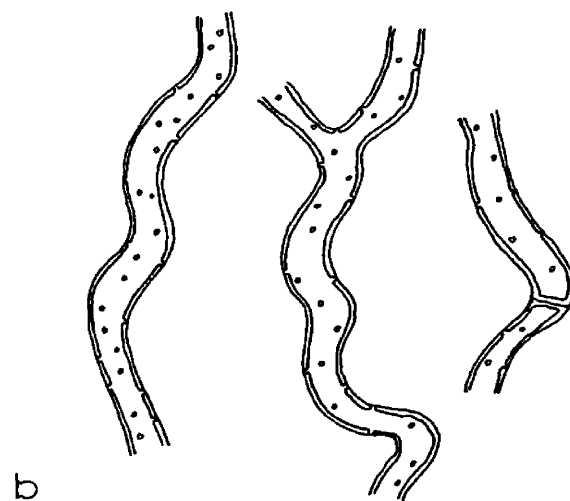
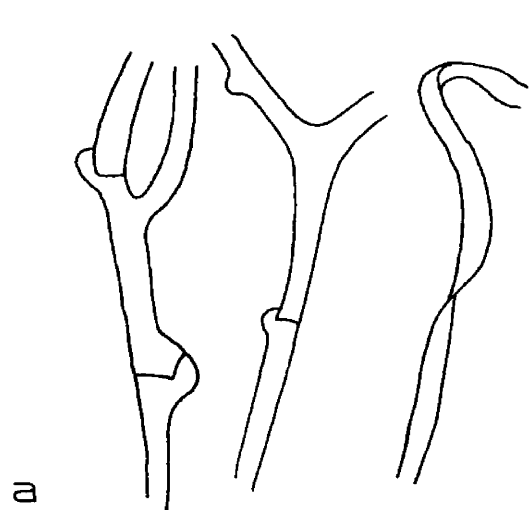




Figure 19. Peridial cells: (a) Calbovista subsculpta endoperidium, (b) C. subsculpta exoperidium, (c) Calvatia fragilis endoperidium, (d) C. tatrensis exoperidium, cutis region.

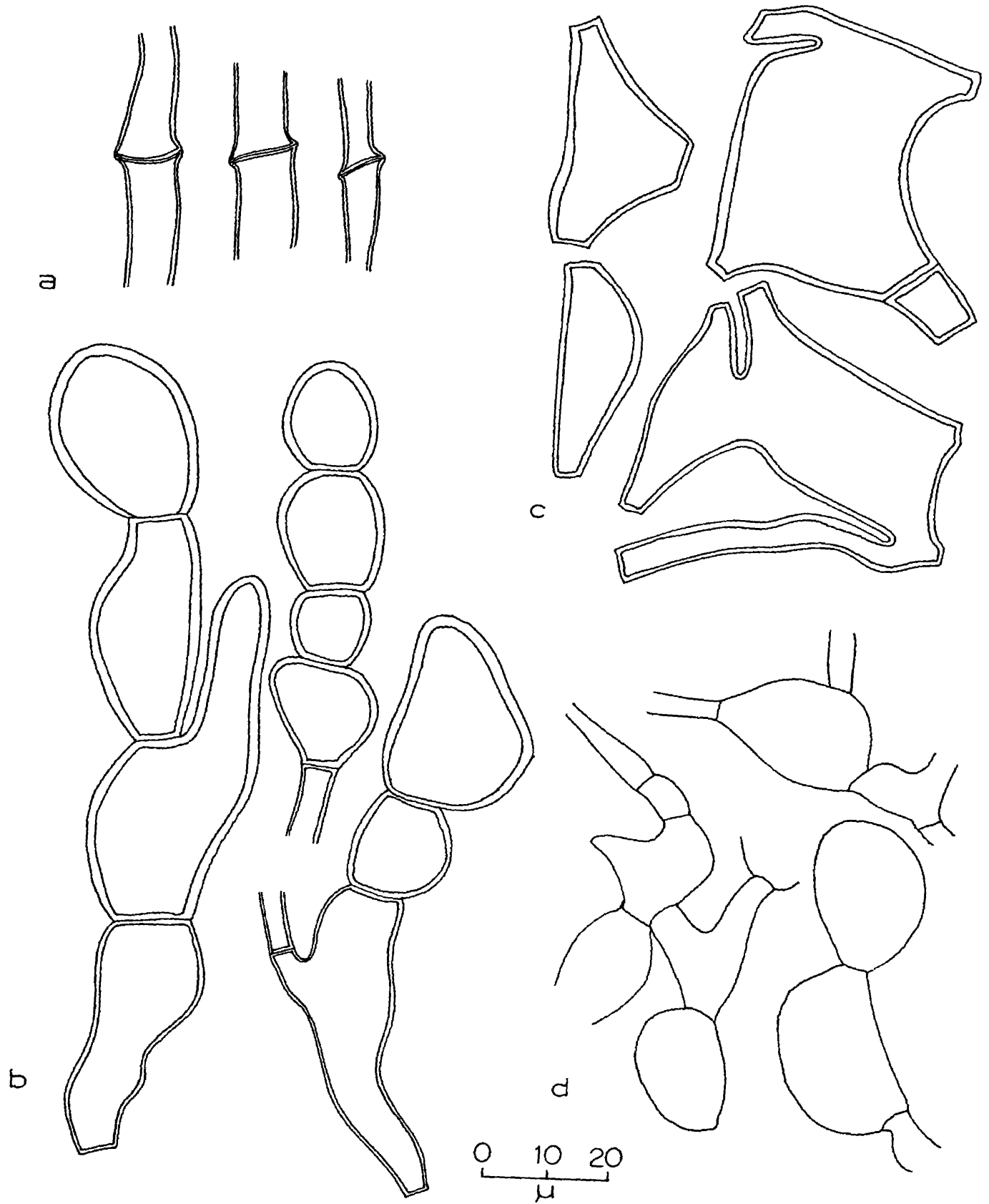


Figure 20. Peridial cells: (a) Bovista pila exoperidium,  
(b) B. plumbea exoperidium, (c) Disciseda defodiodis endoperidium,  
(d) D. defodiodis exoperidium.

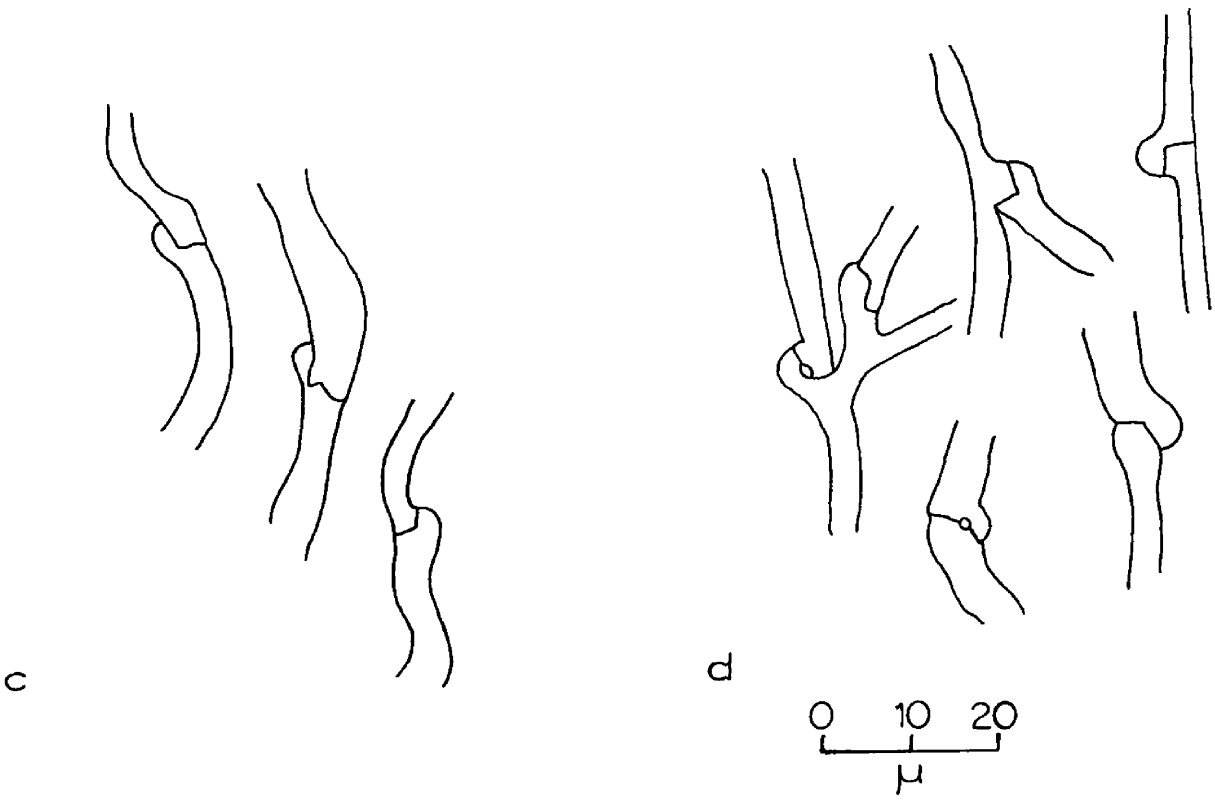
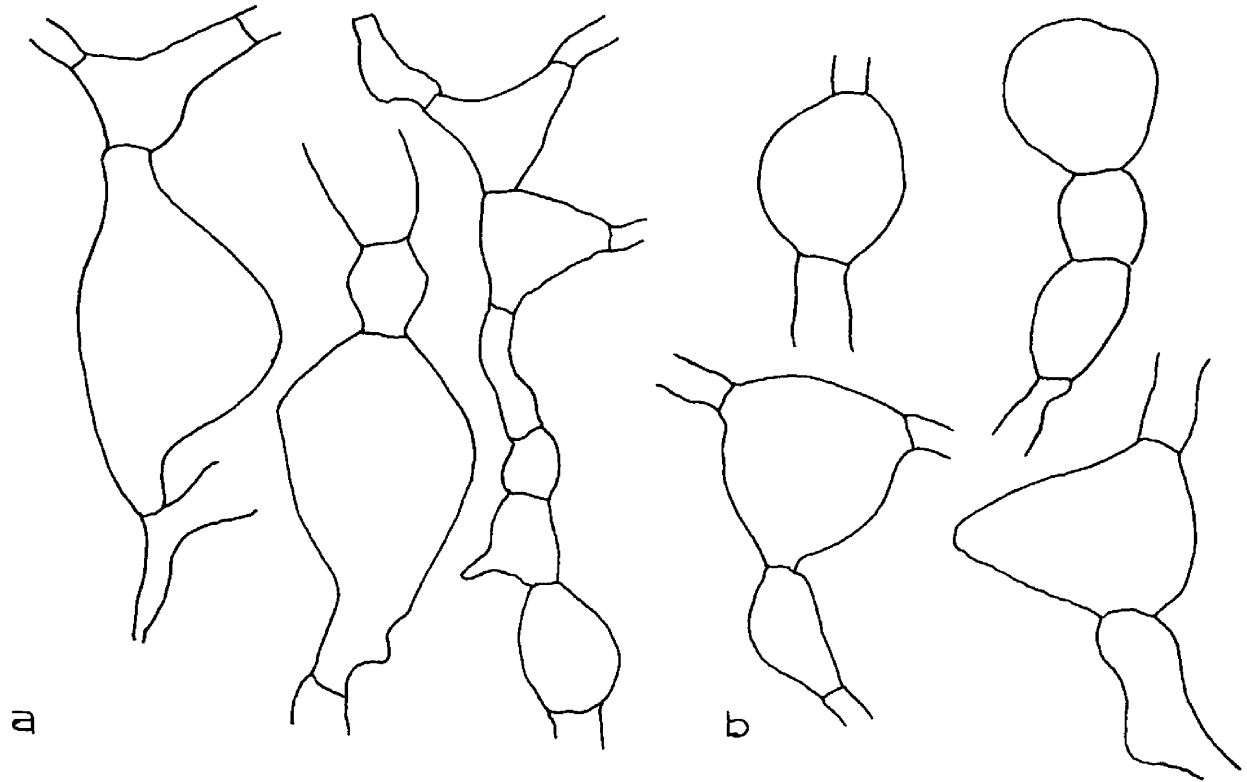
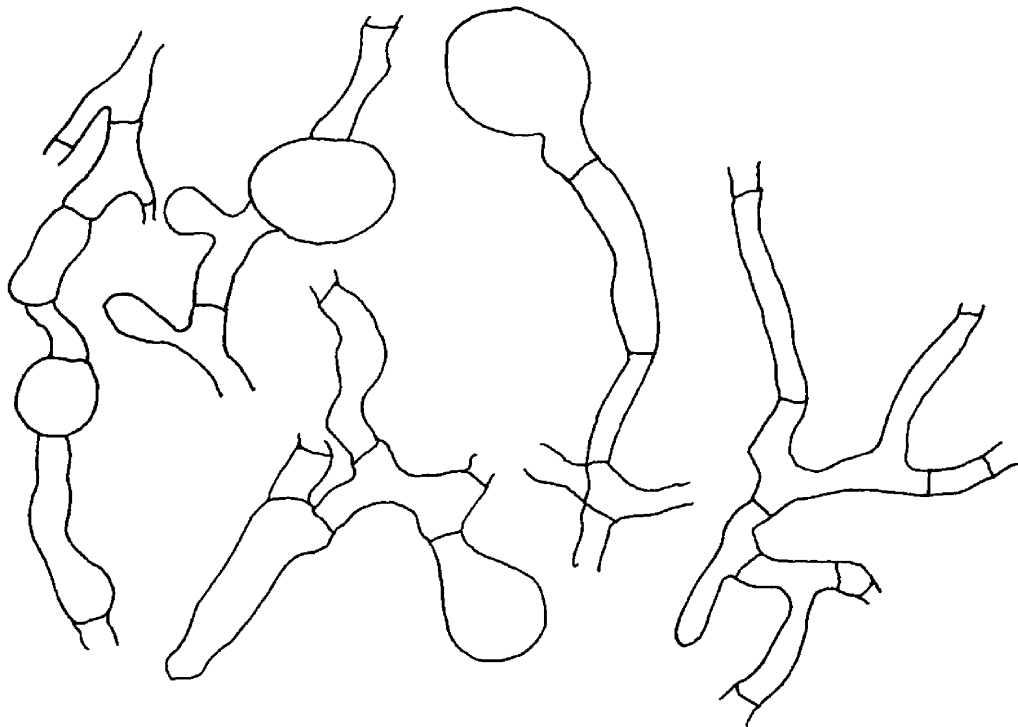
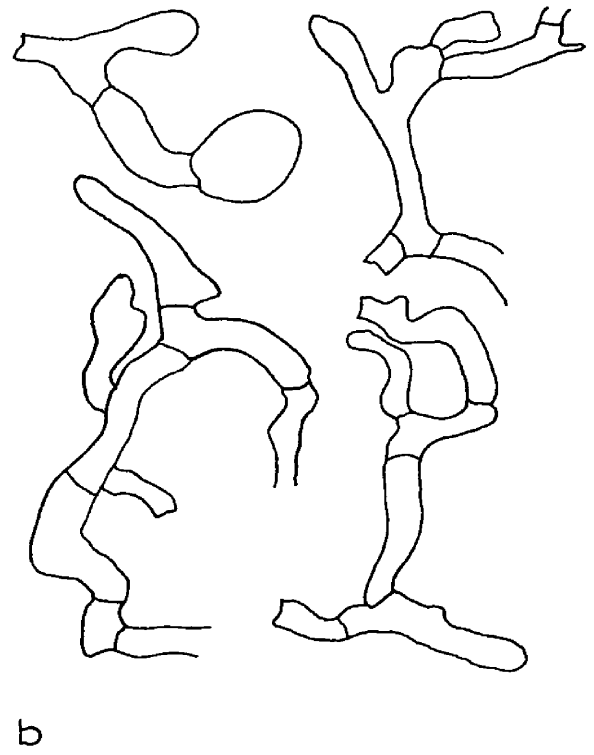
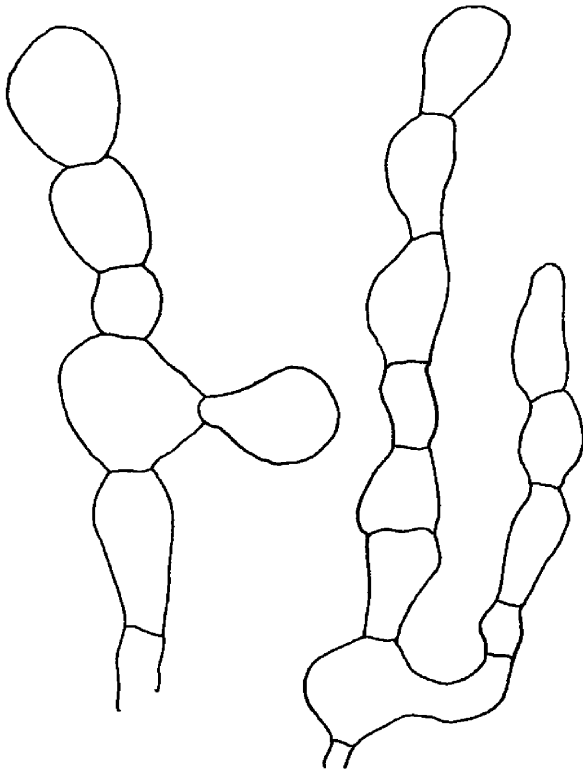
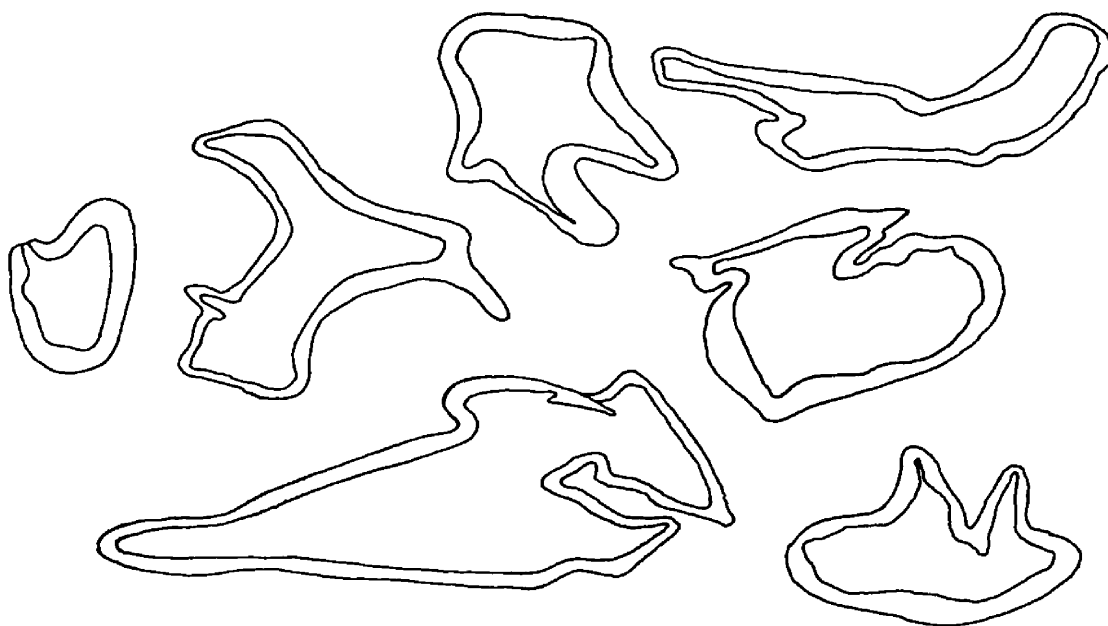


Figure 21. Peridial cells: (a) Vascellum curtisii exoperidial spines, (b) Lycoperdon pusillum exoperidium, cutis region, (c) L. polymorphum exoperidium, cutis region.

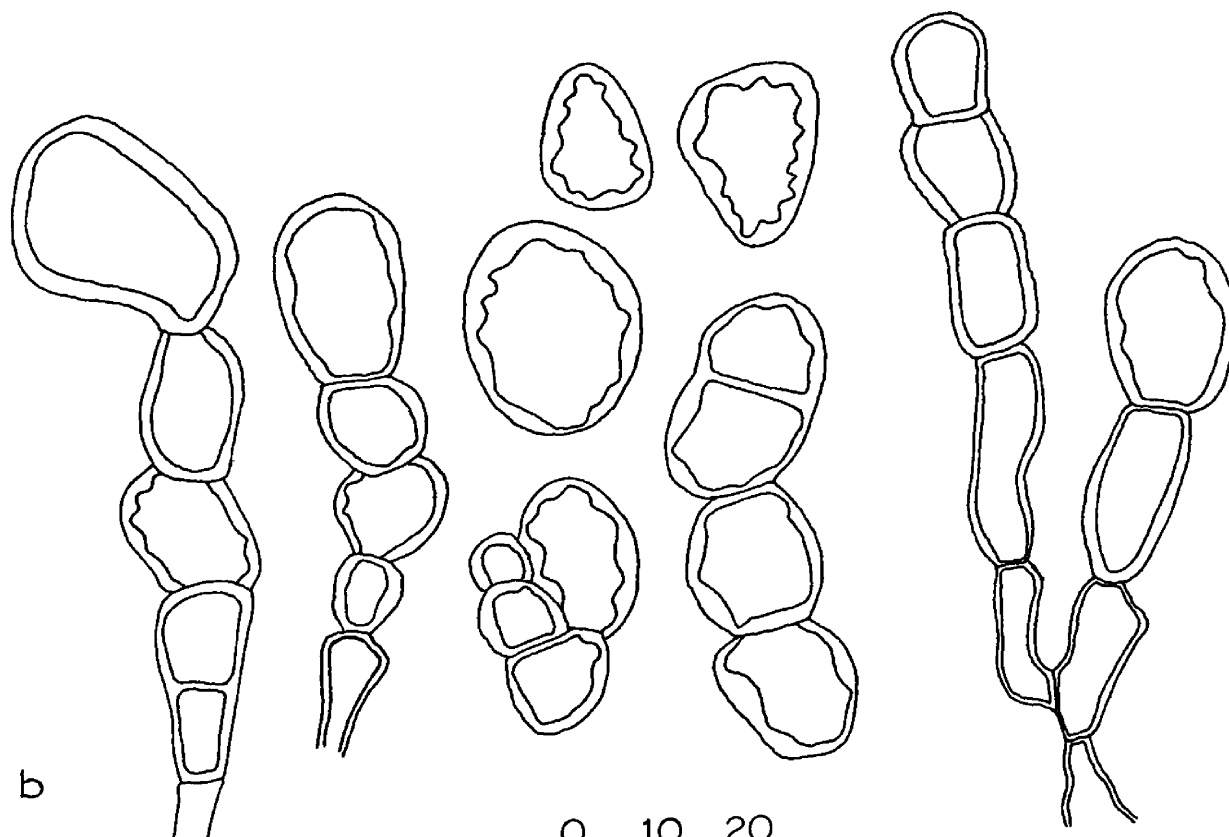


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Figure 22. Peridial cells: (a) Lycoperdon pyriforme, cutis and warts, (b) L. umbrinum, exoperidial spines.



a

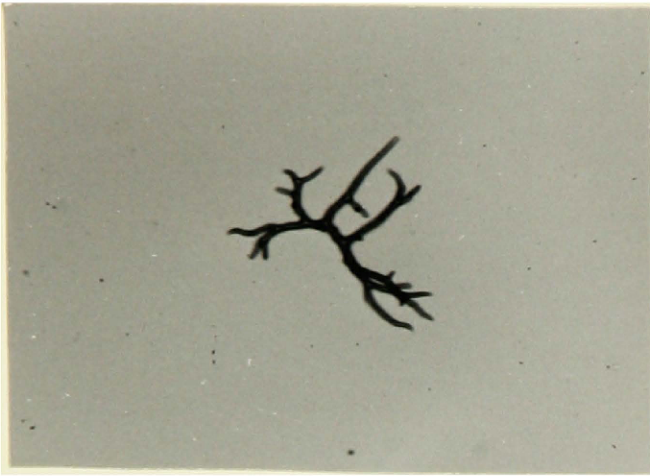


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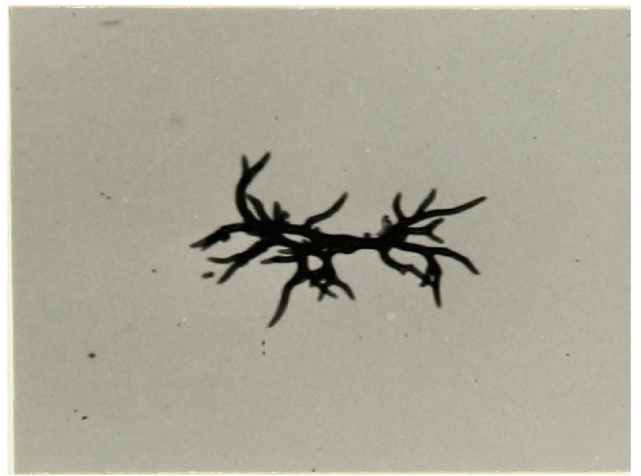
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Plate 1. (a), (b), (c) Capillitial elements of Calbovista  
subsculpta x60, (d), (e) Capillitial elements of Mycenastrum  
corium x125.



a



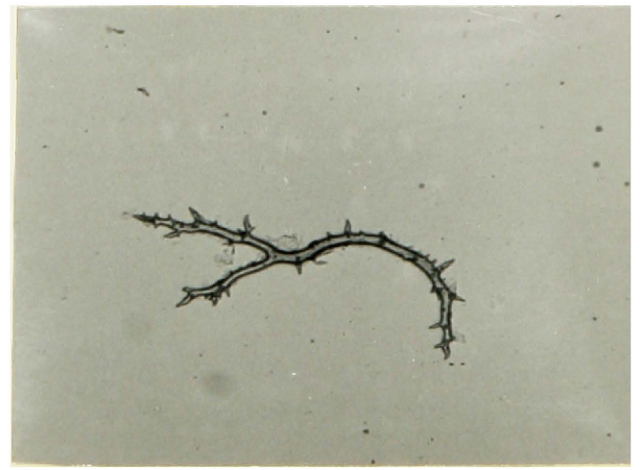
b



c

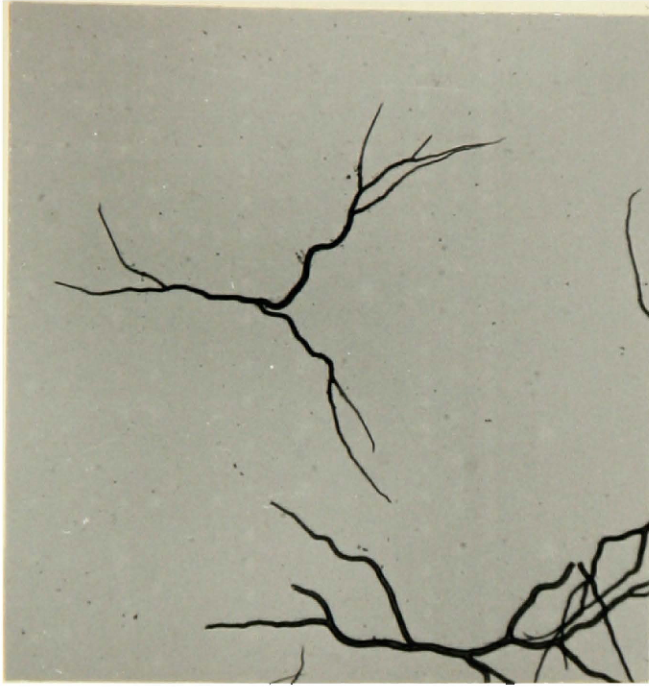


d

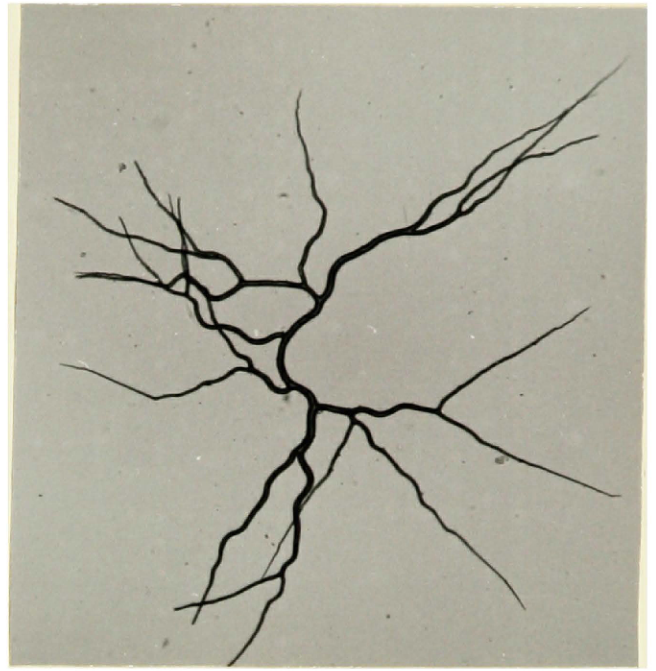


e

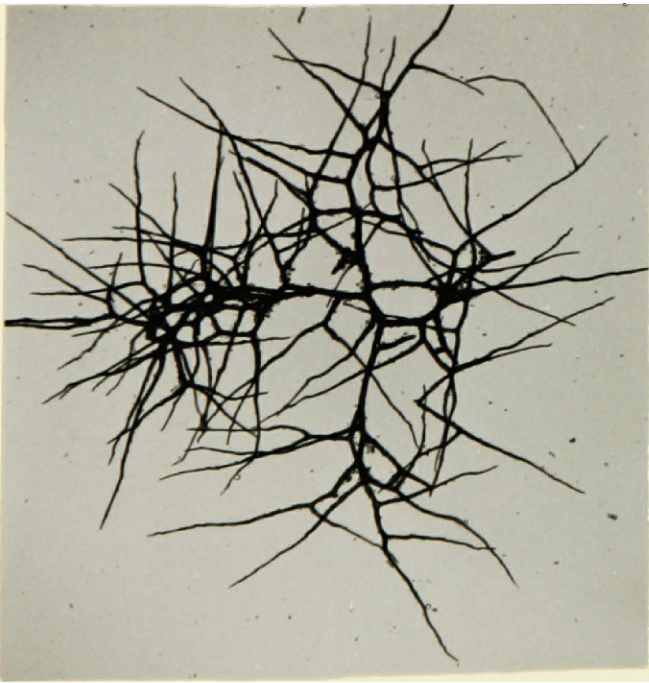
Plate 2. (a), (b) Capillitial elements of Bovista minor x60,  
(c), (d) Capillitial elements of Bovista pila x 60.



a



b



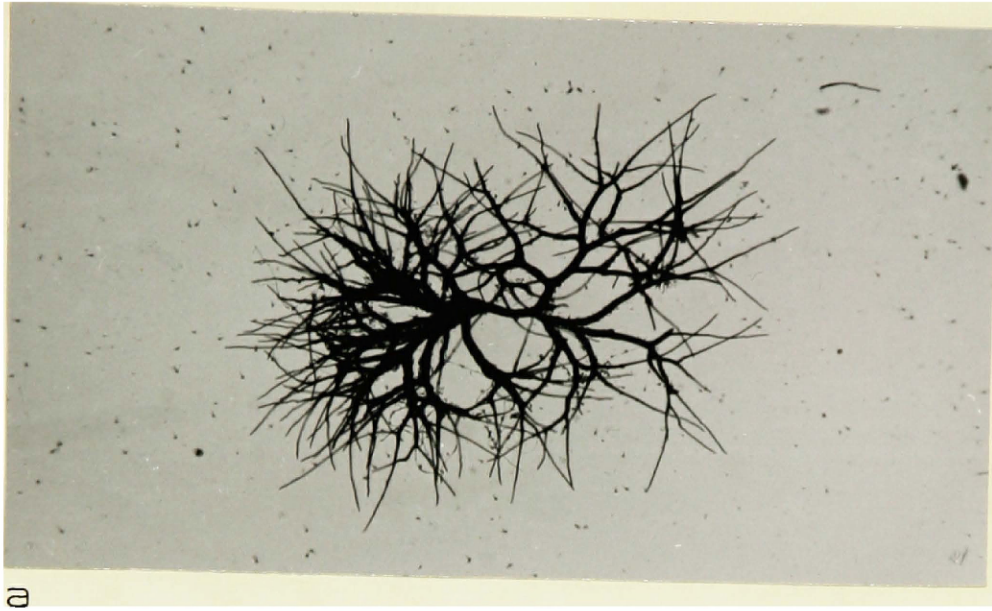
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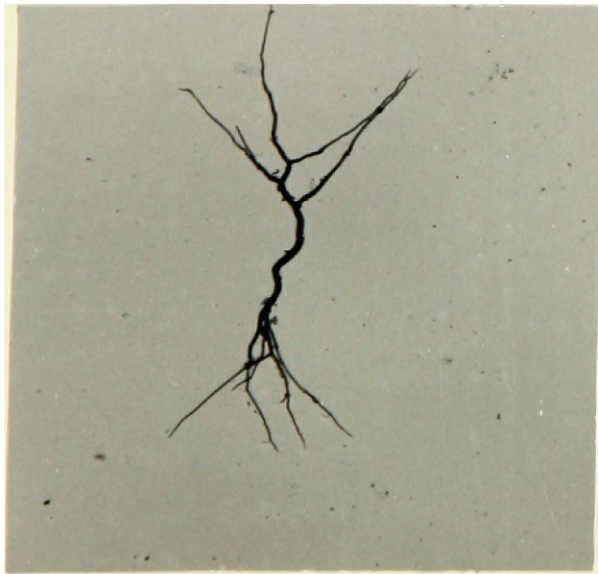
d

Plate 3. (a) Capillitial element of Bovista plumbea x 60,  
(b), (c) Capillitial elements of Bovista tomentosa, x 60

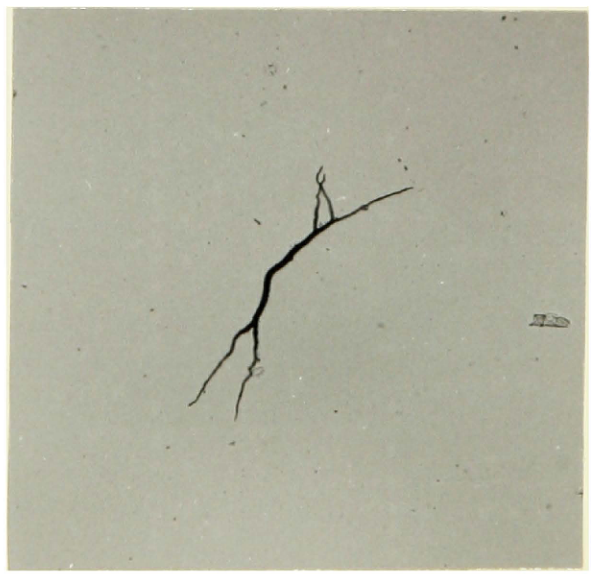




a



b



c

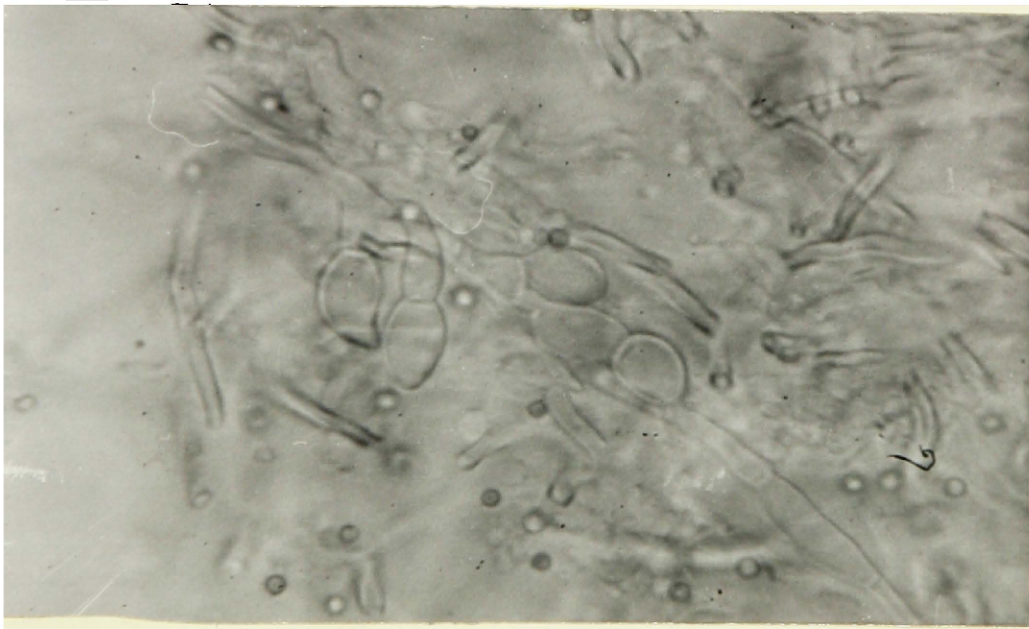
Plate 4. (a) Spore case of Geastrum pectinatum showing sulcate peristome,  $\times 1\frac{1}{2}$ , (b) Cross-section of G. pectinatum showing collar of mesoperidium around the pedicel,  $\times \frac{1}{2}$ , (c) Endoperidial tissue of Calbovista subsculpta showing large, inflated cells growing toward the gleba,  $\times 250$ .



a



b



c



## LITERATURE CITED

- Bowerman, C. A. 1961. Lycoperdon in Eastern Canada with special reference to the Ottawa district. Can. J. Botany, 39: 353-383.
- Bowerman, C. A., and Groves, J. W. 1962. Notes on fungi from Northern Canada. V. Gasteromycetes. Can. J. Botany, 40: 239-354.
- Brodie, H. J. 1966. A new species of Cyathus from the Canadian Rockies. Can. J. Botany, 44: 1235-1237.
- \_\_\_\_\_. 1967. New record of a large Cyathus from Western Canada. Mycologia, 59: 532-533.
- \_\_\_\_\_. 1968. The Nidulariaceae of Canada. The Can. Field-Nat., 82: 2-14.
- \_\_\_\_\_. 1970a. A previously unnamed species of Cyathus from the Cypress Hills, Alberta. Can. J. Botany, 48: 749-750.
- \_\_\_\_\_. 1970b. Crucibulum parvulum, a very small new bird's nest fungus from northwestern North America. Can. J. Botany, 48: 847-849.
- Bronchart, R., and Demoulin, V. 1971. Ultrastructure de la paroi des basidiospores de Lycoperdon et de Scleroderma (Gastéromycètes) comparée à celle de quelques autres spores de champignons. Protoplasma, 72: 179-189.
- \_\_\_\_\_. 1973. Ultrastructure de la paroi sporale des Gastéromycètes Mycenastrum corium et Abstoma reticulatum en rapport avec leur position systématique. Bull. Soc. Roy. Bot. Belg., 106: 267-272.
- Coker, W. C., and Couch, J. N. 1928. The Gasteromycetes of the Eastern United States and Canada. Chapel Hill, N. C.: Univ. of North Carolina Press: reprint ed., Lehre, Germany: J. Cramer, 1969.
- Cunningham, G. H. 1942. The Gasteromycetes of Australia and New Zealand. Dunedin, N. Z.: J. McIndoe.

- Demoulin, V. 1969. Les Gastéromycètes. Introduction à l'étude des Gastéromycètes de Belgique. Les Naturalistes Belges, 50: 225-270.
- \_\_\_\_\_. 1970. La typification des Lycoperdon décrits par Persoon. Lejeunia, nouv. ser., 55: 1-20.
- \_\_\_\_\_. 1971. Lycoperdon norvegicum Demoulin sp. nov. A new Gasteromycete with Boreo-Continental distribution in Europe and North America. Norw. J. Bot., 18: 161-167.
- \_\_\_\_\_. 1972. Espèces nouvelles ou méconnues du genre Lycoperdon (Gastéromycètes). Lejeunia, nouv. ser., 62: 1-28.
- Dissing, H., and Lange, M. 1961. The genus Geastrum in Denmark. Bot. Tidsskr., 57(1): 1-27.
- Dring, D. M. 1973. "Gasteromycetes". In The Fungi: An Advanced Treatise. Volume IVB, pp. 451-478. Edited by G. C. Ainsworth, Frederick K. Sparrow, and Alfred S. Sussman. New York: Academic Press.
- Eckblad, F.-E. 1955. The Gasteromycetes of Norway. The epigean genera. Nytt. Mag. Bot., 4: 19-86.
- \_\_\_\_\_. 1971. Spores of Gasteromycetes studied in the scanning electron microscope (SEM) I. Norw. J. Bot., 18: 145-151.
- Gregory, P. H., and Nixon, H. L. 1950. Electron micrographs of spores of some British Gasteromycetes. Trans. Brit. Mycol. Soc., 33: 359-363.
- Hansen, L. 1962. A Danish find of Mycenastrum corium with notes on its anatomy. Bot. Tidsskr., 58: 204-212.
- Johnson, M. M. 1929. The Gasteromycetae of Ohio. Ohio Biol. Survey Bull. 22, 4(7): 273-352.
- Kambly, P. E., and Lee, R. E. 1936. The Gasteromycetes of Iowa. Univ. Iowa Studies Nat. Hist., 17(4): 121-185.
- Kornerup, A., and Wanscher, J. H. 1967. Methuen handbook of colour, 2nd ed. London, England: Methuen & Co. Ltd.
- Kreisel, H. 1962. Die Lycoperdaceae der Deutschen Demokratischen Republik. Feddes Repert., 64(2/3): 89-201, tab. I-IX; reprint ed., Lehre, Germany: J. Cramer, 1973.
- \_\_\_\_\_. 1963. The taxonomic position of Lycoperdon curtisii Berk. and L. subpratense C. G. Lloyd. Feddes Repert., 68: 86-87.

- Kreisel, H. 1967. Taxonomisch-pflanzengeographische monographie der gattung Bovista. Nova Hedwigia, 25: 1-244; reprint ed., Lehre, Germany: J. Cramer, 1967.
- Lange, M. 1948. Macromycetes part I. The Gasteromycetes of Greenland. Medd. om Gronland, 147(4): 1-32.
- Lloyd, C. G. 1913. Mycological Writings 4: 8.
- Lohman, M. L. 1927. The Iowa species of Lycoperdon. Univ. Iowa Studies Nat. Hist., 12(4): 1-28.
- Long, W. H., and Stouffer, D. J. 1948. Studies in the Gasteromycetes: XVI. The Geastraceae of the southwestern United States. Mycologia, 40: 547-585.
- Longnecker, W. M. 1927. The geasters of Iowa. Univ. Iowa Studies Nat. Hist., 12(4): 29-43.
- Miller, O. K., Jr. 1969. Notes on Gasteromycetes of the Yukon Territory and adjacent Alaska. Can. J. Botany, 47: 247-250.
- \_\_\_\_\_. 1972. Mushrooms of North America. New York: E. P. Dutton.
- Morse, E. E. 1942. Geaster limbatus: a new variety. Mycologia, 33: 139-142.
- Newcomer, E. H. 1953. A new cytological and histological fixing fluid. Science, 118: 161.
- Palmer, J. T. 1955. Observations on Gasteromycetes. 1-3. Trans. Brit. Mycol. Soc., 38: 317-334.
- \_\_\_\_\_. 1968. A chronological catalogue of the literature to the British Gasteromycetes. Nova Hedwigia, 15: 65-178; reprint ed., Lehre, Germany: J. Cramer, 1968.
- Shaffer, R. L. 1975. The major groups of Basidiomycetes. Mycologia, 67: 1-18.
- Smith, A. H. 1951. Puffballs and their allies in Michigan. Ann Arbor, Mich.: Univ. of Michigan Press.
- Zeller, S. M. 1944. Representatives of the Mesophelliaceae in North America. Mycologia, 36: 627-637.
- \_\_\_\_\_. 1947. More notes on Gasteromycetes. Mycologia, 39: 282-312.
- \_\_\_\_\_. 1949. Keys to the orders, families, and genera of the Gasteromycetes. Mycologia, 41: 36-57.

Zeller, S. M., and Smith, A. H. 1964. The genus Calvatia in North America. Lloydia, 27(3): 148-186.