

THE UNIVERSITY OF MANITOBA

TAXONOMY OF THE GENUS *CERATOCYSTIS* IN MANITOBA

by

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## ABSTRACT

From Manitoba hardwoods and conifers, 183 collections were examined for *Ceratocystis*. Most previously described species, including many type specimens, were also studied.

Among morphological characters used to separate species of *Ceratocystis*, those of the ascospore are the most reliable and stressed in this study. Three-dimensional examination of ascospores, particularly in species possessing spores with sheaths, is necessary to determine spore shape accurately. Four ascospore sheath types are recognized: uniform, single-brimmed, double-brimmed, and quadrangular or ossiform.

Since the conidial state is distinctive in some species of *Ceratocystis*, and of diagnostic value in others, the conidial state is considered an integral part of the species diagnosis and the method of conidium formation is stressed.

Based mainly on ascospore characters, the genus *Ceratocystis* is herein organized into four groups:

1. The Minuta Group;
2. The Ips Group;
3. The Fimbriata Group;
- and 4. The Pilifera Group.

It is felt that species placed in a particular group are more closely related to species within that group than they are to species placed in any of the other groups. A key to the Groups of species and keys to the species of each of the four respective groups are provided.

The following new species are described by the author: *C. aequivaginata*, *C. arborea*, *C. cainii*, *C. columnaris*, *C. concentrica*, *C. conicicollis*, *C. coronata*, *C. crenulata*, *C. curvicollis*, *C. davidsonii*, *C. deltoideospora*, *C. fasciata*, *C. introcitrina*, *C. longispora*, *C. minima*, *C. ossiformis*, *C. pallidobrunnea*, *C. parva*, *C. populicola*, *C. pseudoeurophioides*, *C. pseudominor*, *C. pseudonigra*, *C. spinifera*, *C. torticiliata*, *C. tubicollis*. In addition, descriptions of the conidial states of the following species are given herein for the first time: *C. angusticollis* Wright and Griffin, *C. dolominuta* Griffin, *C. spinulosa* Griffin.

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## HERBARIUM ABBREVIATIONS

Herbarium abbreviations used throughout the text are those of: Lanjouw, J. and F.A. Stafleu. 1964. Index Herbariorum, Part I. The herbaria of the world. Regnum Veg. 31:1-251.

However, since the Mycological Herbarium, Department of Botany, University of Manitoba, is not designated in the above publication, collections deposited in this herbarium are designated by the letters WIN(M).

## DEFINITION OF TERMS

Terms relating to descriptions of ascospores.

*end view.* The view parallel to the long axis of the ascospore.

*plan view.* The view perpendicular to the long axis of an ascospore, at a right angle to the side view.

*side view.* The view perpendicular to the long axis of an ascospore, which shows any curvature of the body of the spore.

Terms relating to descriptions of geometric forms which may not conform strictly to published definitions.

*acicular.* Needle-shaped.

*arcuate.* Geometrically similar to *lunate* but more strongly curved; arc-like

*cucullate.* Hood- or cowl-like in form.

*falcate.* Geometrically similar to *lunate* but less strongly curved (as illustrated in Ainsworth, G.C. Ainsworth and Bisby's Dictionary of the Fungi. 6th edition. C.M.I. 1971. Plate XVI, figs. 9 & 10.).

*lunate.* The shape of a spore in which the radius of the arc forming the concave face is greater than that of the arc forming the convex surface.

*obtuse.* Rounded.

*quadrangular.* Having four angles or projections.

*truncate.* Ending abruptly as though with the end cut off; blunt.

Terms relating to descriptions of conidial states as recently proposed by Ellis (6).

*collarete*. A fringe of the cell wall frequently surrounding the opening or openings in a phialidic conidiogenous cell.

*conidiogenous cell*. A cell which produces conidia.

*conidiophore*. A hyphal element bearing conidia or conidiogenous cells.

*denticulate*. A term applied to conidiogenous cells bearing denticles.

*determinate*. A term referring to conidiophores or conidiogenous cells which have ceased elongating after the production of a terminal conidium or chain of conidia.

*discrete*. A term applied to conidiogenous cells which often have a distinctive shape.

*integrated*. A term applied to conidiogenous cells that are incorporated in the main axis or branches of a conidiophore where they are either terminal or intercalary.

*macronematous*. A term applied to conidiophores which are morphologically very different from purely vegetative hyphae; they are usually erect.

*micronematous*. A term applied to conidiophores which are morphologically very similar to purely vegetative hyphae.

- mononematous*. A term applied to conidiophores that are solitary or caespitose (cf. synnematous).
- monophialidic*. A term which refers to phialidic conidiogenous cells that possess only one opening.
- percurrent*. A term applied to conidiogenous cells that continue to elongate after production of the first conidium.
- phialidic*. A term referring to conidiogenous cells which produce conidia, often in large numbers in basipetal succession through one or more openings in the cell wall; the cell wall does not contribute to conidial formation.
- polyblastie*. A term referring to conidiogenous cells that blow out conidia at more than one point.
- semi-macronematous*. A term applied to conidiophores that differ only slightly from other hyphae; they are often ascending but seldom erect.
- stipe*. The unbranched lower part of a synnematous conidiophore.
- sympodial*. A term which refers to a conidiogenous cell that elongates by growth of a succession of apices each of which develops laterally and behind the previously formed apex. Each apex terminates with the formation of a conidium or conidia.
- synnematous*. A term applied to conidiophores which are composed of numerous threads or filaments tightly adpressed or fused along most of their length.

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## INTRODUCTION

The blueing or blue-stain fungi comprise a group of organisms belonging to several different taxonomic groups. Most of these fungi belong to the genus *Ceratocystis* Ellis & Halsted emend. Bakshi (1) and, depending upon the species, may be either saprophytes or primary plant parasites.

The saprophytic forms are of economic and ecological interest for they live on nutrient substances present in the cells, particularly those of the medullary rays and other parenchymatous cells, causing considerable destruction. Not infrequently they will also attack lignified cells walls to a limited extent.

In the wood of dead or dying standing trees, pulp or timber wood or lumber, the dark mycelium extends rapidly both radially and longitudinally causing a greenish, bluish, bluish-grey or almost black discoloration or stain which is frequently of economic significance.

Many of these saprophytic forms are transmitted by wood-inhabiting insects of various species. In a number of cases, it is obvious this transmission is probably casual; any insect with an appropriate life history could move the fungus about. Some *Ceratocystis* spp., however, seem to be intimately associated with specific insect species in such a way that the relationship

between the two entities seems almost to be truly symbiotic.

In addition to saprophytic species, there are to be found within the genus a number of primary plant parasites: *C. ulmi* (Buism.) C. Moreau (Dutch elm disease), *C. fagacearum* (Bretz) Hunt (oak-wilt), *C. coerulescens* (Münch) Bakshi (maple sap-streak), all of which are of major economic importance wherever they occur.

In response to the possibility that the forest industry within Manitoba may undergo a major enlargement, this study of the genus *Ceratocystis* was undertaken within the province to gain information as to their potential for causing economic loss. As originally conceived, the project was to have had two main aspects: (1) the taxonomy of the species found in Manitoba, and (2) their relationship to insect vectors. Shortly after collecting was begun and identifications started, it became apparent that a large number of collections would not fit into previously described taxa. It was also discovered that with a few exceptions, the cultural characteristics had been assigned far less importance than was warranted in separating taxa. Thus, in order to properly understand the genus as it occurs in Manitoba and to lay a proper foundation for future studies, an attempt has been made to describe and figure as many species of *Ceratocystis* as could be obtained from two

particular forests. In so doing, special emphasis has been placed on the morphology of the conidial state (i.e. the nature of the conidiogenous cell as well as the nature of the structure on which they are borne) both on agar and on wood.

## MATERIALS AND METHODS

The Duck Mountain Provincial Forest (area = 1451 sq. mi.) and the Sandilands Provincial Forest (area = 584 sq. mi.) were the two Manitoba forest areas selected for sampling in this study, and this investigation is based on 183 collections, 173 of which were obtained by the author on field trips over the past four years. For comparison with material collected locally, all the *Ceratocystis* collections contained in The University of Toronto herbarium were examined, as well as 4 collections obtained by the author in British Columbia. Additional material examined included type specimens from the National Fungus Collections, Plant Industry Station, Beltsville, Md. U.S.A., cultures from the American Type Culture Collection, and collections from the Forest Research Station at Maple, Ontario and the Forest Research Station of the Federal Department of Forestry Research Laboratory, Edmonton, Alberta.

All field material was examined with a dissecting microscope and whole mounts of perithecia were prepared for examination under higher magnification. In cases where perithecia were abundant, the collections were air-dried at 21°C and preserved as herbarium specimens. When perithecia were not abundant, the samples were placed in polyethylene containers lined with moist paper towelling, and incubated in these closed containers at normal laboratory temperatures. The incubated specimens were

examined periodically and treated in the same manner as fresh field collections.

Cultures of all species encountered were obtained, wherever possible, by transferring ascospore ooze with a sterile needle to petri plates containing pablum agar (1% mixed cereal pablum, 2.0% agar). When perithecia were produced on the artificial medium, and species identity was confirmed, transfers were made from the plate cultures to agar slants in tubes containing pablum agar or malt agar (2.0% malt extract, 1.5% agar), to be retained as stock cultures. Pablum agar was found to be the most suitable artificial medium for promoting normal perithecial development, but in some instances, malt agar was a more suitable substrate. Generally, however, cultures on malt agar produced more luxuriant vegetative growth, a greater abundance of conidia, and a higher incidence of aberrant perithecia.

All of the cultures were also grown in culture tubes containing short lengths of wood which were autoclaved for 15 minutes at 120°C. In order to ensure suitable moisture conditions for growth, a sufficient quantity of water was introduced into the tubes, prior to autoclaving, to submerge the lower one-third of the wood pieces. Fresh jack pine and balsam-fir were found to be the most reliable wood substrates for promoting the development of perithecia and were used for all cultures, regardless



of the host species from which they originated.

Fungi obtained in culture were grown on pablum agar under ordinary laboratory light and temperature conditions. During 10-day incubation periods, three general growth rates were recognized: (1) slow, radial growth up to 10mm; (2) intermediate, radial growth from 10-30 mm; and (3) rapid, radial growth over 30 mm.

Critical examination of all the characters was done with a Wild phase contrast microscope on material mounted in 0.02% cotton blue in lactophenol. Measurements were made with the use of an ocular micrometer and photomicrographs were taken of all the relevant features. In the case of species which produce opaque perithecia, the fruiting bodies were bleached by placing them on a microscope slide in a drop of 0.3% aqueous solution of sodium hypochlorite. When the perithecia were bleached sufficiently to reveal the cellular detail, the slide was irrigated with distilled water and the material was mounted in lactophenol cotton blue for observation in the usual manner.

All photomicrographs were taken with a Wild Mk.1a camera fitted with a 35mm film carrier. Kodak Panatomic-X film was used exclusively, and was developed in Kodak Microdol-X developer diluted 1:3 (1 part Microdol-X stock solution; 3 parts distilled water) to produce negatives of medium density with low contrast and minimum grain.

The negatives were printed on Kodak Polycontrast (F) photographic paper developed in Kodak D-72 paper developer diluted 1:2 (1 part D-72 stock solution; 2 parts distilled water), and contrast was controlled in printing so as to reproduce as nearly as possible the tonality of the images as seen with the microscope.

THE GENUS *CERATOCYSTIS*

As recounted by Hunt (11), *Ceratocystis* (apparently from *ceratos* = horn and *cyst* = pouch or sac) was established by Ellis and Halsted [Halsted (9)] in 1890. *Ceratocystis* was described as a monotypic genus, and a specific description of *C. fimbriata*, the type species of the genus, was given by Halsted and Fairchild (10) in 1891 in which the generic concept was also clearly established. In the original description the perithecia and the ascospores produced in evanescent asci were misinterpreted as pycnidia and conidia. The subsequent history of the type species is very much confused. On the basis of the supposed pycnidial stage Saccardo (17) discarded *Ceratocystis* and transferred the species to *Sphaeronaema*. Elliot (5), in 1923, established that the "pycnidia" of *S. fimbriatum* were perithecia and he transferred the species to *Cerato-stomella*. Subsequently the species was transferred to *Ophiostoma* by Nannfeldt [Melin and Nannfeldt (14)] and to *Endoconidiophora* by Davidson (3). The generic name *Ceratocystis* was revived by Bakshi (1) in 1950 and applied to the group of species including *C. fimbriata* and its relatives.

Inasmuch as no generic diagnosis was given either in the original description or subsequently when the genus was transferred amongst the various genera of the Ascomycetes, Hunt (12), in his revision of the genus *Ceratocystis* in 1956, gave the following generic diagnosis:

*CERATOCYSTIS* Ellis and Halsted, emend. Bakshi, Commonw.

Mycol. Instit., Paper 35:2. 1951.

N.J. Agr. Expt. Sta. Bul. 76:14. 1890, and Jour. Mycol.

7:1. 1891.

*Perithecia produced singly or in clusters, nonstromatic, the bases brown to black with elongate black necks; perithecial centrum plectascaceous; paraphyses lacking; asci evanescent, with 8 spores; ascospores hyaline, 1-celled, exuded from the ostiole in a sticky matrix. Imperfect stages include endogenously and exogenously produced conidia.*

Although Hunt placed the genera *Endoconidiophora* Munch (15) and *Grosmannia* Goid. (7) in synonymy with *Ceratocystis*, he created sections within *Ceratocystis*, two of which were based on the characteristics of these two genera. The sections designated by Hunt were: Sec. I, species with an endoconidial imperfect stage; Sec. II, species with a *Lep-tographium* or *Graphium* imperfect stage; and Sec. III, species with mycelial conidia only. However, the differences between the various conidial states may not be as clear as was suggested by Hunt, since Hughes (11) and Kendrick (13), among others, have suggested that the exact method of conidium formation may be of greater importance in classification of the Hyphomycetes than the structures supporting the conidiogenous cells.

Wright and Cain (18) thoroughly reviewed the taxo-

nomy of the genus *Ceratocystis* in 1961 and they placed greater emphasis on ascospore morphology as the fundamental character for the separation of species. They also suggested that the exact method of conidial formation may be a more significant feature than that of the presence or absence of single conidiophores or coremia.

During the present investigation of the genus *Ceratocystis*, it has become apparent that characters based on the perfect state only are not always adequate for the separation of species and the conidial state must be considered an essential part of the species diagnosis. The approach has been therefore, to describe the entire life cycle of the organism, and for this purpose it is felt that the terminology used by Ellis (6) to describe Dematiaceous Hyphomycetes is particularly applicable to the conidial states of *Ceratocystis*.

Since the publication of Hunt's monograph approximately 60 additional species of *Ceratocystis* have been described, and the Sections established by Hunt contain species which seem to bear little relationship to each other. Griffin (8), in reporting on his survey of the genus *Ceratocystis* in Ontario, did not present the species under the Sections established by Hunt but relied mainly on ascospore morphology for the separation of species. Griffin's presentation, in part, recognized groups of species based on similarities of the ascospores and pro-

vides a basis for re-organization of the genus into groups of species which are presumably more closely related than the sections used by Hunt.

The species of *Ceratocystis* in Manitoba, as presented here, are divided into four groups, based on ascospore types recognized by Griffin, with some modifications. And although they are not presented as formal taxa, the groups have been constructed to reflect as nearly as possible the relationships which I consider to exist within the genus. The groups are defined as follows:

1. The Minuta Group. This group includes all the species with elongated and usually curved ascospores that possess a hyaline gelatinous sheath which is attenuated at the ends. Within this group two subgroups may be recognized: (1) that which contains species with broad cylindrical or conical perithecial necks which terminate in rounded apices, or in apices in which the hyphal elements that comprise the outer layer of the neck continue into ostiolar hyphae; and (2) that which contains species in which the perithecial necks are tapered to narrow truncate apices which may or may not produce ostiolar hyphae. Members of this latter subgroup have perithecial necks with a fasciated appearance. This appearance is due to the formation of thick, more or less coincident septa in the adjacent hyphal elements which comprise the outer

layer of the neck. In this respect, the perithecia closely resemble those of some members of the *Ips* group. All the species in this group produce hyaline, unbranched or branched, conidiophores bearing conidigenous cells which are polyblastic and sympodial.

2. The *Ips* Group. This group is composed of species that produce ascospores which are cylindrical with obtuse ends, or are dumb-bell-shaped. These ascospores are surrounded either by a uniform hyaline gelatinous sheath or a sheath that is extended to appear rectangular, ossiform, or pillow-shaped in side or plan view. In end view the sheath is quadrangular. Two subgroups are recognized within this group: (1) a group comprising species which produce perithecia with ostiolar hyphae and have conidial states similar to those of the *Minuta* Group; and (2) a group of species which produce perithecia without ostiolar hyphae and which may produce pigmented synnematus conidiophores and phialidic conidigenous cells.

3. The *Fimbriata* Group. This group includes all species that produce curved, lunate, or orange-section-shaped ascospores possessing either a uniform hyaline gelatinous sheath or a sheath that is variously extended to appear half-moon-shaped, hat-shaped, or cucullate in side view. This heterogeneous assemblage of species includes most of the conidial types found in the genus *Ceratozystis*

and includes a variety of perithecial morphology. Although species within the group may differ significantly, a continuum of relationships prevents delineation of any subgroups at this time.

4. The Pilifera Group. This group includes those species which produce curved, ovoid, or cylindrical ascospores which lack a gelatinous sheath. Species in this group produce a variety of types of perithecia, and both synnematosus and mononematosus conidiophores are produced. Denticulate conidiogenous cells, which may or may not be swollen at the tips, are exclusive to some species of this group, although within this group some species have conidiogenous cells of types represented in other groups as well.

As noted earlier, particular attention has been paid to the nature of the conidial state of the various species studied during this investigation. However, no attempt has been made to assign such states to genera of the Fungi Imperfecti since taxonomic problems exist within some of the imperfect genera to which conidial states would be assigned that are beyond resolution within the scope of this investigation. For example, many of the synnematosus forms would be referable to the genus *Graphium* Corda, the lectotype of which, *Graphium penicillioides* Corda, has annellides as reported by Ellis (6). It will be clear to the reader that synnematosus conidial



states of different *Ceratocystis* species described in this thesis may have either phialides, annellides, or sympodulae and, in at least one case, both sympodulae and phialides (*C. cainii*). Thus it is clear that imperfect states with different conidiogenous cell-types would have to be included within the genus *Graphium* -- a practice which should be avoided in view of the current trends within the taxonomy of the Fungi Imperfecti.

In addition, as pointed out by Barron (2), such synnematos forms have mononematous counterparts in genera such as *Phialocephala* (phialides), *Verticicladiella* (sympodulae), and *Leptographium* (annellides) and it is necessary that the relationship between the *Graphium* complex and these mononematous forms be clarified before conidial state names can be assigned to the imperfect states of many of the *Ceratocystis* species discussed herein.

Because such difficulties exist with so many of the species studied, it was felt that in order to be consistent, it would be best not to use conidial state names for any of the species discussed in this thesis.

KEY TO THE GROUPS OF *CERATOCYSTIS*

## SPECIES DISCUSSED HEREIN

1. Ascospores elongated, usually curved, possessing a hyaline, gelatinous sheath which is attenuated at the ends. Sheath appearing lunate, falcate or acicular in side or plan view.....  
.....The Minuta Group (page 16)
2. Ascospores cylindrical with obtuse ends or dumb-bell-shaped, not curved, surrounded by a uniform, hyaline, gelatinous sheath or a sheath that is extended to appear rectangular, ossiform, or pillow-shaped in side or plan view and quadrangular in end view.....The Ips Group (page 59)
3. Ascospores curved, lunate, or orange-section-shaped, possessing either a uniform, hyaline, gelatinous sheath, or a sheath that is variously extended to appear half-moon-shaped, hat-shaped, or cucullate in side view.....The Fimbriata Group (page 91)
4. Ascospores curved, orange-section-shaped, lunate, ovoid, or cylindrical; gelatinous sheath lacking....  
.....The Pilifera Group (page 126)

## KEY TO THE SPECIES OF THE MINUTA GROUP

1. Apex of neck truncate
  2. Base of neck ornamented with spiny protuberances....  
..... 14. *C. spinulosa*
  2. Base of neck not ornamented with spiny protuberances
    3. Ascospores (including sheath) less than 8 $\mu$  long  
..... 5. *C. crenulata*
    3. Ascospores (including sheath) more than 8 $\mu$  long
      4. Ascospores (including sheath) less than 11 $\mu$  long  
..... 13. *C. spinifera*
      4. Ascospores (including sheath) more than 11 $\mu$  long  
..... 7. *C. fasciata*
1. Apex of neck obtuse or extending into ostiolar hyphae
  5. Perithecia hyaline..... 1. *C. alba*
  5. Perithecia pigmented
    6. Base of perithecium much paler than the neck
      7. Base of perithecium pallid....*C. minuta-bicolor*
      7. Base of perithecium ochraceous..... *C. ochracea*
    6. Base of perithecium brown to black, essentially  
concolorous with the neck
      8. Ostiolar hyphae visible only when the perithecia  
are bleached..... 4. *C. conicicollis*
      8. Ostiolar hyphae hyaline, readily visible without  
bleaching
        9. Ostiolar hyphae less than 5 $\mu$  long
          10. Ascospores (including sheath) more than 20 $\mu$

- long..... *C. falcata*
10. Ascospores (including sheath) less than 20 $\mu$  long  
 ..... 8. *C. longispora*
9. Ostiolar hyphae more than 5 $\mu$  long
11. Ascospores (including sheath) less than 8 $\mu$  long  
 ..... 6. *C. dolominuta*
11. Ascospores (including sheath) more than 8 $\mu$  long
12. Ascospore sheath oval in plan view.....  
 .....2. *C. crassivaginata*
12. Ascospore sheath acicular in plan view
13. Necks usually less than 35 $\mu$  long
14. Ascospores (exclusive of sheath) with  
 obtuse ends..... 12. *C. parva*
14. Ascospores (exclusive of sheath) with  
 truncate ends
15. Perithecia pale to mid brown.....  
 .....11. *C. pallidobrunnea*
15. Perithecia dark brown to black.....  
 ..... 9. *C. minima*
13. Necks usually more than 35 $\mu$  long
16. Ostiolar hyphae develop as extensions of the cells  
 composing the outer layer of the neck; perithecia  
 develop in concentric rings on agar.....  
 ..... 3. *C. concentrica*
16. Ostiolar hyphae develop from elements underlying those  
 composing the outer layer of the neck..10. *C. minuta*

1. *Ceratocystis alba* DeVay, Davidson, & Moller, Mycologia 60: 636, 1968. Plate X, Figs. e-g.

*C. alba* has been reported on almond, apricot, walnut, and Colorado spruce. In Manitoba, perithecia of a hyaline species resembling *C. alba* were found developing on the bases and necks of perithecia of *C. huntii*, or in association with the dark vegetative hyphae. The nature of this association has not been determined and attempts at culture of the fungus were not successful.

MANITOBA HOST: *Pinus banksiana*

SPECIMEN EXAMINED: WIN(M) 69-35 (with *C. dolominuta*, *C. huntii*, and *C. minuta*).

2. *Ceratocystis crassivaginata* Griffin, Can. J. Bot. 46: 701, 1968. Plate XI, Figs. a-c.

*C. crassivaginata* is readily identified by the broad gelatinous sheath which surrounds the ascospores as seen in plan view. Although this species has been adequately illustrated elsewhere (8), figures of ascospores and ostiole are provided here for comparison with those of other species included in this study.

MANITOBA HOSTS: *Fraxinus nigra*, *Populus tremuloides*

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-12, 69-14, 69-39, 69-63, 70-09, all on *Populus tremuloides* (all with *C. pallidobrunnea*), 70-16 on *Fraxinus nigra* (with *C. spinulosa*); Ontario: MFB 7633, 7634, on *Picea mariana*, 7635,

on *Populus tremuloides*.

3. *Ceratocystis concentrica* sp. nov. Plate I, Figs. a-l.

Perithecia in cultura in annulis concentricis pro-dientia, globosa, brunnea vel nigra, 45-90 $\mu$  diam; collum brunneum vel nigrum, cylindricum vel contractum, rectum vel curvatum, 35-85 $\mu$  longum, ad basim 20-30 $\mu$ , ad apicem 12-20 $\mu$  latum; hyphae ostiolaris hyalinae, aciculares, convergentes, 5.0-20 $\mu$  longae, ad basim 1.0-1.5 $\mu$  diam; asci clavati vel fusiformes, evanescentes, octospori, 12-15  $\times$  2.5-3.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae falcatae cum extremis obtusis, superne fusiformes, ab extremo non visae, (3.0)4.0-8.0(10)  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis, 7.5-15(18)  $\times$  0.7-1.0 $\mu$ . Coloniae albae; hyphae septatae, parietibus tenuibus; conidiophora hyalina, simplicia; conidia hyalina, aseptata, clavata, T- vel Y- formia, 1.5-3.5(6.0) $\mu$  longa, 1.0-1.5(2.5) $\mu$  lata ad apicem, 0.5-1.0 $\mu$  ad basim.

Hab. in cortice interno *Abietis balsameae*.

*Perithecia* brown to black, superficial on inner bark of balsam fir; in culture, developing in concentric rings on superficial mycelium; bases globose, 45-90 $\mu$  in diameter, outer layer of the peridium composed of dark, thick-walled, irregularly-shaped cells, 2.5-10 $\mu$  in diameter; necks cylindrical or tapered towards the apex, straight or curved, 35-85 $\mu$  long, 20-30 $\mu$  wide at the base,

12-20 $\mu$  near the tip, composed of dark, thick-walled, septate hyphal elements, 2.0-3.0 $\mu$  wide, which terminate in an obtuse apex; ostiolar hyphae hyaline, acicular, converging to form a narrow ostiole, 5.0-20 $\mu$  long, 1.0-1.5 $\mu$  thick at the base, formed by hyphal elements comprising the outer layer of the neck. *Asci* 8-spored, evanescent, clavate when young, broadly fusiform when mature, 12-15  $\times$  2.5-3.5 $\mu$ . *Ascospores* hyaline, 1-celled, falcate with obtuse ends in side view, fusiform in plan view, end view not seen, (3.0)4.0-8.0(10)  $\times$  0.7-1.0 $\mu$ , enclosed in a hyaline gelatinous sheath; sheath appearing falcate in side view, acicular in plan view, 7.5-15(18)  $\times$  0.7-1.0 $\mu$ .

Perithecia develop on autoclaved wood and in agar culture in 7-10 days.

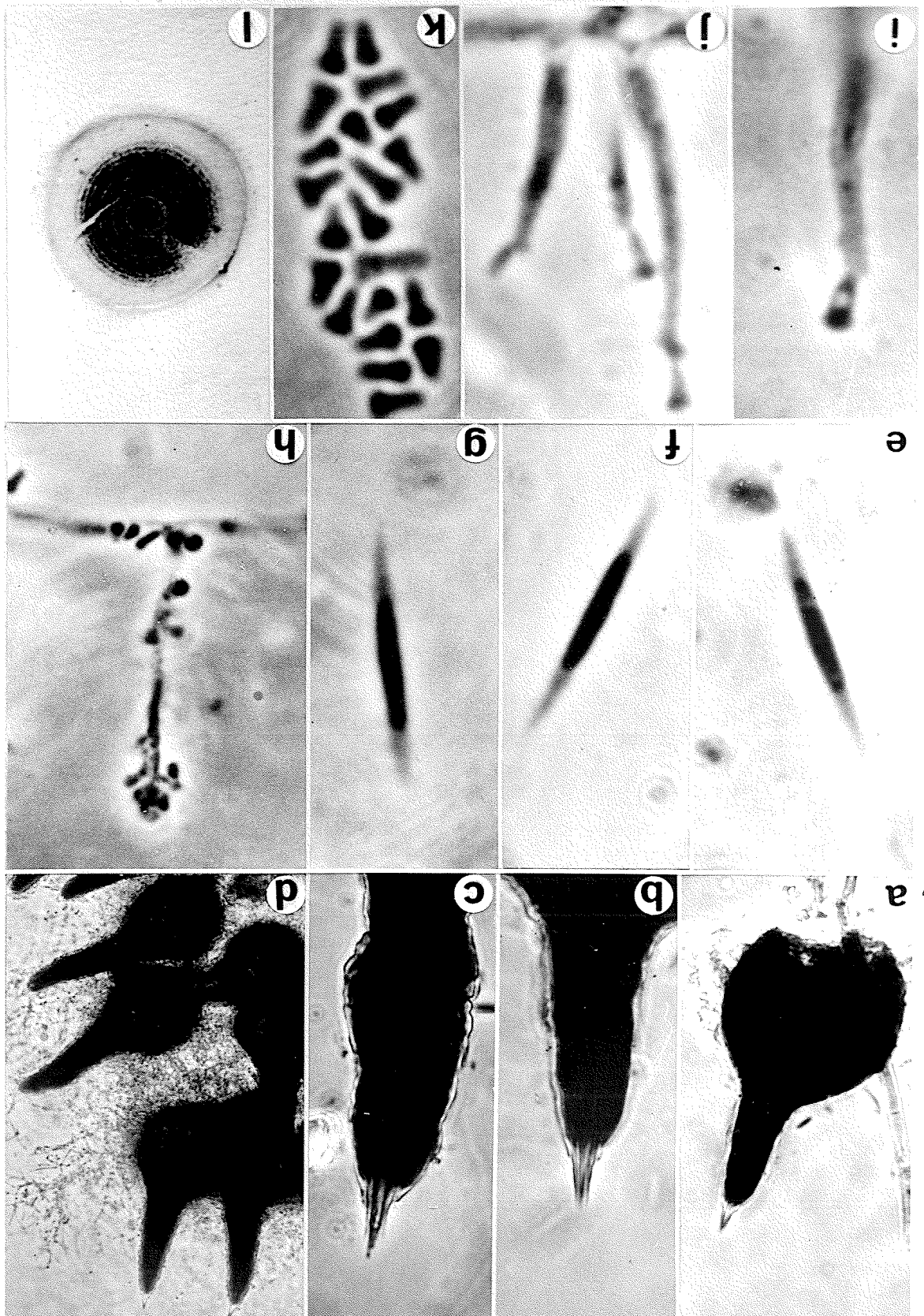
*Colonies* on agar effuse, agar not pigmented. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.7-3.0 $\mu$  wide. *Conidiophores* hyaline, semi-macronematous, mononematous, unbranched, up to 35 $\mu$  long, 1.5-2.5 $\mu$  wide at the base, tapered towards the apex. *Conidiogenous cells* polyblastic, integrated, sympodial, cylindrical. *Conidia* hyaline, 1-celled, broadly clavate, T- or Y- shaped, 1.5-3.5(6.0) $\mu$  long, 1.0-1.5(2.5) $\mu$  wide at the broadest part, 0.5-1.0 $\mu$  wide at the point of attachment.

## PLATE I

*Ceratocystis concentrica* WIN(M) 71-21

- Fig. a Perithecia ( $\times 500$ )  
Figs. b-c Perithecial necks ( $\times 1000$ )  
Fig. d Perithecia from culture ( $\times 250$ )  
Figs. e-g Ascospores ( $\times 4000$ )  
Fig. h Unbranched conidiophore ( $\times 1500$ )  
Figs. i-j Conidiogenous cells ( $\times 4000$ )  
Fig. k Conidia ( $\times 4000$ )  
Fig. l Culture on pablum agar after 14 days ( $\times 1.5$ )





*C. concentrica* resembles *C. minuta* in perithecial morphology and in ascospore dimensions. The perithecia of *C. concentrica* can be distinguished from those of *C. minuta* in field collections by their ostiolar hyphae which arise as extensions of the hyphal elements comprising the outer layer of the neck; in *C. minuta* the outer layer of hyphal elements terminates at the ostiole and ostiolar hyphae develop from elements situated beneath this layer. In culture *C. concentrica* is readily recognized since it is the only species studied in which the perithecia develop in concentric rings. Production of short, broadly-clavate conidia is a further diagnostic character which separates *C. concentrica* from *C. minuta*. Although *C. spinulosa* produces similar conidia, it differs markedly from *C. concentrica* in perithecial morphology (compare figures on Plate I with figures a-d on Plate X).

HOST: *Abies balsamea*.

TYPE COLLECTION: WIN(M)71-21 (with *C. parva*), Sandilands Forest Reserve, Manitoba, Canada, May 8, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)70-06 (with *C. conicicollis*); Ontario: TRTC 45751 (with *C. conicicollis* and *C. minuta*).

4. *Ceratocystis conicicollis* sp. nov. Plate II Figs. a-k.

Perithecia globosa, nigra et opaca, 80-145 $\mu$  diam;

collum breve, conicum, 20-35 $\mu$  longum, ad basim 30-60 $\mu$  latum; hyphae ostiolaris nigrae, aciculares, convergentes, 5.0-15 $\mu$  longae, ad basim 1.5-2.5 $\mu$  diam; asci clavati vel elliptico-fusiformes, evanescentes, octospori, 11-15  $\times$  2.5-3.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae falcatae cum extremis obtusis, superne fusiformes, ab extremo non visae, 5.0-10  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis, 10-15  $\times$  1.0-1.2 $\mu$ . Coloniae albae; hyphae 1.0-2.5 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia; conidia hyalina, aseptata, clavata, 3.5-4.5 $\mu$  1.2-2.5 $\mu$ .

Hab. in ligno et cortice interno *Abietis balsameae*.

*Perithecia* superficial on wood, in culture, developing on superficial mycelium or embedded in the agar medium, black and opaque in transmitted light, cellular detail visible only when the perithecia are bleached; bases globose, 80-145 $\mu$  in diameter, outer layer of the peridium composed of thick-walled, more or less isodiametric cells, 2.0-7.0 $\mu$  in diameter; necks, conical, 30-60 $\mu$  wide at the base, 20-35 $\mu$  long, the base composed of thick-walled, more or less isodiametric cells, 3.0-7.0 $\mu$  in diameter, the upper part composed of straight, parallel, laterally-fused, hyphal elements, which extend into ostiolar hyphae; ostiolar hyphae black, acicular, 5.0-

15 $\mu$  long, 1.5-2.5 $\mu$  wide at the base, converging to form a narrow opening through which the ascospores are extruded. *Asci* 8-spored, evanescent, clavate when young, elliptic-fusiform when mature, 11-15  $\times$  2.5-3.0 $\mu$ . *Ascospores* hyaline, 1-celled, falcate with obtuse ends in side view, fusiform in plan view, end view not seen, 5.0-10  $\times$  0.7-1.0 $\mu$ , enclosed in a hyaline gelatinous sheath attenuated at the ends; sheath appearing falcate in side view, acicular in plan view, 10-15  $\times$  1.0-1.2 $\mu$ . The spores are extruded from the ostiole in a narrow, thread-like cirrhus.

Perithecia develop on malt agar in 3-4 weeks.

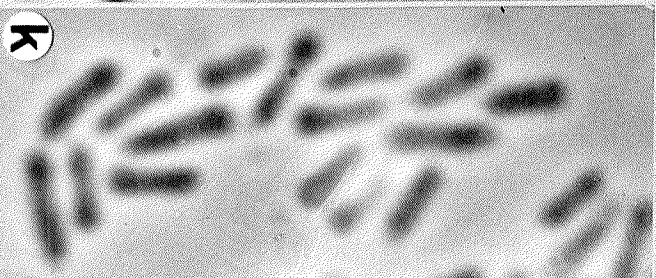
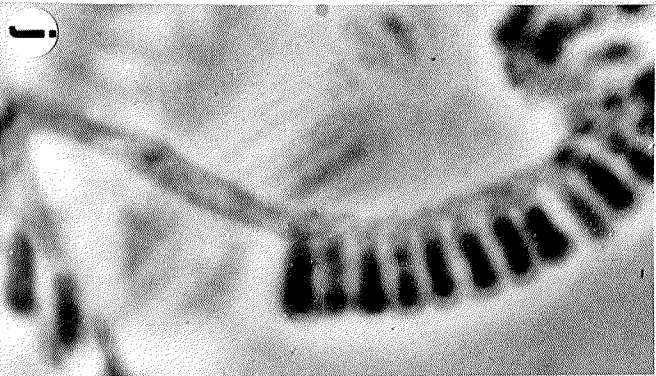
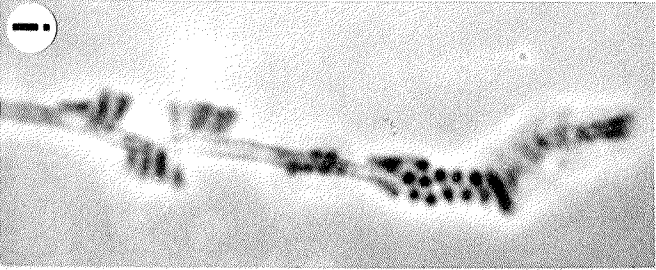
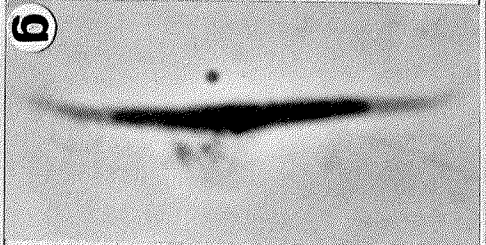
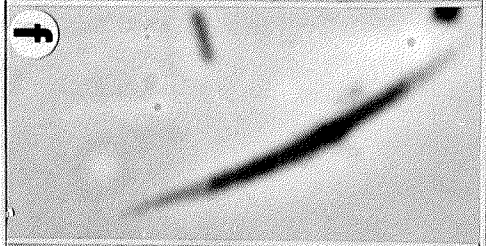
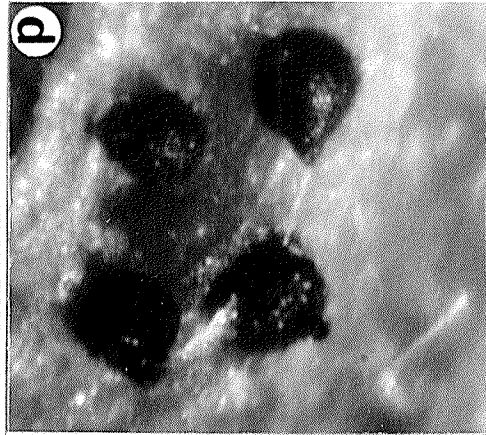
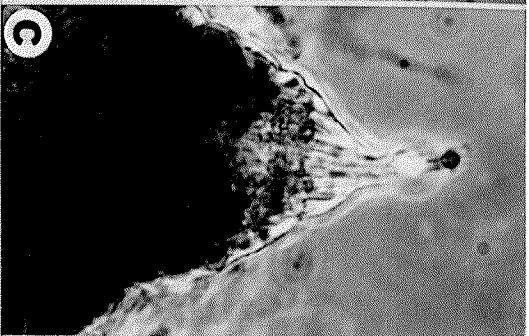
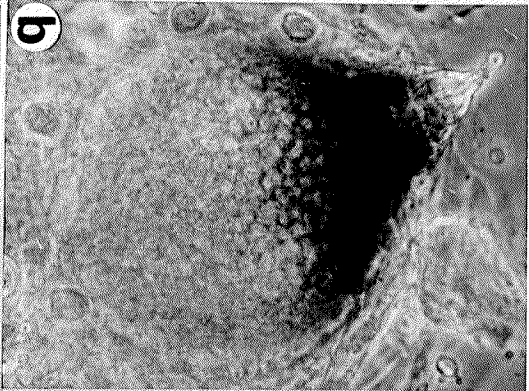
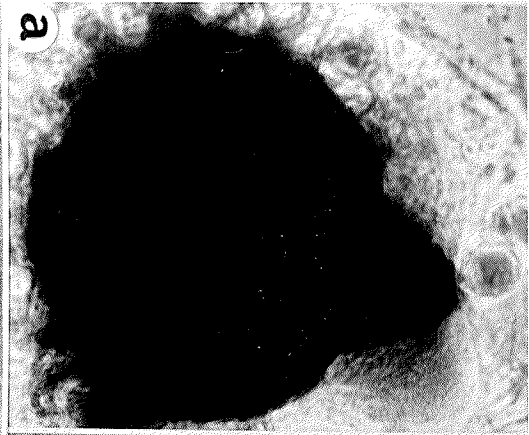
*Colonies* on agar white, cottony; agar not pigmented, except in regions of perithecial development; growth rate slow. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 1.0-2.5 $\mu$  wide. *Conidiophores* micronematous, mononematous. *Conidiogenous cells* polyblastic, integrated, terminal or intercalary, 0.7-1.0 $\mu$  wide. *Conidia* hyaline, 1-celled, clavate, 3.5-4.5  $\times$  1.2-2.5 $\mu$ , arranged in groups, the arrangement giving the conidiophore a brush-like appearance.

*C. conicicollis* is distinguished from all other species in this group by its very dark, rough-walled perithecia and dark ostiolar hyphae which can be seen only when the perithecia are bleached. The only species with which it may be confused is *C. parva*, a short-necked

## PLATE II

*Ceratocystis conicicollis* WIN(M) 69-25

- Fig. a Perithecium ( $\times 500$ )  
Fig. b Perithecium, bleached to show detail ( $\times 500$ )  
Fig. c Perithecial neck (bleached) ( $\times 1000$ )  
Fig. d Perithecia on wood. WIN(M) 71-17 ( $\times 200$ )  
Figs. e-g Ascospores ( $\times 4000$ )  
Figs. h-i Conidiophores ( $\times 1500$ )  
Fig. j Conidiogenous cell ( $\times 4000$ )  
Fig. k Conidia ( $\times 4000$ )



species with which it sometimes occurs. The ostiolar hyphae of *C. parva*, however, are hyaline, the necks usually longer, and the perithecial bases are smooth-walled. The conidial state of *C. conicicollis* is unlike that of any other species in this group. The "brush-like" unbranched conidiophores readily distinguish it from the other species.

HOST: *Abies balsamea*.

TYPE COLLECTION: WIN(M)69-25 (with *C. brunneocrinita*), Duck Mountain Provincial Forest, Manitoba, Canada, May 18, 1969.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)70-06 (with *C. concentrica*), 71-17 (with *C. brunneocrinita*); Ontario: TRTC 33774a (with *C. minuta*), 45751 (with *C. concentrica* and *C. parva*), 33704b, 34624.

5. *Ceratocystis crenulata* sp. nov. Plate III, Figs. a-k.

Perithecia globosa, atrobrunnea vel nigra, 50-100 $\mu$  diam; collum crenatum, atrobrunneum, rectum vel subcurvatum, cylindricum vel contractum, (100)125-175(200) $\mu$  longum, ad basim 18-30 $\mu$ , ad truncatum apicem 6.0-11 $\mu$  latum; hyphae ostiolares hyalinae, cylindricae vel ad apices contractae; rectae vel subcurvatae, parallelae vel divergentes, 10-20 $\mu$  longae, ad basim 1.0-1.5 $\mu$  diam; asci clavati vel fusiformes, evanescentes, octospori, 7.0-9.0  $\times$  3.4-4.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae lunatae cum extremis obtusis, superne fusifor-

mes, ab extremo conspectae rotundae,  $2.5-4.0 \times 0.7-1.0\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis  $6.0-9.0 \times 1.0-1.2\mu$ . Coloniae albae; hyphae  $0.5-2.5\mu$  diam, hyalinae, superficiales vel immer-sae, septatae, parietibus tenuibus vel crassis; conidio-phora hyalina simplicia vel furcata; conidia hyalina, aseptata, clavata cum extremis obtusis, pleurumque in medio constricta  $2.0-4.5(5.0) \times 1.0-2.0(2.5)\mu$ , solitaria dein in muco aggregata.

Hab. in ligno et cortice *Pini banksianae*

*Perithecia* superficial on wood or inner bark tissue; in culture, developing on superficial mycelium or embedded in the agar medium; bases dark brown to black, globose,  $50-100\mu$  in diameter, outer layer of the peridium composed of thick-walled, more or less isodiametric cells,  $2.0-7.0\mu$  in diameter; necks dark brown to black, paler near the apex, tapered, crenulate at the margins, straight or curved,  $(100)125-175(200)\mu$  long,  $18-30\mu$  wide at the base,  $6.0-11\mu$  at the tip, composed of laterally-fused, thick-walled hyphal elements,  $1.5-2.0\mu$  wide, which terminate in a truncate apex; thick septa, more or less coincident in adjacent hyphal elements, give the neck an appearance of having dark bands alternating with paler areas; ostiolar hyphae hyaline, cylindrical or tapered towards the tips, straight or curved, parallel or slightly divergent,  $10-20\mu$  long,  $1.0-1.5\mu$  wide at the base. *Asci* 8-spored,



evanescent, clavate when young, broadly fusiform when mature,  $7.0-9.0 \times 3.5-4.5\mu$ . *Ascospores* hyaline, 1-celled, lunate with obtuse ends in side view, acicular in plan view, globose in end view,  $2.5-4.0 \times 0.7-1.0\mu$ , enclosed in a hyaline gelatinous sheath; sheath appearing falcate in side view, acicular in plan view,  $6.0-9.0 \times 1.0-1.2\mu$ .

Perithecia develop on autoclaved wood and on agar media in 2-3 weeks.

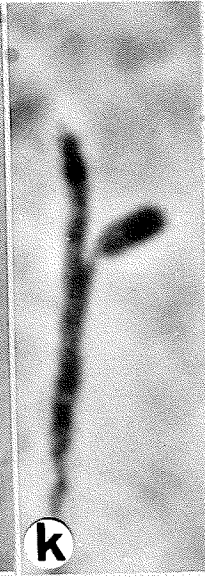
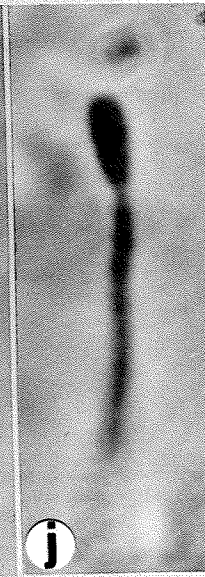
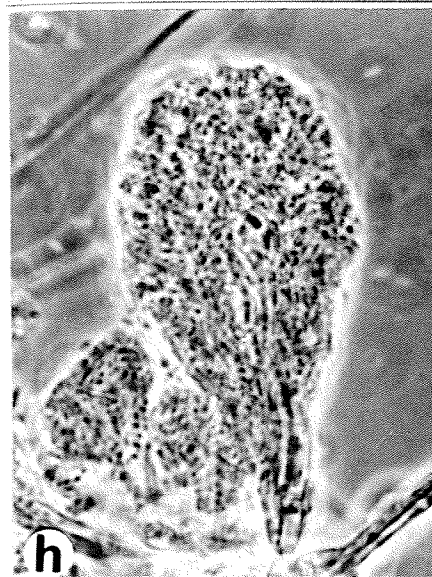
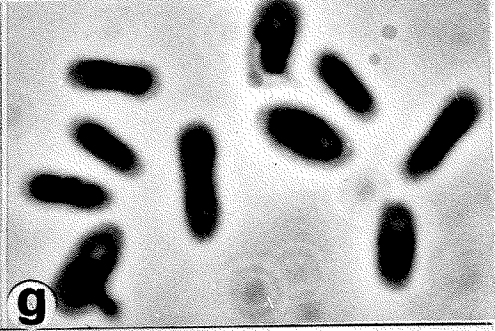
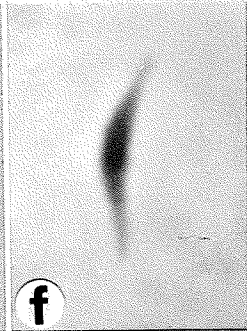
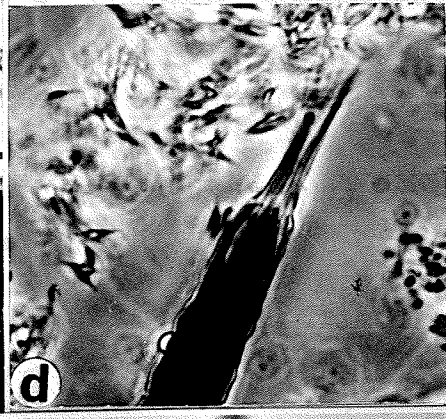
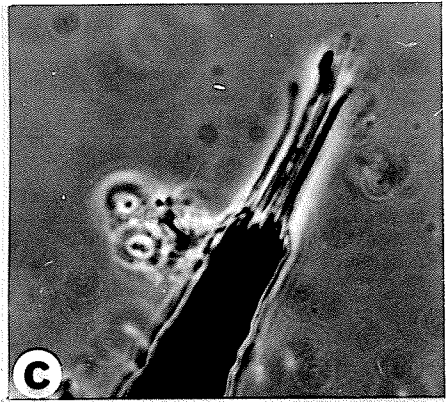
*Colonies* on agar white, cottony, becoming glistening due to masses of conidia in slime; agar not pigmented, or developing brown areas in older cultures; growth rate intermediate. *Mycelium* superficial and immersed. *Hyphae* hyaline, septate, thin-walled,  $0.5-2.5\mu$  wide, becoming thick-walled in regions of developing perithecia. *Conidiophores* hyaline, macronematous or semi-macronematous, mononematous, unbranched or branched. *Conidiogenous cells* polyblastic, terminal, integrated, cylindrical, sympodial,  $1.0-2.0\mu$  wide. *Conidia* hyaline, 1-celled, clavate, oblong with obtuse ends, or ovoid, frequently with a slight median constriction,  $2.0-4.5(5.0) \times 1.0-2.0(2.5)\mu$ , formed solitarily but becoming aggregated in slimy heads.

The perithecia of *C. crenulata* resemble those of *C. fasciata* and *C. spinifera* in that the lower portions of the necks have a fasciated appearance and the upper portions tend to be paler, with cellular detail becoming indistinct. *C. crenulata*, however, is readily distinguish-

## PLATE III

*Ceratocystis crenulata* WIN(M)70-17

- Figs. a-b Perithecia ( $\times 500$ )  
Figs. c-d Apices of perithecial necks ( $\times 1000$ )  
Figs. e-f Ascospores ( $\times 4000$ )  
Fig. g Conidia ( $\times 4000$ )  
Fig. h Branched conidiophore ( $\times 1000$ )  
Figs. i-k Conidiogenous cells ( $\times 4000$ )



shed from these latter two species by its short ascospores, longer ostiolar hyphae, and larger perithecia.

HOST OF TYPE: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)70-17, Sandilands Forest Reserve, Manitoba, Canada, May 24, 1970.

ADDITIONAL SPECIMENS EXAMINED: WIN(M)69-30 on *Picea mariana* (with *C. europhioides* and *C. leucocarpa*).

6. *Ceratocystis dolominuta* Griffin, Can. J. Bot. 46: 702, 1968. Plate XI, Figs. e-g.

*C. dolominuta* was first described on the basis of a single collection and had not been grown in culture (8). Isolates have been obtained from Manitoba collections which resemble type material of this species in all respects. On this basis, the conidial state of *C. dolominuta* is described as follows:

*Colonies* on agar hyaline to white, becoming glistening due to masses of conidia in cream-colored or whitish slime; agar not pigmented; growth rate intermediate. *Mycelium* superficial and immersed. *Hyphae* hyaline, septate, thin-walled, 0.7-2.5 wide, becoming thick-walled in older cultures. *Conidiophores* hyaline, macronematous, mononematous, unbranched or consisting of a stipe and 1-3 series of branches arranged in a penicillate fashion, frequently arising together and then mimicking a synnema. *Conidiogenous cells* hyaline, polyblastic, discrete, sympodial, usually curved, tapered towards the

tip, 10-20 $\mu$  long, 1.0-1.5 $\mu$  wide at the base. *Conidia* hyaline, 1-celled, clavate to oblong with obtuse ends, slightly constricted in the middle, 2.5-5.0  $\times$  1.0-1.5 $\mu$ , formed solitarily but becoming aggregated in slimy heads.

*C. dolominuta* cannot be distinguished from *C. minuta* on the basis of perithecial morphology or the conidial state. The shorter ascospores, however, are a constant character that serves to separate it from the latter species.

SPECIMENS EXAMINED: Ontario: MFB 7636 ( $\equiv$ DAOM 110152)

Manitoba: WIN(M) 6935 on *Pinus banksiana* (with *C. alba*, *C. huntii*, *C. minuta* and *C. sagmatospora*), 70-24 on *P. banksiana*, 69-18 on *Picea mariana* (with *C. europhioides*, *C. pseudonigra*, *C. cainii* and *C. sagmatospora*).

7. *Ceratocystis fasciata* sp. nov. Plate IV, Figs. a-n.

Perithecia in culturo agaro non evoluta, in ligno sterili evoluta, globosa, atrobrunnea vel nigra, 50-85 $\mu$  diam; collum atrobrunneum pallidius versus apicem, rectum vel curvatum, contractum, 50-100 $\mu$  longum, ad basim 15-25 $\mu$ , ad truncatum apicem 5.0-6.0 $\mu$  latum; hyphae ostiolarum hyalinae, cylindricae, rectae, parallelae vel convergentes, 4.0-6.0 $\mu$  longae et 0.5-0.7 $\mu$  diam; asci clavati vel elliptico-fusiformes, evanescentes, octospori, 12-16  $\times$  2.5-3.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae falcatae cum extremis obtusis, superne fusiformes, ab extremo non visae, 5.0-8.0  $\times$  0.5-1.0 $\mu$ , cum vagina gela-

tinosa; vagina falcata a latere conspecta, superne acicularis, cum extremis attenuatis,  $12-16 \times 0.7-1.2\mu$ .

Coloniae albae; hyphae  $1.0-2.0\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia vel verticillate furcata; conidia hyalina, aseptata, clavata vel oblonga cum extremis obtusis,  $2.5-7.5 \times 1.0-2.0\mu$ ; endoconidia oblonga cum extremis obtusis,  $2.5-3.0 \times 1.5-1.7\mu$ .

Hab. in ligno *Pseudotsugae menziesii*.

*Perithecia* superficial on wood or on inner bark tissue; bases globose, dark brown to black,  $50-85\mu$  in diameter, outer layer of the peridium composed of thick-walled, irregularly-shaped, interlocking cells,  $2.5-8.0\mu$  in diameter; necks dark brown, paler at the tip, tapered towards the apex. straight to curved,  $50-100\mu$  long,  $15-25\mu$  wide at the base, composed of parallel, thick-walled, laterally-fused, hyphal elements,  $2.0-2.5\mu$  wide, which become indistinct in the distal portion of the neck and terminate in a truncate apex  $5.0-6.0\mu$  wide; thick septa, which are more or less coincident in adjacent hyphal elements, give the lower part of the neck an appearance of having dark bands alternating with lighter areas; ostiolar hyphae hyaline, cylindrical, straight, parallel or convergent,  $4.0-6.0 \times 0.5-0.7\mu$ . *Asci* 8-spored, evanescent, clavate when young, elliptic-fusiform when mature,  $12-16 \times 2.5-3.5\mu$ . *Ascospores* hyaline, 1-celled, falcate

with obtuse ends in side view, fusiform in plan view, end view not seen,  $5.0-8.0 \times 0.5-1.0\mu$ , enclosed in a hyaline gelatinous sheath attenuated at the ends; sheath appearing falcate in side view, acicular in plan view,  $12-16 \times 0.7-1.2\mu$ . The spores are extruded from the ostiole in a thin, thread-like cirrhus.

Perithecia not produced on agar but develop abundantly in approximately 3 weeks on autoclaved pine.

*Colonies* on agar hyaline to white with sparse aerial mycelium; agar not pigmented in young culture, developing slate gray areas in aging cultures; growth rate intermediate. *Mycelium* superficial and immersed. *Hyphae* hyaline, septate, thin-walled,  $1.0-2.0\mu$  wide. *Conidiophores* semi-macronematous, mononematous, mostly unbranched, occasionally verticillately branched. *Conidiogenous cells* hyaline, polyblastic, terminal, integrated, sympodial, cylindrical,  $1.0-1.2\mu$  wide. *Conidia* hyaline, 1-celled, clavate or oblong with obtuse ends, frequently slightly constricted medially,  $2.5-7.5 \times 1.0-2.0\mu$ ; oblong endoconidia with obtuse ends,  $2.5-3.0 \times 1.5-1.7\mu$ , observed in several hyphae, method of liberation not determined.

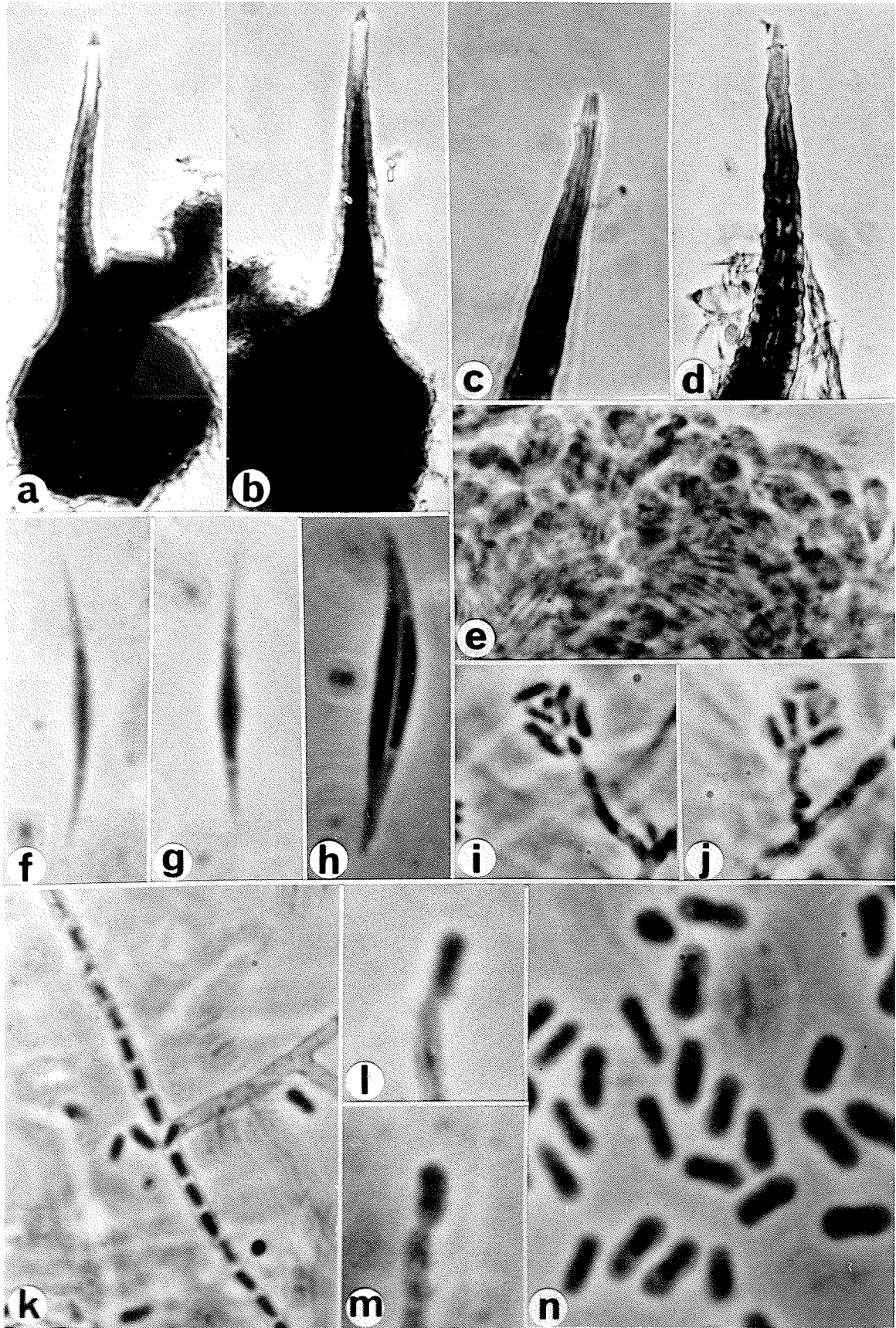
The perithecia of *C. fasciata* are very similar to those of *C. spinifera*, but have larger bases and longer necks. The ascospores (including sheath) are longer, and it is the only species in this group that produces endoconidia. The similarity of this species to *C. cre-*

## PLATE IV

*Ceratocystis fasciata* WIN(M) 71-30

- Figs. a-b Perithecia ( $\times 500$ )  
Figs. c-d Perithecial necks ( $\times 1000$ )  
Fig. e Asci ( $\times 2000$ )  
Figs. f-h Ascospores ( $\times 4000$ )  
Figs. i-j Unbranched conidiophores ( $\times 2000$ )  
Fig. k Endoconidia ( $\times 2000$ )  
Figs. l-m Conidiogenous cells ( $\times 4000$ )  
Fig. n Conidia ( $\times 4000$ )





*nulata* has already been mentioned (see discussion of *C. crenulata*).

HOST: *Pseudotsuga menziesii*.

TYPE COLLECTION: WIN(M)71-30, Seymour Arm, B.C. Canada, August 24, 1971.

8. *Ceratocystis longispora* sp. nov. Plate V, Figs. a-j.

Perithecia globosa vel subglobosa, atrobrunnea vel nigra, 40-100 $\mu$  diam; collum atrobrunneum vel nigrum, ad apicem contractum, rectum, 30-75 $\mu$  longum, ad basim 25-35 $\mu$  latum, ad obtusum apicem 13-18 $\mu$ ; hyphae ostiolaris hyalinae, convergentes, ad apicem obtusum contractae, 2.0-5.0 $\mu$  longae, ad basim 1.0-1.2 $\mu$  diam; asci non visi; ascosporae hyalinae, aseptatae, a latere conspectae falcatae cum extremis obtusis, superne fusiformes, ab extremo non visae, 7.0-13  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis cum extremis attenuatis, 13-20  $\times$  1.0-1.2 $\mu$ . Coloniae albae; hyphae 0.7-2.5 $\mu$  diam, hyalinae, superficiales vel immersae, parietibus tenuibus; conidiophora hyalina, simplicia; conidia hyalina, aseptata, clavata, T- vel Y-formia, 4.0-13  $\times$  1.5-2.5 $\mu$ .

Hab. in ligno *Pini banksianae*

*Perithecia* superficial on wood, in culture, developing on superficial mycelium or embedded in the agar medium; bases dark brown to black, globose to subglobose, 40-100 $\mu$  wide, outer layer of the peridium composed of

thick-walled, more or less isodiametric cells, 3.0-10 $\mu$  in diameter; necks dark brown to black, tapered towards the apex, straight, 30-75 $\mu$  long, 25-35 $\mu$  wide at the base, 13-18 $\mu$  near the tip, composed of parallel, thick-walled, laterally-fused, septate hyphal elements which terminate in an obtuse apex; ostiolar hyphae hyaline, tapered towards obtuse tips, 2.0-5.0 $\mu$  long, 1.0-1.2 $\mu$  wide at the base, formed by elements underlying those comprising the outer layer of the neck, converging to form a rounded cap at the apex. *Asci* not seen. *Ascospores* hyaline, 1-celled, falcate with obtuse ends in side view, fusiform in plan view, end view not seen, 7.0-13  $\times$  0.7-1.0 $\mu$ , enclosed in a hyaline gelatinous sheath; sheath attenuated at the ends, appearing falcate in side view, acicular in plan view, 13-20  $\times$  1.0-1.2 $\mu$ . The spores are extruded through the ostiole in a thin thread-like cirrhus.

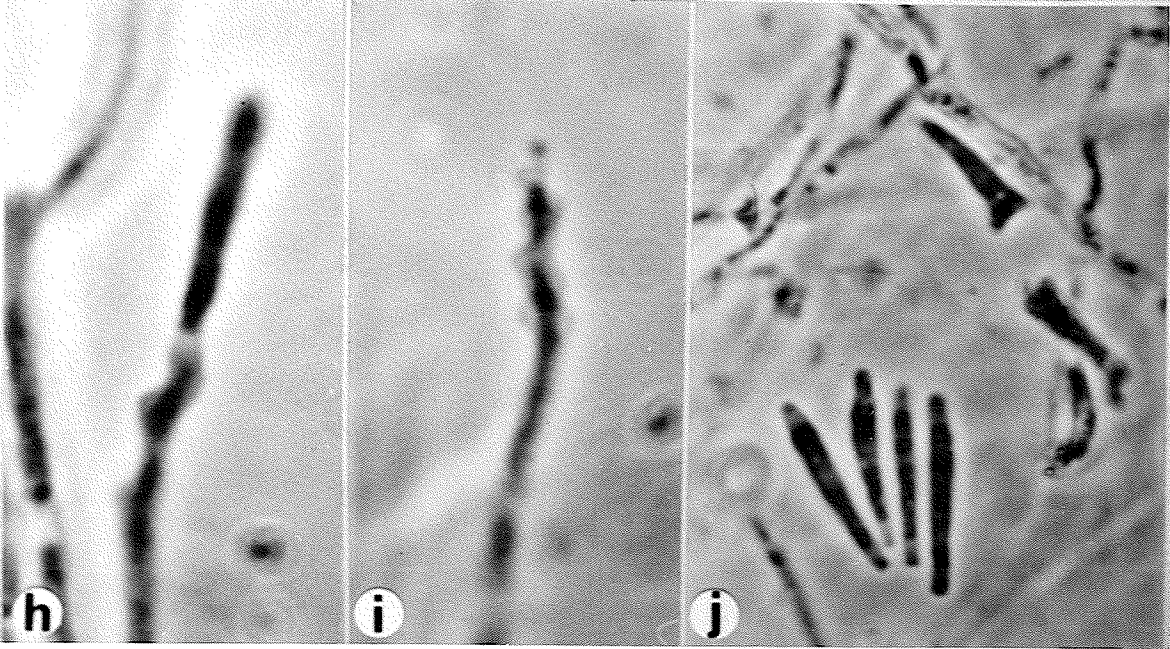
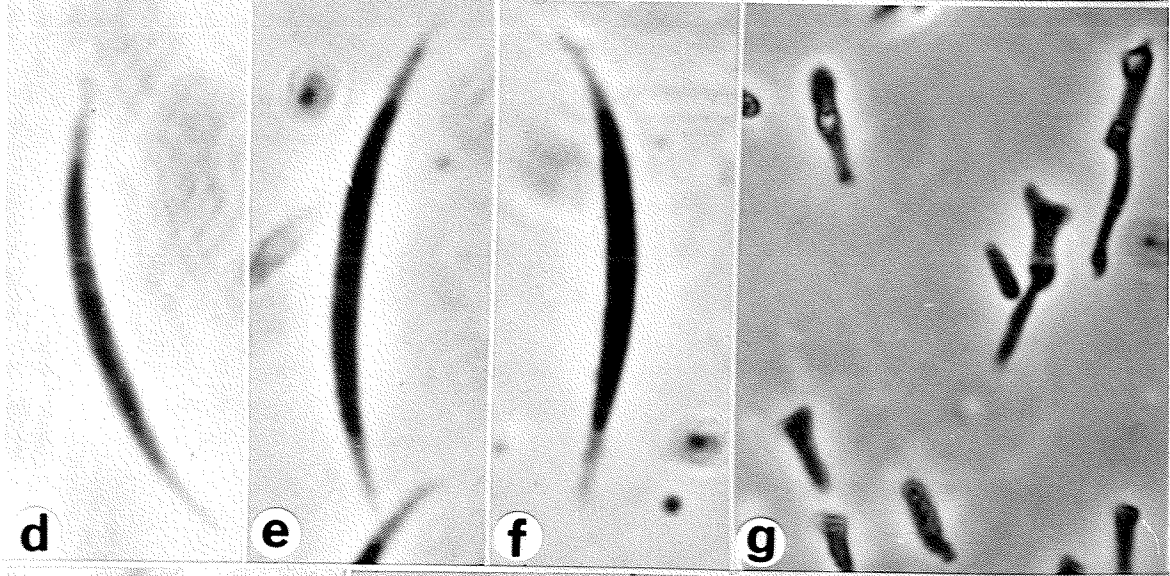
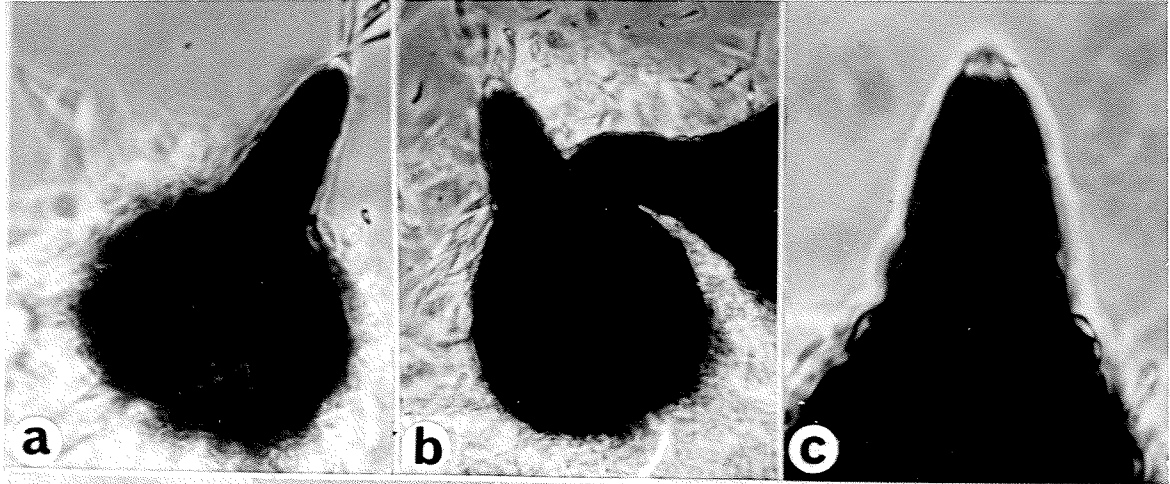
Perithecia develop singly or in groups on autoclaved wood or agar medium in 10-14 days.

*Colonies* on agar hyaline, appressed; agar not pigmented; growth rate slow. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.7-2.5 $\mu$  wide. *Conidiophores* micronematous, mononematous. *Conidiogenous cells* hyaline, polyblastic, terminal, integrated, sympodial, cylindrical, 1.0-2.0 $\mu$  wide. hyaline, 1-celled, clavate, T-shaped, or Y-shaped, 4.0-13  $\times$  1.5-2.5 $\mu$ .

## PLATE V

*Ceratocystis longispora* WIN(M)71-07

- Figs. a-b Perithecia (×500)  
Fig. c Perithecial neck and apex (×1000)  
Figs. d-f Ascospores (×4000)  
Fig. g Conidia (×2000)  
Figs. h-i Conidiogenous cells (×4000)  
Fig. j Conidia (×2000)



The perithecia of *C. longispora* are distinguished from those of other species in this group by their short, rounded ostiolar hyphae, and tapered necks. In culture this species is easily identified by its long fusiform conidia which develop into T- and Y-shaped forms.

HOST: *Pinus banksiana*

TYPE COLLECTION: WIN(M)71-07 (with *C. deltoideospora*, *C. minima* and *C. tubicollis*), Sandilands Forest Reserve, Manitoba, Canada, May 8, 1971.

ADDITIONAL SPECIMENS EXAMINED: none to date.

9. *Ceratocystis minima* sp.nov. Plate VI, Figs. a-k.

Perithecia globosa, atrobrunnea vel nigra, 40-75(85) $\mu$  diam; collum breve, conicum, 10-25 $\mu$  longum, ad basim 20-30 $\mu$  latum, ad obtusum apicem 14-18 $\mu$ ; hyphae ostiolares hyalinae vel pallido-brunneae, aciculares, convergentes, 5.0-15 $\mu$  longae, ad basim 1.0-1.5 $\mu$  diam; asci late fusiformes, evanescentes, octospori, 14-16  $\times$  3.0-4.0 $\mu$ ; ascospores hyalinae, aseptatae, a latere conspectae allantoidae vel falcatae cum extremis truncatis, superne cylindricae vel fusiformes cum extremis truncatis, ab extremo non visae, (3.0)4.0-6.0  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis, 11.5-16  $\times$  1.0-1.2 $\mu$ . Coloniae albae; hyphae 0.7-4.0 $\mu$  diam, hyalinae, superficiales vel immersae, parietibus tenuibus vel crassis; conidiophora hyalina, simplicia vel penicillate furcata; conidia hyalina, aseptata,

clavata vel oblonga cum extremis obtusis, pleurumque in medio constricta.

Hab. in ligno *Pini banksianae*.

*Perithecia* dark brown to black, superficial on wood; in culture, developing mostly on superficial mycelium; bases globose, 40-75(85) $\mu$  in diameter, outer layer of the peridium composed of thick-walled, polygonal cells, 2.5-7.0 $\mu$  in diameter; necks short, conical, 10-25 $\mu$  long, 20-30 $\mu$  wide at the base, 14-18 $\mu$  near the apex, composed of thick-walled hyphal elements, 2.0-2.5 $\mu$  wide, which terminate in an obtuse apex; ostiolar hyphae light brown to hyaline, acicular, 1.0-1.5 $\mu$  thick at the base, 5.0-15 $\mu$  long, converging to form a narrow opening. *Asci* 8-spored, evanescent, broadly-fusiform, 14-16  $\times$  3.0-4.0 $\mu$ . *Ascospores* hyaline, 1-celled, allantoid or falcate with truncate ends in side view, cylindrical or fusiform with truncate ends in plan view, end view not seen, (3.0)4.0-6.0  $\times$  0.7-1.0 $\mu$ , enclosed in a hyaline gelatinous sheath; sheath appearing falcate in side view, acicular in plan view, 11.5-16  $\times$  1.0-1.2 $\mu$ . The spores are extruded through the ostiole in a narrow cirrhus.

*Perithecia* develop in abundance on autoclaved wood and on agar in 7-10 days.

*Colonies* on agar cottony, white, becoming glistening due to masses of conidia in slime; agar not pigmented.

*Mycelium* superficial and immersed. *Hyphae* hyaline, sep-



tate, thin-walled, or thick-walled with a granular coating, 0.7-4.0 $\mu$  wide. *Conidiophores* hyaline, macronematous or semi-macronematous, mononematous, up to 100 $\mu$  long, unbranched or penicillately branched; stipe and branches composed of thick-walled, cylindrical, oval, pyriform, or globose cells, 4.0-15  $\times$  1.5-8.0 $\mu$ . *Conidiogenous cells* polyblastic, discrete, sympodial, tapered, 1.5-2.0 $\mu$  thick at the base, 0.7-1.0 at the tip, arranged penicillately on the branches. *Conidia* hyaline, 1-celled, clavate or oblong with obtuse ends to slightly constricted in the middle, 2.5-5.0(8.0)  $\times$  0.7-1.5(2.0) $\mu$ .

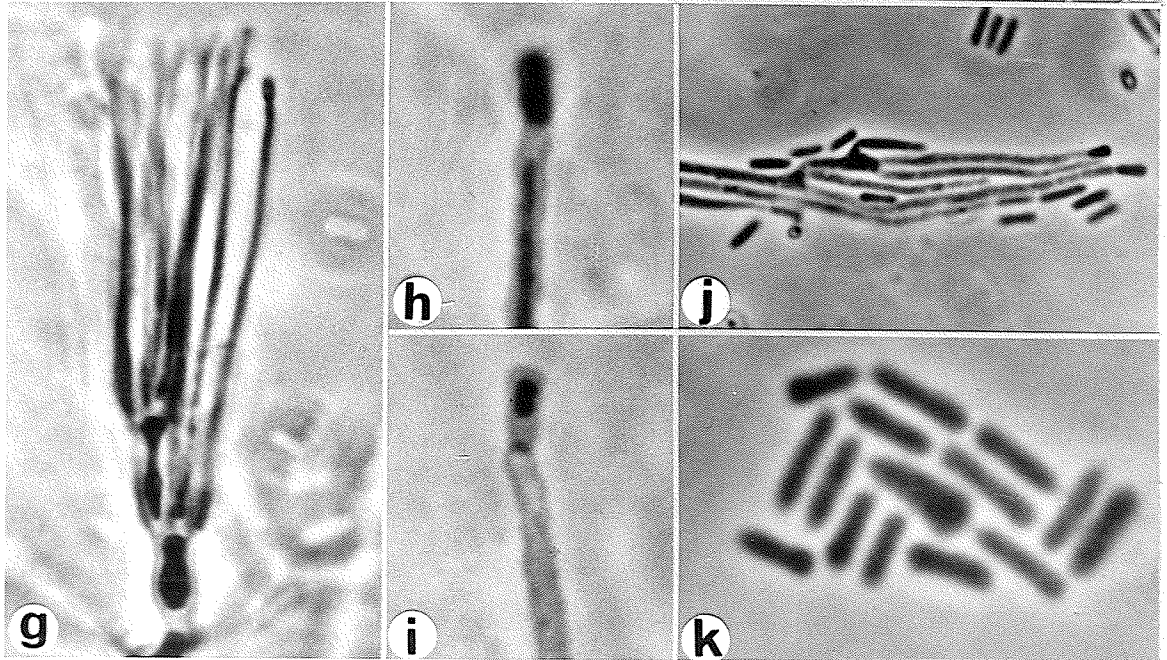
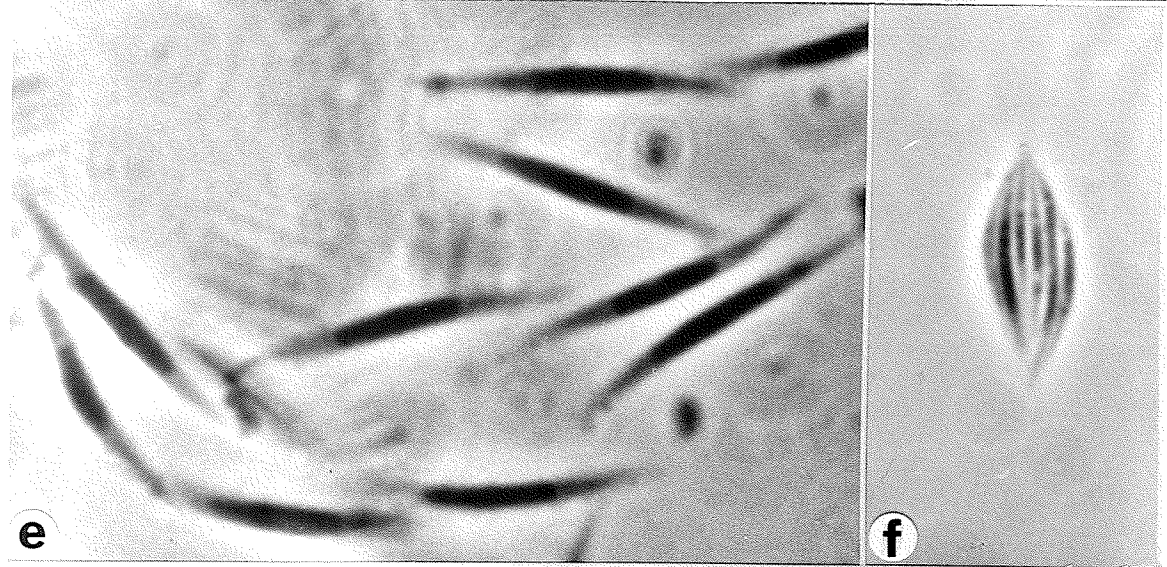
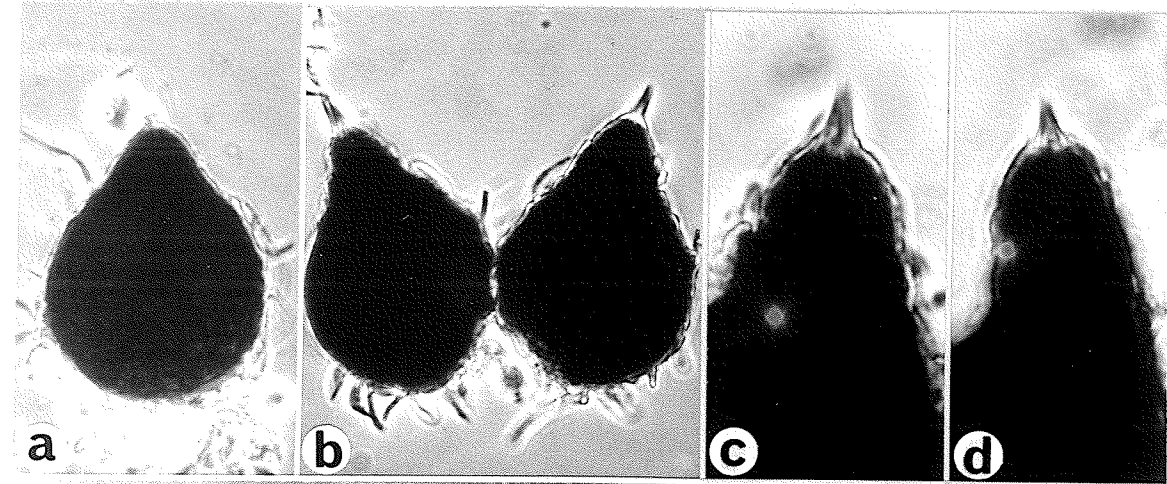
*C. minima* is a common species on pine and appears to be secondary in succession to *C. minuta*. The short-necked perithecia separate it from the latter species. It may be confused with *C. parva*, a short-necked species which occurs on balsam fir. The ascospores (excluding sheath) of *C. parva*, however, are longer and have obtuse ends whereas those of *C. minima* have truncate ends. In culture, *C. parva* is recognized by the conidiogenous cells which produce conidia sympodially in a 'loose' spiral, giving the cells a zig-zag appearance; the conidia of *C. minima* are produced in a 'tight' spiral and the conidiogenous cells resemble phialides (compare figs. i-j, Plate VIII and figs h-i, Plate VI). Another species with which *C. minima* may be confused is *C. pallidobrunnea*. The latter, however, occurs only on deciduous hosts and produces curved conidia.



## PLATE VI

*Ceratocystis minima* WIN (M) 69-37

- Figs. a-b Perithecia ( $\times 500$ )  
Figs. c-d Perithecial necks ( $\times 1000$ )  
Fig. e Ascospores ( $\times 4000$ )  
Fig. f Ascus ( $\times 2000$ )  
Fig. g Branched conidiophore ( $\times 1500$ )  
Figs. h-i Conidiogenous cells ( $\times 4000$ )  
Fig. j Mycelium on agar ( $\times 1500$ )  
Fig. k Conidia ( $\times 4000$ )



HOST OF TYPE: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)69-37, Sandilands Forest Reserve, Manitoba, Canada, June 6, 1969.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)69-56 on *Pinus resinosa* (with *C. deltoideospora* and *C. tubicollis*), 71-07 on *P. banksiana* (with *C. deltoideospora* and *C. tubicollis*), 71-03 on *P. resinosa* (with *C. aequivaginata*); Ontario: TRTC 33703, 34665 on *P. sylvestris*; 33701, 45754 on *P. strobus*; 39554, 45753 on *P. banksiana*.

10. *Ceratocystis minuta* (Siem.), Hunt, Lloydia 19:49, 1956. Plate XI, Figs. h-i.

=*Ophiostoma minutum* Siem., Planta Polonica 7(3):23, 1939.

Several Manitoba collections of *C. minuta* exhibit perithecia with hyaline bases and buff-colored necks, and this characteristic lack of pigmentation persists in perithecia produced from cultures grown on agar. Since the cultural characteristics and perithecial morphology do not otherwise differ from those of other collections of *C. minuta*, this lack of pigmentation is not considered sufficiently significant to warrant placing these collections into a separate taxon.

MANITOBA HOSTS: *Abies balsamea*, *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M)69-43 (with *C. ips*),

69-35 (with *C. alba*, *C. dolominuta*, *C. huntii*, *C. sagmatospora*), 71-26 (with *C. coronata*), 71-27 (with *C. columnaris*), 69-17; Ontario: TRTC 33703, 33773, 33774, 33775, 34661a, 34662, 34665a, 36266a, 36294, 34599b, 39531, 45754.

11. *Ceratocystis pallidobrunnea* sp. nov. Plate VII,  
Figs. a-k.

*Perithecia* globosa, pallido-brunnea vel brunnea, 40-60 $\mu$  diam; collum pallido-brunneum vel brunneum, cylindricum vel contractum, rectum vel curvatum, 15-35(60) $\mu$  longum, ad basim 15-25(35) $\mu$  latum, ad apicem 10-13(18) $\mu$ ; hyphae ostiolaris hyalinae vel pallido-brunneae, aciculares, rectae, parallelae vel convergentes, 7.0-16 $\mu$  longae, ad basim 0.5-1.0 $\mu$  diam; asci late fusiformes vel ellipsoidei, evanescentes, octospori, 15-20  $\times$  5.5-7.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae allantoideae vel falcatae cum extremis truncatis, superne cylindricae vel fusiformes cum extremis truncatis, ab extremo non visae, (3.5)4.5-7.5  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis, (12)14-16  $\times$  1.0-1.2 $\mu$ . Coloniae albae; hyphae 0.5-2.0(2.5) $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus vel crassis, extra granularibus; conidiophora hyalina, simplicia vel penicillate furcata; conidia hyalina, aseptata, allantoidea vel oblonga cum extremis obtusis, (2.5)3.0-4.5(5.0)  $\times$  0.7-1.2 $\mu$ .

Hab. in ligno et cortice interno *Populi tremuloidis*.

*Perithecia* pale to middle brown, superficial on wood or embedded in layers of inner bark tissue; in culture developing mostly on superficial mycelium; bases globose, 40-60 $\mu$  in diameter, outer layer of the peridium composed of thick-walled, irregularly-shaped cells, 2.5-10  $\times$  2.0-7.0 $\mu$ ; necks cylindrical or tapered towards the apex, straight or occasionally curved, 15-35(60) $\mu$  long, 15-25(35) $\mu$  wide at the base, 10-13(18) $\mu$  near the apex, composed of thick-walled, rectangular cells, 3.5-7.5  $\times$  2.0-2.5 $\mu$ ; ostiolar hyphae hyaline to pale brown, acicular, straight, parallel or convergent, 0.5-1.0 $\mu$  thick at the base, 7.0-16 $\mu$  long collectively, formed from cells comprising the outer layer of the neck. *Asci* 8-spored, evanescent, broadly fusiform or ellipsoidal, 15-20  $\times$  5.5-7.0 $\mu$ . *Ascospores* hyaline, 1-celled, allantoid or falcate with truncate ends in side view, cylindrical or fusiform with truncate ends in plan view, end view not seen, (3.5) 4.5-7.5  $\times$  0.7-1.0 $\mu$ , enclosed in a hyaline gelatinous sheath; sheath appearing falcate in side view, acicular in plan view, (12)14-16  $\times$  1.0-1.2 $\mu$ .

*Perithecia* develop sparsely in agar culture in 2-3 weeks.

*Colonies* on agar appressed, hyaline, glistening due to masses of conidia in slime; agar not pigmented. *Mycelium* superficial and immersed. *Hyphae* hyaline, septate,

thin-walled, or thick-walled with a granular coating, 0.5-2.0(2.5) $\mu$  wide. *Conidiophores* macronematous or semi-macronematous, hyaline, up to 50 $\mu$  long, unbranched or penicillately branched to form a stipe and 1-3 series of branches. *Conidiogenous cells* polyblastic, discrete, sympodial, tapered, 1.5-2.0 $\mu$  thick at the base, 0.7-1.0 $\mu$  at the tip, arranged penicillately on the branches. *Conidia* hyaline, 1-celled, allantoid or oblong with obtuse ends, (2.5)3.0-4.5(5.0)  $\times$  0.7-1.2 $\mu$ .

While the perithecia of *C. pallidobrunnea* are similar to those of *C. minima* they are usually paler in color and their ostiolar hyphae do not converge as sharply. Cultures of *C. pallidobrunnea* do not produce perithecia on autoclaved wood and only sparingly on agar, whereas cultures of *C. minima* produce abundant perithecia on these two substrates. The conidia of *C. pallidobrunnea* differ from those of *C. minima* in that they are frequently curved while those of the latter species are not.

The cultural characteristics, coloration of the perithecia, and the shape of the conidia, are the basis for separating *C. pallidobrunnea* from *C. minima*.

HOST: *Populus tremuloides*

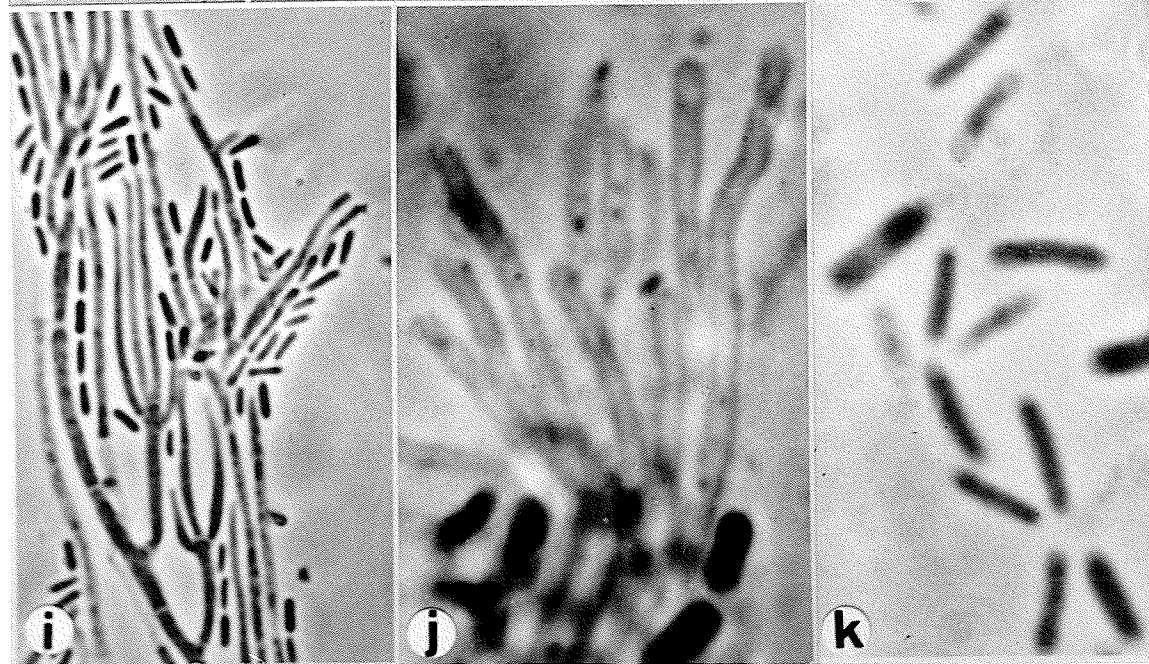
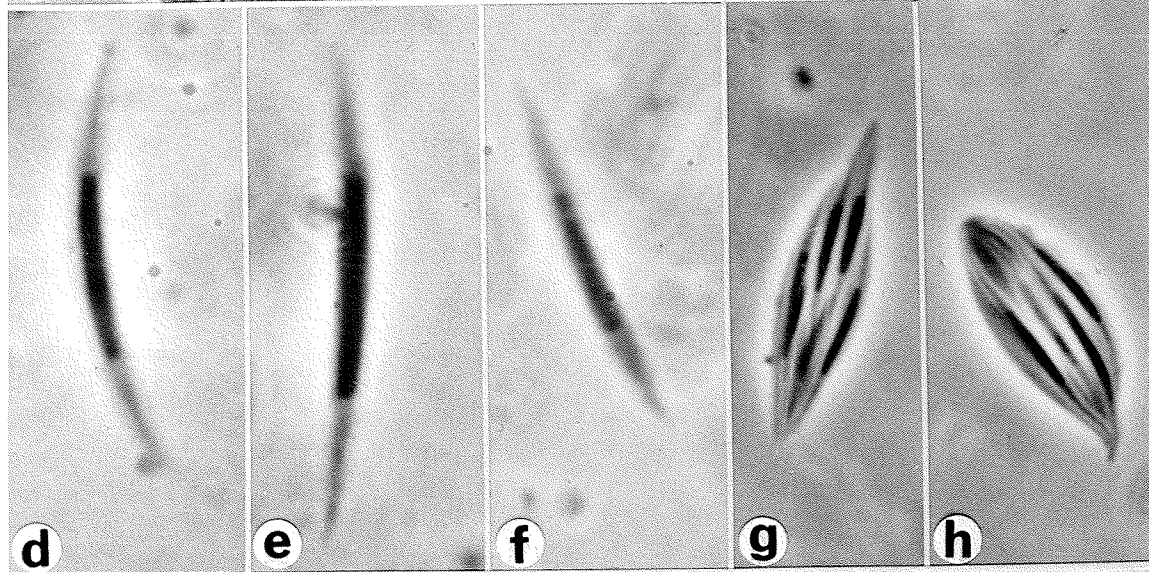
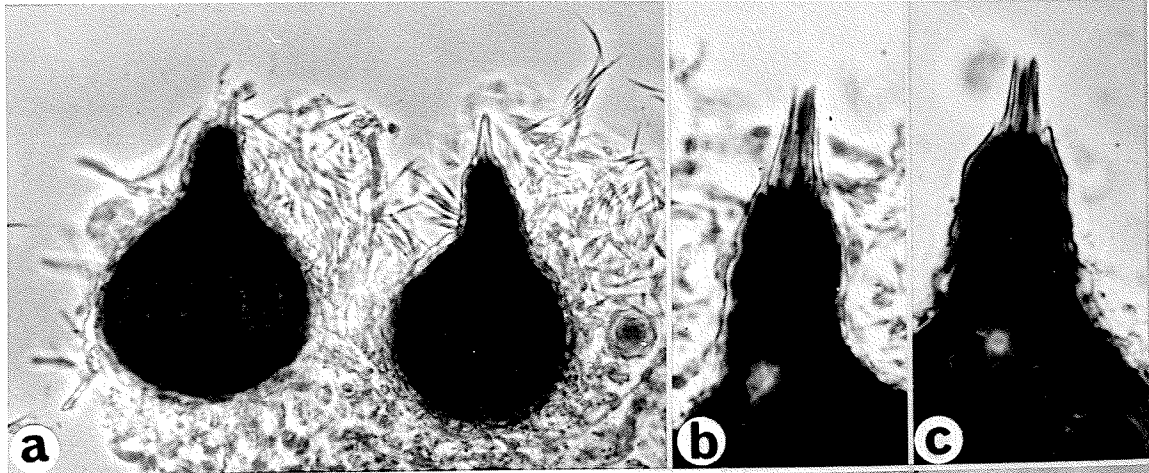
TYPE COLLECTION: WIN(M)69-14, Duck Mountain Provincial Forest, Manitoba, Canada, May 21, 1969.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)69-26, 69-28 (with *C. pilifera*); 69-64 (with *C. tremulo-aurea*);

## PLATE VII

*Ceratocystis pallidobrunnea* WIN(M) 69-14

- Fig. a Perithecia ( $\times 500$ )  
Figs. b-c Perithecial necks and apices ( $\times 1000$ )  
Figs. d-f Ascospores ( $\times 4000$ )  
Figs. g-h Asci ( $\times 2000$ )  
Fig. i Mycelium on agar ( $\times 1500$ )  
Fig. j Conidiogenous cells ( $\times 4000$ )  
Fig. k Conidia ( $\times 4000$ )





69-12, 69-39, 69-63, 70-09 (with *C. crassivaginata*); 70-16 on *Fraxinus nigra* (with *C. spinulosa*, *C. crassivaginata*); 70-15 on *Populus balsamifera* (with *C. crassivaginata*).

12. *Ceratocystis parva* sp. nov. Plate VIII, Figs. a-k.

*Perithecia* globosa, atrobrunnea vel nigra, 60-90 $\mu$  diam; collum atrobrunneum vel nigrum, conicum vel cylindricum, 15-30(45) $\mu$  longum, ad basim 20-45 $\mu$  latum, ad obtusum apicem 12-24 $\mu$ ; hyphae ostiolaris hyalinae, rectae, aciculares, convergentes, 5.0-15 $\mu$  longae, ad basim 1.0-2.0 $\mu$  latae; asci juveniles subglobosi vel clavati, 8.0  $\times$  3.0 $\mu$ , asci maturi non visi; ascosporae hyalinae, aseptatae, a latere conspectae falcatae, superne fusiformes, ab extremo non visae, 5.5-10  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis vel sigmoidea, 12-15(18)  $\times$  1.0-1.5 $\mu$ . Coloniae albae; hyphae 0.5-1.5 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia vel furcata; conidia hyalina, aseptata, clavata, 2.5-4.5  $\times$  0.7-1.5 $\mu$ , solitaria, acropleurogena dein in muco aggregata.

Hab. in cortice interno *Abietis balsameae*.

*Perithecia* dark brown to black, cellular detail visible only when the perithecia are bleached, superficial on inner bark of *Abies balsamea*, in culture developing on superficial mycelium or embedded in the agar

medium; bases globose, 60-90 $\mu$  in diameter, outer layer of the peridium composed of dark brown, interwoven, hyphal elements, 1.0-2.5 $\mu$  wide, and thick-walled, irregularly-shaped, interlocking cells with a maximum length of 12.5 $\mu$  and a minimum width of 2.5 $\mu$ ; necks conical or cylindrical, 15-30(45) $\mu$  long, 20-45 $\mu$  wide at the base, 12-24 $\mu$  at the tip, composed of thick-walled, rectangular cells, 2.5-5.0  $\times$  1.5-2.5 $\mu$ , which terminate in an obtuse apex; ostiolar hyphae hyaline, straight, acicular, converging to form a narrow opening, 5.0-15 $\mu$  long, 1.0-2.0 $\mu$  wide at the base, formed by elements internal to those comprising the outer layer of the neck. *Asci* evanescent, subglobose to clavate when young, up to 8.0  $\times$  3.0 $\mu$ ; mature asci not seen. *Ascospores* hyaline, 1-celled, falcate in side view, fusiform in plan view, 5.5-10  $\times$  0.7-1.0 $\mu$ , end view not seen, surrounded by a hyaline gelatinous sheath; sheath appearing falcate in side view, acicular or sigmoid in plan view, 12-15(18)  $\times$  1.0-1.5 $\mu$ . The spores are extruded from the ostiole in a hyaline, thread-like cirrhus.

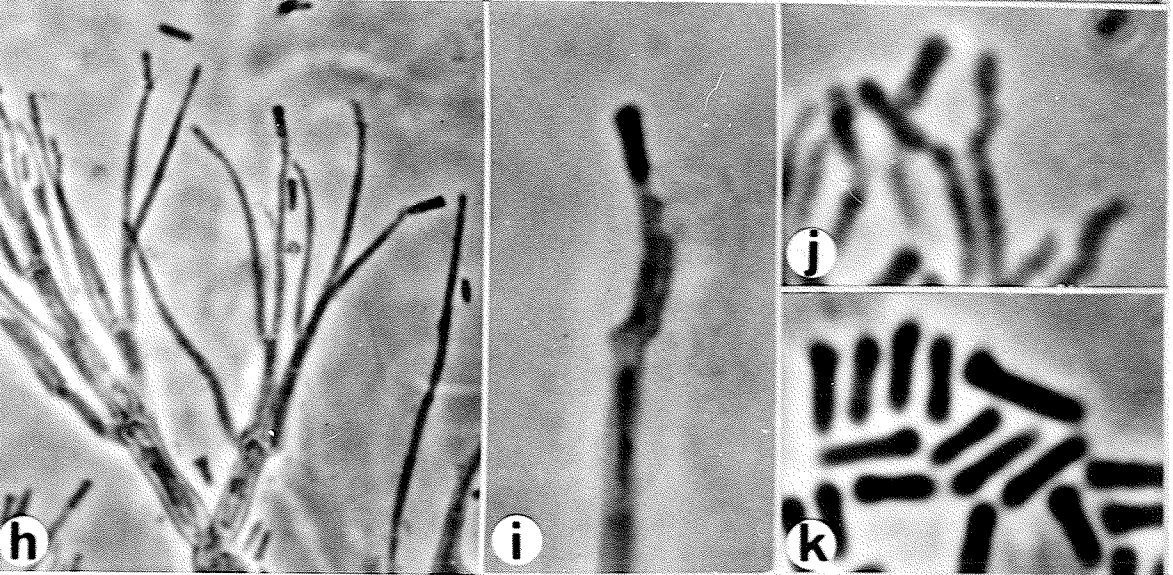
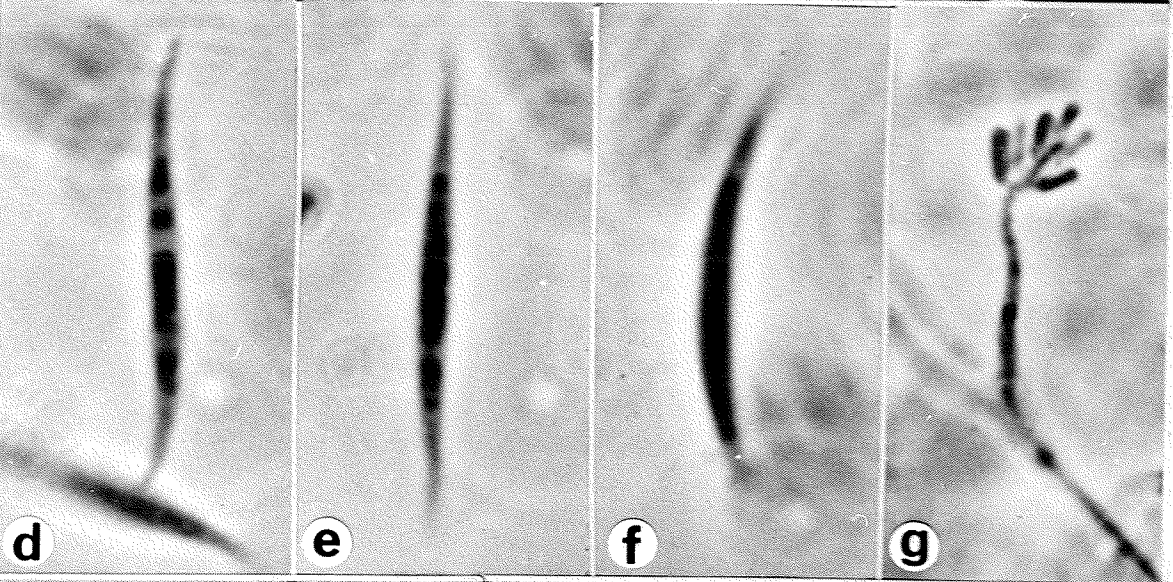
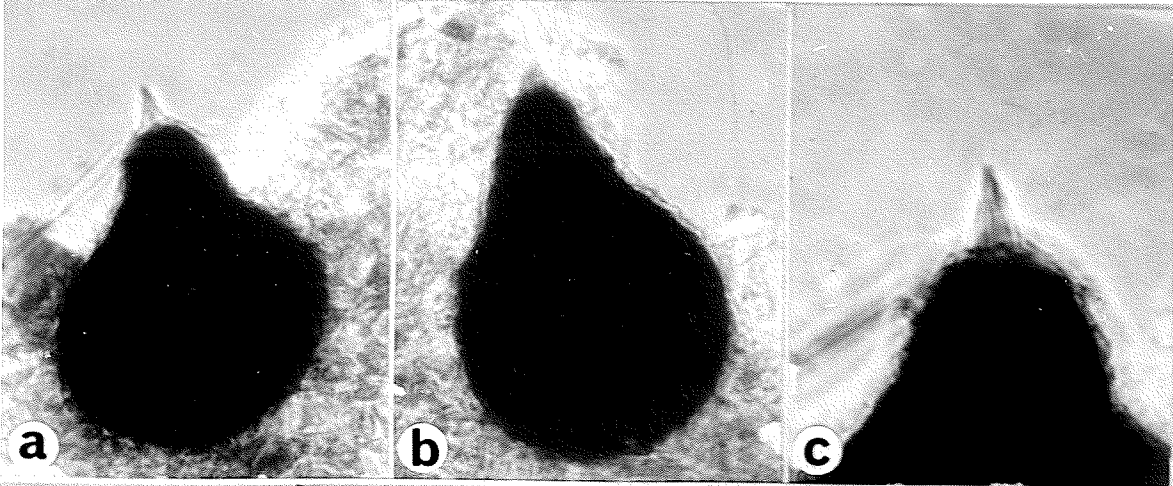
Perithecia develop on pabulum agar and on autoclaved wood in 3-4 weeks.

*Colonies* on agar compact, cottony, hyaline or white; agar not pigmented. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.5-1.5 $\mu$  wide. *Conidiophores* macronematous, mononematous, hyaline, unbranched or branched; branches usually in 1-2 series;

## PLATE VIII

*Ceratocystis parva* WIN(M)71-21

- Figs. a-b Perithecia ( $\times 500$ )  
Fig. c Perithecial neck ( $\times 1000$ )  
Figs. d-f Ascospores ( $\times 4000$ )  
Fig. g Unbranched conidiophore ( $\times 2000$ )  
Fig. h Branched conidiophores ( $\times 1500$ )  
Figs. i-j Conidiogenous cells ( $\times 4000$ )  
Fig. k Conidia ( $\times 4000$ )



stipes up to  $30 \times 6.0\mu$ , composed of 1-4 cells. *Conidio-  
diogneous cells* polyblastic, integrated, 1-3 per branch,  
sympodial, hyaline, cylindrical,  $15-40 \times 0.7-1.5\mu$ .

*Conidia* formed solitarily but become aggregated in slimy  
heads up to  $20\mu$  in diameter, acropleurogenous, hyaline,  
clavate,  $2.5-4.5 \times 0.7-1.5\mu$ .

The similarity of *C. parva* to other short-necked  
species in this group has already been mentioned (see  
discussions of *C. conicicollis* and *C. minima*).

HOST: *Abies balsamea*

TYPE COLLECTION: WIN(M)71-21 (with *C. concentrica*), San-  
dilands Forest Reserve, Manitoba, Canada, May 8, 1971.

OTHER COLLECTIONS EXAMINED: Ontario: TRTC 45751 ( with  
*C. conicicollis*).

13. *Ceratocystis spinifera* sp. nov. Plate IX, Figs. a-k.

Perithecia in cultura non evoluta, globosa, atro-  
brunnea vel nigra,  $35-60\mu$  diam, spinulis pallido-brunneis  
 $2.0-25\mu$  longis et  $1.0-2.0\mu$  latis ad basim ornata; collum  
atrobrunneum pallidius versus apicem, rectum vel curvatum,  
contractum,  $45-60\mu$  longum, ad basim  $12-17\mu$ , ad truncatum  
apicem  $3.5-5.0\mu$  latum; hyphae ostiolaris hyalinae, rectae,  
contractae, parallelae vel divergentes,  $5.0\mu$  longae, ad  
basim  $0.7-1.0\mu$  diam; asci clavati vel elliptico-fusifformes,  
evanescentes, octospori,  $10-11 \times 2.5-4.0\mu$ ; ascosporae  
hyalinae, aseptatae, a latere conspectae falcatae cum  
extremis obtusis, superne fusiformes, ab extremo non

visae,  $5.0-6.0 \times 0.7-1.0\mu$ , cum vagina gelatinosa; vagina falcata a latere conspecta, superne acicularis,  $8.5-11 \times 0.7-1.0\mu$ . Coloniae albae; hyphae  $0.7-2.5\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus vel crassis; conidiophora hyalina, simplicia vel furcata; conidia hyalina, aseptata, solitaria, acropleurogena, clavata vel ovoidea,  $2.0-5.0 \times 1.5-2.0\mu$ .

Hab. in cortice *Pini banksianae*

*Perithecia* superficial on inner bark and on cork tissue in insect galleries in bark; bases globose, dark brown to black,  $35-60\mu$  in diameter, outer layer of the peridium composed of thick-walled, more or less isodiametric cells,  $2.0-7.0\mu$  in diameter, frequently ornamented with a variable number of pale-brown, thick-walled, blunt spines,  $2.0-25 \times 1.0-2.0\mu$ ; necks dark brown, paler near the apex, straight or curved, tapered towards the tip,  $45-60\mu$  long,  $12-17\mu$  wide at the base, composed of parallel, thick-walled, laterally-fused, septate hyphal elements which terminate in a truncate apex  $3.5-5.0\mu$  wide; thick septa which are more or less coincident in adjacent hyphal elements give the lower portion of the neck an appearance of having dark bands alternating with lighter areas; ostiolar hyphae, when present, hyaline, straight, tapering towards the tips, parallel or convergent, up to  $5.0\mu$  long,  $0.7-1.0\mu$  wide at the base. *Asci* 8-spored, evanescent, clavate when young, elliptic-fusi-

form when mature.  $10-11 \times 2.5-4.5\mu$ . *Ascospores* hyaline, 1-celled, falcate with obtuse ends in side view, fusiform in plan view, end view not seen,  $5.0-6.0 \times 0.7-1.0\mu$ ; enclosed in a hyaline gelatinous sheath, attenuated at the ends; sheath falcate in side view, acicular in plan view,  $8.5-11 \times 0.7-1.2\mu$ .

Perithecia not produced in agar culture; several perithecia developed on autoclaved pieces of *Abies balsamea* in 2 months but not on *Pinus banksiana*.

*Colonies* on agar hyaline to white, cottony or appressed; agar not pigmented except for brown areas developing in older cultures; growth rate slow. *Mycelium* superficial and immersed. *Hyphae* hyaline, septate, thin-walled, or thick-walled with a granular surface,  $0.7-2.5\mu$  wide. *Conidiophores* hyaline, macronematous, mononematous, unbranched or branched. *Conidiogenous cells* polyblastic, terminal, discrete, cylindrical, sympodial,  $0.7-1.0\mu$  wide. *Conidia* hyaline, 1-celled, acropleurogenous, clavate to ovoid,  $2.0-5.0 \times 1.5-2.0\mu$ ; conidia produced along the sides of the conidiogenous cells formed on short, broad denticles.

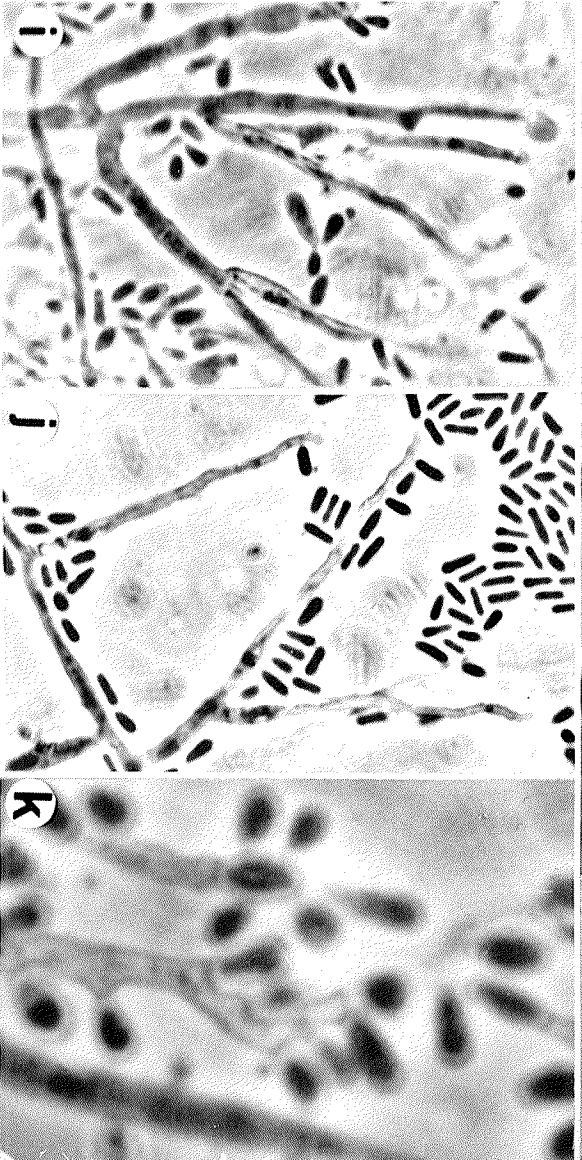
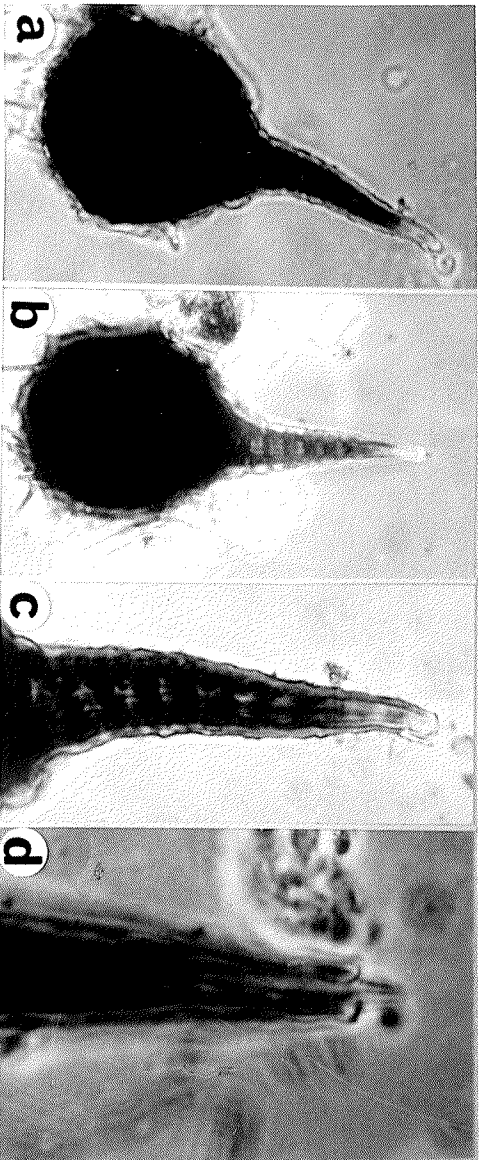
The similarity of *C. spinifera* to other species in this group has already been mentioned (see discussion of *C. crenulata* and *C. fasciata*). It seems most closely related to *C. fasciata* in that the perithecia of this species and *C. spinifera* are very similar except for the smaller

## PLATE IX

*Ceratocystis spinifera* WIN(M)71-07

- Figs. a-b Perithecia (×500)  
Fig. c Perithecial neck (×1000)  
Fig. d Neck apex (×2000)  
Fig. e Ascospores (×4000)  
Figs. f-g Conidiogenous cells (×4000)  
Fig. h Conidia (×4000)  
Figs. i-j Conidiophores and conidia (×1500)  
Fig. k Conidiogenous cells showing terminal and  
intercalary production of conidia (×4000)





size of those of the latter species. Cultures of *C. spinifera* appear to have different physiological requirements for perithecial production than those of *C. fasciata* since only a few perithecia were obtained from inoculations of *C. spinifera* onto autoclaved wood, while cultures of *C. fasciata* produced abundant perithecia on the same substrate.

The differences in size of the perithecia, length of the ascospores, and cultural characteristics, are the basis for separating *C. spinifera* and *C. fasciata*.

HOST: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)71-07, Sandilands Forest Reserve, Manitoba, Canada, April 10, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)69-45, 71-02, 71-04.

14. *Ceratocystis spinulosa* Griffin, Can. J. Bot. 46: 713, 1968. Plate X, Figs. a-d.

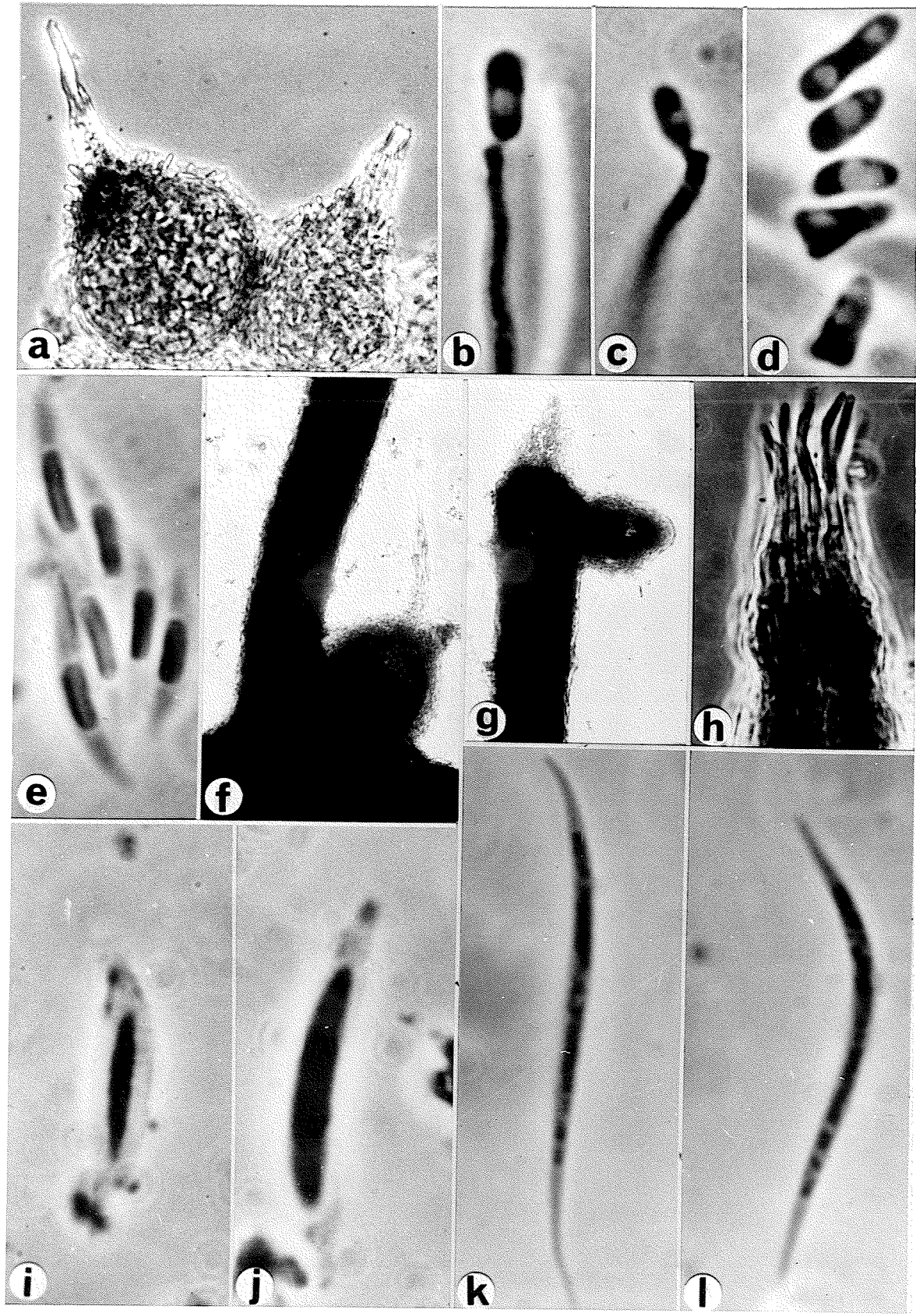
*C. spinulosa* was described on the basis of the perfect state. Cultures have been obtained from a Manitoba collection which resembles the type material of this species in all respects and, on this basis, the conidial state of *C. spinulosa* is described as follows:

*Colonies* on agar hyaline to white, becoming glistening due to masses of conidia in slime; agar not pigmented in young cultures, becoming pigmented slate gray in old cultures; growth rate slow. *Mycelium* superficial

## PLATE X

Additional illustrations of *Ceratocystis* spp.  
of the Minuta Group

- Fig. a *C. spinulosa* WIN(M)70-16. Perithecia ( $\times 500$ )
- Figs. b-c *C. spinulosa* WIN(M)70-16. Conidiogenous cells  
and conidia ( $\times 4000$ )
- Fig. d *C. spinulosa* WIN(M)70-16. Conidia ( $\times 4000$ )
- Fig. e *C. alba* WIN(M)69-35. Ascospores ( $\times 4000$ )
- Figs. f-g *C. alba* WIN(M)69-35. Perithecia growing on  
perithecial necks of *C. huntii* ( $\times 250$ )
- Fig. h *C. ochracea* MFB 7638. Apex of perithecial neck  
( $\times 1000$ )
- Figs. i-j *C. ochracea* MFB 7638. Ascospores ( $\times 4000$ )
- Figs. k-l *C. falcata* TRTC 33037. Ascospores ( $\times 4000$ )

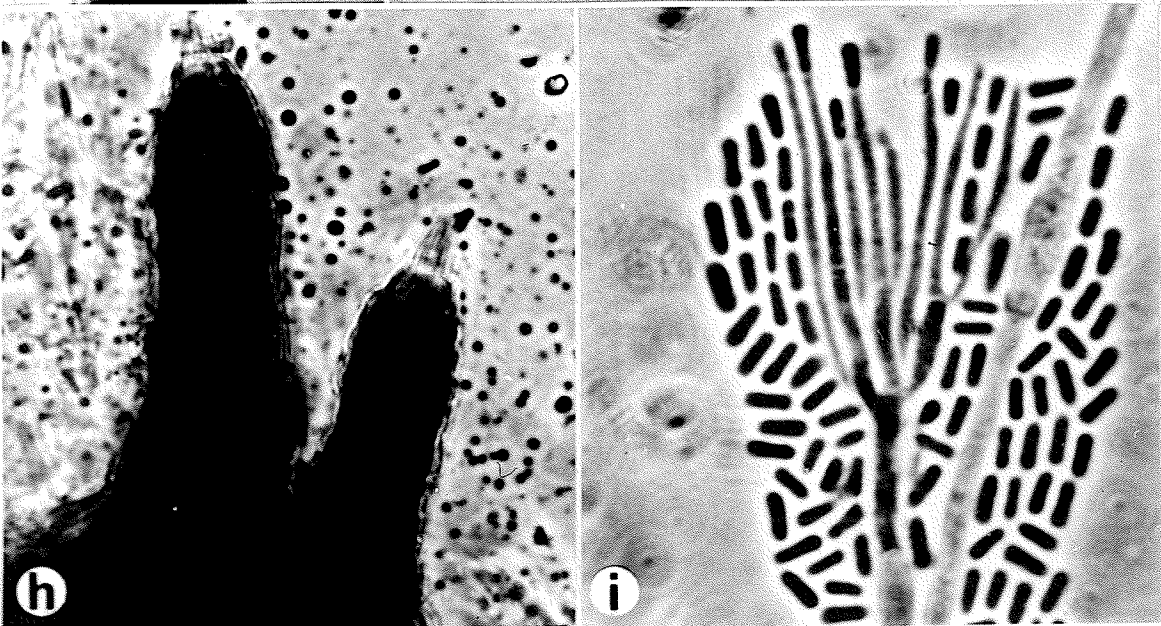
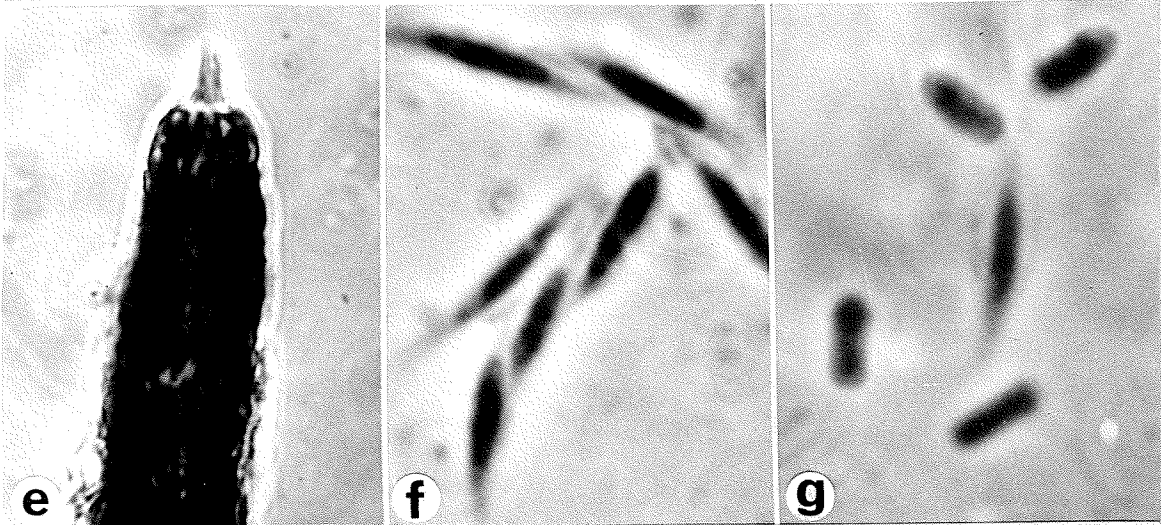
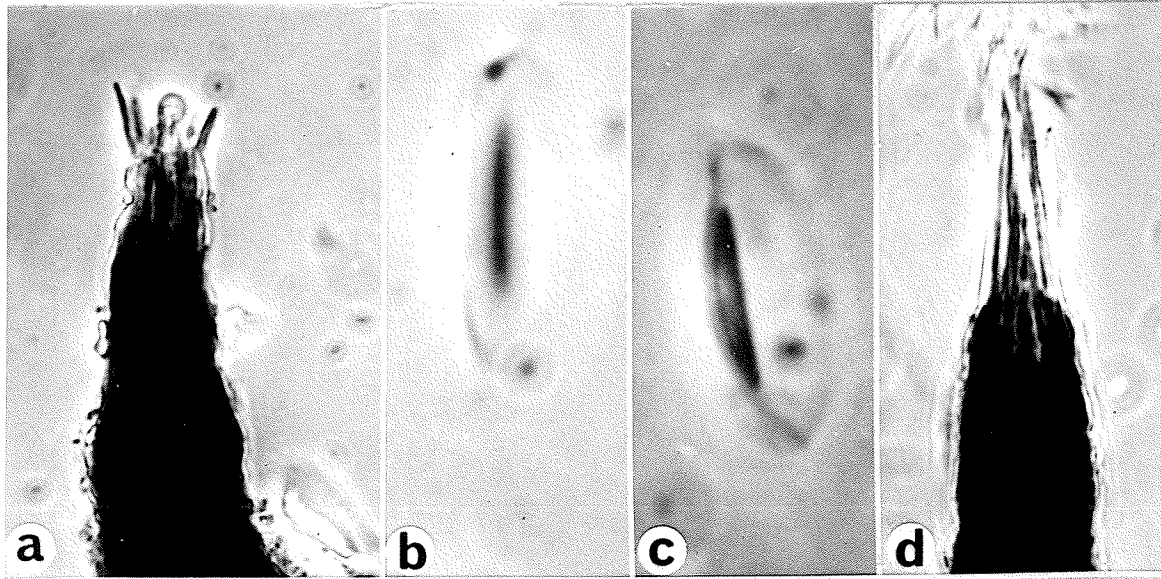


## PLATE XI

Additional illustrations of *Ceratocystis* spp.  
of the Minuta Group

- Fig. a *C. crassivaginata* WIN(M) 69-39. Perithecial neck ( $\times 1000$ )
- Figs. b-c *C. crassivaginata* WIN(M) 69-39. Ascospores ( $\times 4000$ )
- Fig. d *C. pallida* MFB 7639. Perithecial neck apex ( $\times 1000$ )
- Fig. e *C. dolominuta* WIN(M) 69-18. Perithecial neck ( $\times 1000$ )
- Fig. f *C. dolominuta* WIN(M) 69-18. Ascospores ( $\times 4000$ )
- Fig. g. *C. dolominuta* WIN(M) 69-18. Conidia and ascospore ( $\times 4000$ )
- Fig. h. *C. minuta* WIN(M) 71-26. Perithecial necks ( $\times 1000$ )
- Fig. i. *C. minuta* WIN(M) 71-26. Branched conidiophore ( $\times 2000$ )





and immersed. *Hyphae* hyaline, septate, thin-walled, 1.0-2.0 $\mu$  wide. *Conidiophores* micronematous or macro-nematous, mononematous, unbranched or sparingly branched in a verticillate manner. *Conidiogenous cells* polyblastic, integrated or discrete, terminal, sympodial, tapered towards the tips, 1.5-2.0 $\mu$  wide at the base. *Conidia* hyaline, 1-celled, clavate with a median constriction, T-shaped, Y-shaped, globose, or subglobose, 2.5-5.5(7.0)  $\times$  1.2-2.0 $\mu$ .

SPECIMENS EXAMINED: Ontario: MFB 7640 ( $\equiv$ DAOM 110151)

Manitoba: WIN(M)70-16 on *Fraxinus nigra* (with *C. crassivaginata*, *C. pallidobrunnea*).

The following species have not been found in Manitoba but have been examined for purposes of comparison and are considered to belong to the Minuta Group:

*Ceratocystis falcata* Wright and Cain, Can. J. Bot. 39:1226. 1961. Plate X, Figs. k-l. SPECIMEN EXAMINED: TRTC 33037.

*Ceratocystis minuta-bicolor* Davidson, Mycopathol. Mycol. Appl. 28:280. 1966. SPECIMEN EXAMINED: CFB R-587.

*Ceratocystis ochracea* Griffin, Can. J. Bot. 46:706. 1968. Plate X, Figs. h-j. SPECIMEN EXAMINED: MFB 7638.

*Ceratocystis pallida* Griffin, Can. J. Bot. 46:708. 1968. Plate XI, Fig. d. SPECIMEN EXAMINED: MFB 7639.

*Ceratocystis stenospora* Griffin, Can. J. Bot.  
46:714. 1968. SPECIMEN EXAMINED: MFB 7643.

The following species has not been examined but,  
from the description appearing in the literature, is  
probably referable to the Minuta Group:

*Ceratocystis retusi* Davidson and Hinds, Mycologia  
64:407. 1972.



## KEY TO THE SPECIES OF THE IPS GROUP

1. Ostiolar hyphae present
  2. Ostiolar hyphae parallel or convergent, less than 10 $\mu$  long
    3. Necks cylindrical, bent or crooked, apex truncate  
..... 4. *C. curvicollis*
    3. Necks tapered, straight or curved, apex obtuse  
..... *C. nigra*
  2. Ostiolar hyphae parallel or divergent, more than 10 $\mu$  long
    4. Necks usually less than 150 $\mu$  long; conidia deltoid  
..... 5. *C. deltoideospora*
    4. Necks usually more than 150 $\mu$  long; conidia clavate
      5. Ascospore sheath extended to form flanges, ossiform in side or plan view
        6. Hyphal elements comprising neck terminating in an obtuse or truncate apex, ostiolar hyphae develop from apex..... 8. *C. pseudonigra*
        6. Hyphal elements comprising neck extending into ostiolar hyphae, apex of neck not sharply defined..... 2. *C. brunneocrinita*
      5. Ascospore sheath uniform; not forming flanges  
..... 1. *C. arborea*
1. Ostiolar hyphae absent
  7. Length of neck usually less than diameter of base of perithecium, apex truncate.....9. *C. tubicollis*

- 7. Length of neck greater than diameter of base of perithecium, apex obtuse
- 8. Ascospore sheath quadrangular or pillow-shaped in side and plan view
  - 9. Base of perithecium brown to black
    - 10. Base of perithecium less than 200 $\mu$  in diameter  
..... 6. *C. ips*
    - 10. Base of perithecium more than 200 $\mu$  in diameter  
..... *C. montia*
  - 9. Base of perithecium light colored... *C. bicolor*
- 8. Ascospore sheath ossiform in side or plan view
  - 11. Phialoconidia clavate, medially constricted...  
.....7. *C. ossiformis*
  - 11. Phialoconidia not medially constricted.....  
.....3. *C. columnaris*

1. *Ceratozystis arborea* sp. nov. Plate XII, Figs. a-k.

*Perithecia* globosa, atrobrunnea vel nigra, (75)100-150 $\mu$  diam; collum atrobrunneum vel nigrum, contractum, parvum curvatum, 400-800 $\mu$  longum, ad basim 20-40 $\mu$ , ad obtusum apicem 12-18 $\mu$  latum; hyphae ostiolaris hyalinae, septatae, divergentes, contractae vel maxima 40 $\mu$  longae, ad basim 2.0-2.5 $\mu$  diam, ad apicem truncatum 1.0-1.5 $\mu$  diam; asci juveniles clavati, maturi sub-globosi, evanescentes, usque ad 8.0  $\times$  5.0 ; ascosporae hyalinae, aseptatae, a latere conspectae et superne oblongae vel in medio constrictae cum extremis obtusis, ab extremo conspectae rotundae, 2.0-4.0  $\times$  1.0-1.5 $\mu$ , cum vagina gelatinosa aequabili 0.2-0.5(1.5) $\mu$  crassa. Coloniae albae; hyphae 1.0-2.0 $\mu$  diam, hyalinae, septatae, immersae, parietibus tenuibus; conidiophora in synnemata aggregata; synnemata hyalina vel pallido-brunnea, 150-250(3000) $\mu$  alta et (5)12-75 $\mu$  lata, ad apices attenuata vel dendroidea; conidia acropleurogena, aseptata, clavata, solitaria dein in muco aggregata, 2.0-12  $\times$  1.3-3.0 $\mu$ .

Hab. in ligno *Piceae marianae*.

*Perithecia* superficial on wood, in culture developing on superficial mycelium or embedded in the agar; bases globose, dark brown to black, (75)100-150 $\mu$  in diameter, outer layer of the peridium composed of dark, angular cells, thick-walled in outline, 4-16 $\mu$  in diameter;

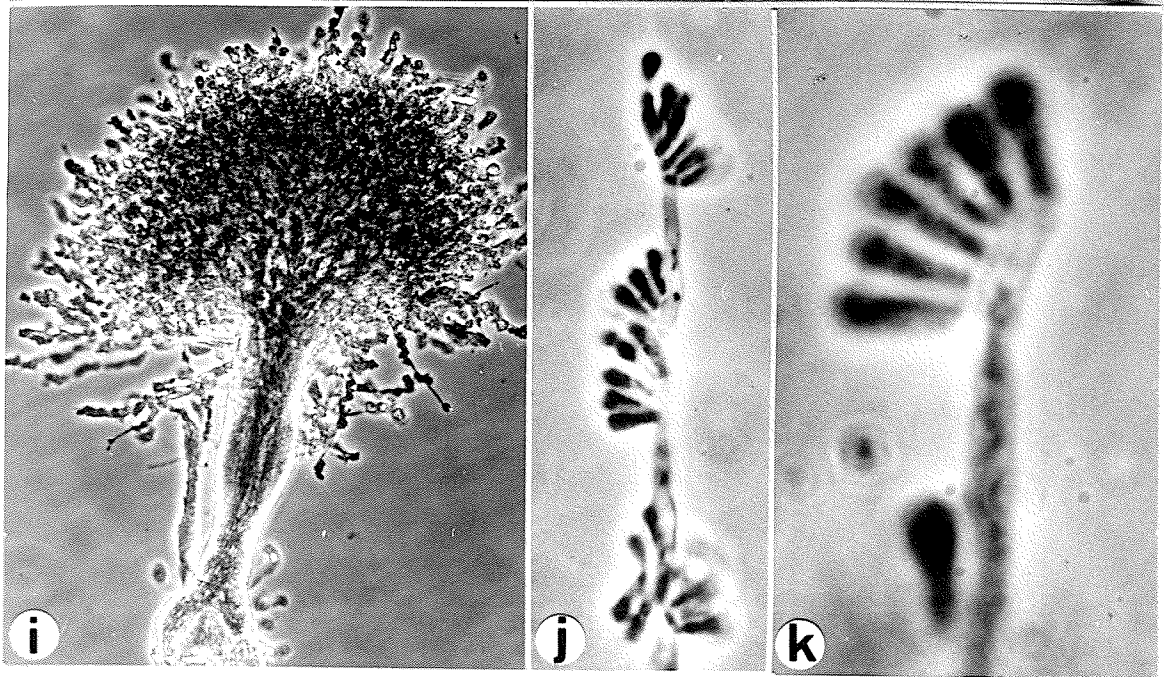
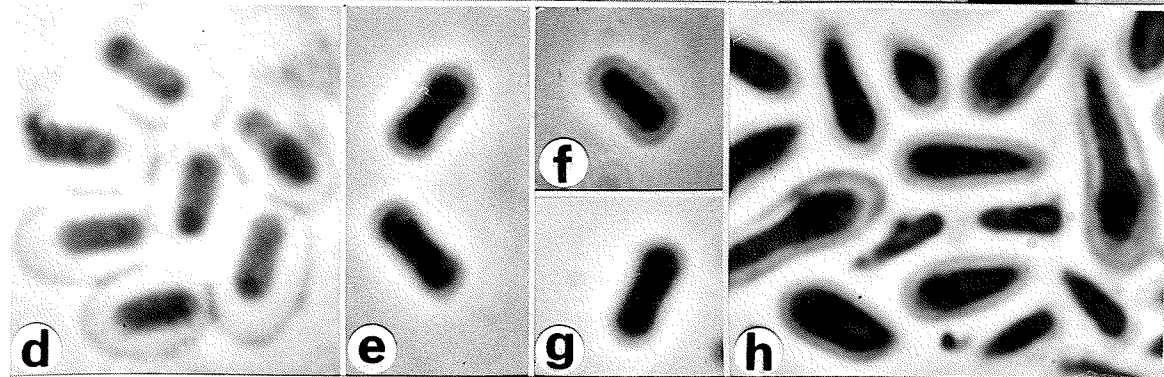
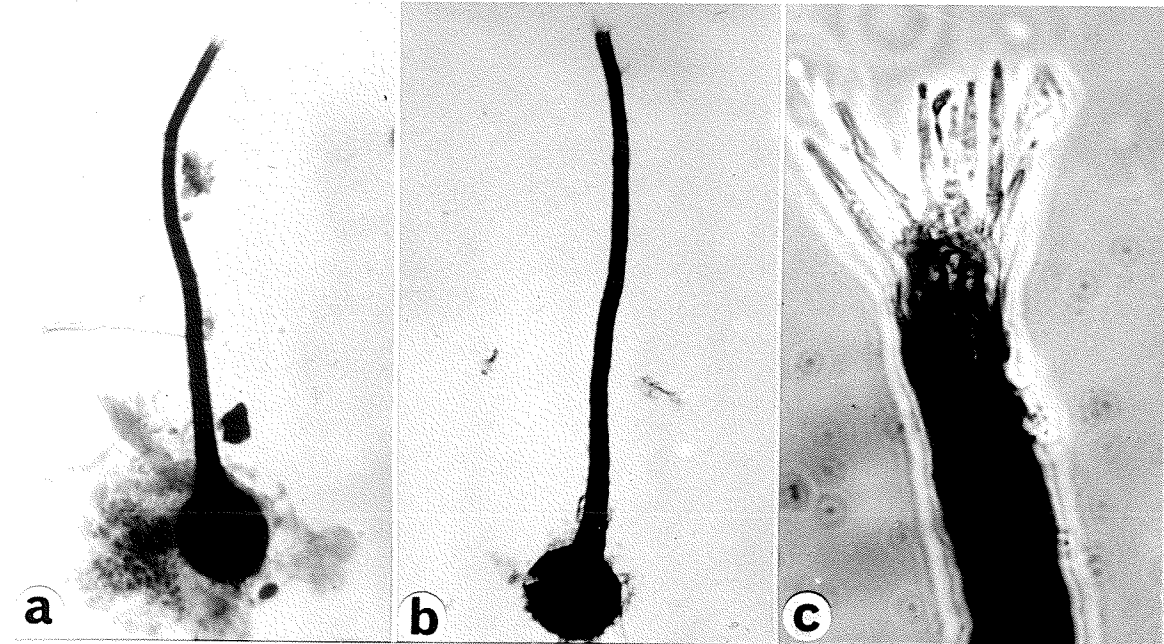
necks dark brown to black, tapered, slightly curved, 400-800 $\mu$  long, 25-40 $\mu$  wide at the base, 12-18 $\mu$  at the tip, composed of parallel, laterally-fused, thick-walled hyphal elements, 2.0-2.5 $\mu$  wide, which terminate in an obtuse apex; ostiolar hyphae, when present, hyaline, septate, divergent, tapered to a blunt tip, up to 40 $\mu$  long, 2.0-2.5 $\mu$  wide at the base, 1.0-1.5 $\mu$  wide near the tip, develop as extensions from the outer layer of neck cells and may function as conidiophores. *Asci* 8-spored, evanescent, clavate when young, sub-globose when mature, up to 8.0  $\times$  5.0 $\mu$ . *Ascospores* hyaline, 1-celled, oblong with obtuse ends in side and plan view, usually medially constricted, globose in end view, 2.0-4.0  $\times$  1.0-1.5 $\mu$ , surrounded by a uniform, hyaline, gelatinous sheath, 0.2-0.5(0.7) $\mu$  thick; the spores collect in a hyaline droplet at the tip of the neck. Perithecia develop on agar and on autoclaved wood in 3-4 weeks.

*Colonies* on agar compact, glistening due to copious production of conidia in slime. *Mycelium* mostly immersed, agar pigmented light brown. *Hyphae* hyaline, thin-walled, septate, 1.0-2.0 $\mu$  wide. *Conidiophores* macronematous, synnematous. *Synnemata* hyaline to medium brown, 150-250 (3000)  $\times$  (5)12-75 $\mu$ , individual threads 1.5-2.0 $\mu$  thick, twisted due to helical growth of individual threads, capped by a cream-colored slime head, pointed at the apex, or splayed out to form a structure resembling a tree.

## PLATE XII

*Ceratocystis arborea* WIN(M) 69-23

- Figs. a-b Perithecia ( $\times 100$ )  
Fig. c Apex of perithecial neck ( $\times 1000$ )  
Figs. d-g Ascospores ( $\times 4000$ )  
Fig. h Conidia ( $\times 4000$ )  
Fig. i Synnemata ( $\times 250$ )  
Fig. j Single conidiophore from a synnema ( $\times 1500$ )  
Fig. k Tip of conidiogenous cell ( $\times 4000$ )



*Conidiogenous cells* polyblastic, integrated, terminal becoming intercalary, sympodial, approximately  $1.5\mu$  wide. *Conidia* formed solitarily but usually becoming aggregated in a slimy head, acropleurogenous, 1-celled, clavate to broadly clavate,  $2.0-12 \times 1.0-3.0\mu$ .

The medially constricted ascospores, surrounded by a uniform gelatinous sheath, readily distinguish *C. arborea* from all other species of *Ceratocystis*. The conidial state in which the conidiophores develop into 'tree-like' forms is also distinctive of this species, and is unlike that of any other species examined. The apices of the necks, with robust ostiolar hyphae, somewhat resemble those of *C. brunneocrinita*, but the ascospores and the conidial state readily separate *C. arborea* from the latter species.

HOST: *Picea mariana*.

TYPE COLLECTION: WIN(M) 69-23, Duck Mountain Provincial Forest, Manitoba, Canada, May 22, 1969.

ADDITIONAL SPECIMENS EXAMINED: WIN(M) 69-20.

2. *Ceratocystis brunneocrinita* Wright and Cain, Can. J. Bot. 39: 1218, 1961. Plate XIX, Figs. a-c.

Wright and Cain described the gelatinous sheath which surrounds the ascospores of *C. brunneocrinita* as being rectangular in shape, but observations with a phase contrast microscope show that the sheath is ossiform in outline, and is similar to the sheath found in *C. nigra*

and other species in this group (see Fig. C, Plate XIX).

MANITOBA HOST: *Abies balsamea*.

SPECIMENS EXAMINED: Manitoba: WIN(M)71-17 (with *C. conicicollis*), 71-21 (with *C. concentrica*, *C. parva*), 70-35, 71-28; Ontario: TRTC 33379, 33697, 33704, 34581, 45764, 45765, 45766; MFB 7379 (with *C. minuta*), 7413.

3. *Ceratocystis columnaris* sp. nov. Plate XIII, Figs. a-k.

*Perithecia* globosa, pallido- vel atrobrunnea, (60)120-200(250) $\mu$  diam; collum nigrum, rectum vel flexuosum, parum contractum, in agar 420-750 $\mu$  longum vel in ligno 2000 $\mu$  longum, ad basim 30-40 $\mu$ , ad apicem 12-20 $\mu$  latum, pileo hyalino tectum; hyphae ostiolaris non visae; asci juveniles clavati, maturi subglobosi, evanescentes, octospori, usque 7.5  $\times$  5.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae et superne oblongae cum extremis obtusis, ab extremo conspectae rotundae, 2.5-5.0  $\times$  1.2-1.5 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne ossiformis, ab extremo conspecta quadrangula, in medio 0.5 $\mu$  lata, in extremis 2.5 $\mu$  lata.

Coloniae albae; hyphae 0.7-3.0 $\mu$  diam, hyalinae, septatae, parietibus crassis; conidiophora simplicia vel in synnemata aggregata; synnemata pallido-brunnea vel brunnea, 200 $\mu$  alta et 100 $\mu$  lata; phialoconidia acrogena, aseptata, clavata vel cylindrica, (2.5)4.0-6.0(7.5)  $\times$  (1.0)1.5-2.0(3.5) $\mu$ , in muco aggregata.

*Hab.* in ligno et cortice interno *Pini banksianae*.



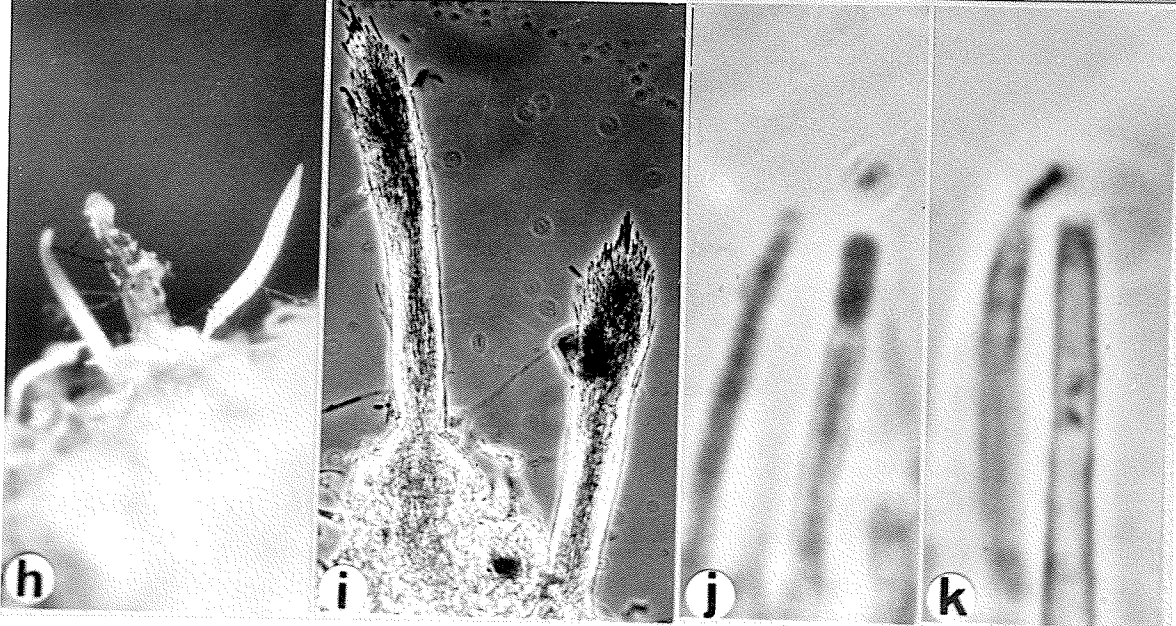
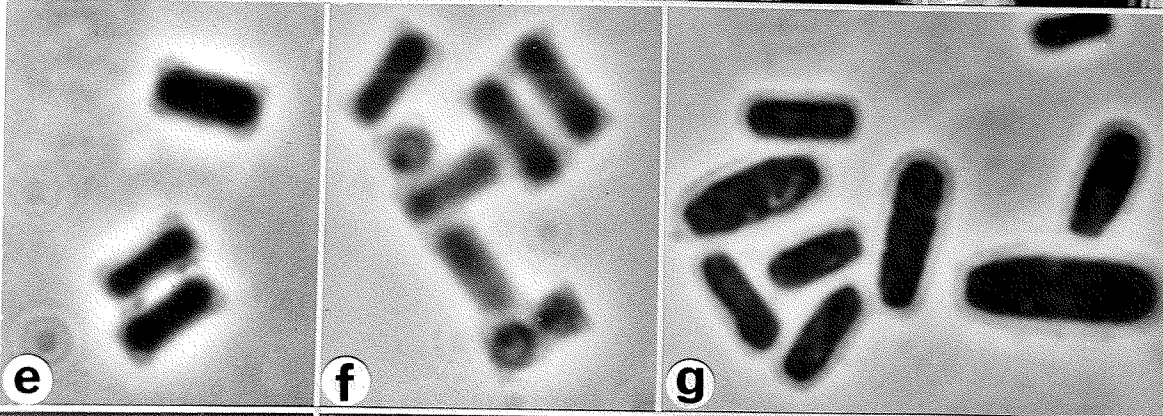
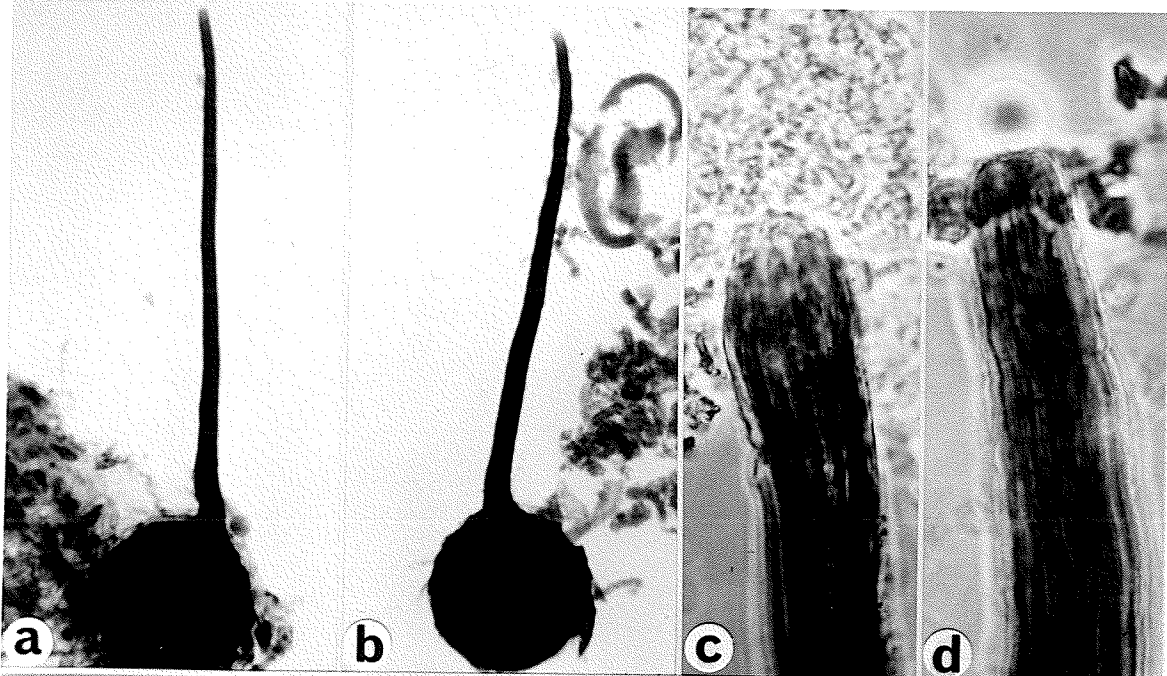
*Perithecia* superficial on wood or embedded in inner face of bark, in culture developing in 2-3 weeks on superficial mycelium or embedded in the agar; bases globose, light to dark brown, (60)120-200(250) $\mu$  in diameter, outer layer of the peridium composed of dark, thick-walled cells, 2.5-12 $\mu$  in diameter, or of thick-walled, vermiform hyphal elements, approximately 2.5 $\mu$  wide; necks black, straight or bent, slightly tapered, 420-750 $\mu$  long, up to 2000 $\mu$  when embedded in bark, 30-40 $\mu$  wide at the base, 12-20 $\mu$  at the tip, composed of straight, multiseptate, laterally-fused, hyphal elements, 2.0-3.0 $\mu$  wide, covered at the apex by a hyaline gelatinous cap; ostiolar hyphae absent. *Asci* 8-spored, evanescent, clavate when young, sub-globose when mature, attaining a maximum dimension of 7.5  $\times$  5.0 $\mu$ . *Ascospores* hyaline, 1-celled, oblong with obtuse ends in side and plan view, globose in end view, 2.5-5.0  $\times$  1.25-1.5 $\mu$ , surrounded by a hyaline, gelatinous sheath; sheath ossiform in side and plan view, quadrangular in end view, up to 0.5 $\mu$  thick and flared to a width of 2.5 $\mu$  at the ends; the spores collect in a hyaline droplet at the tip of the neck.

*Colonies* effuse; malt agar pigmented medium brown, pabulum agar not pigmented. *Mycelium* mostly immersed. *Hyphae* thin-walled, hyaline, or thick-walled, pale brown, 0.7-3.0 $\mu$  wide. *Conidiophores* macronematous or semi-macronematous, mononematous or synnematous. *Synnemata*

## PLATE XIII

*Ceratocystis columnaris* WIN(M)71-27

- Figs. a-b Perithecia ( $\times 100$ )
- Figs. c-d Apices of perithecial necks ( $\times 1000$ )
- Figs. e-f Ascospores ( $\times 4000$ )
- Fig. g Conidia ( $\times 4000$ )
- Fig. h Columnar masses of phialoconidia (left and right of center) ( $\times 60$ )
- Fig. i Synnemata ( $\times 250$ )
- Figs. j-k Conidiogenous cells ( $\times 4000$ )



light to medium brown, solitary or cespitose, up to  $250 \times 100\mu$ . *Conidiogenous cells* monophialidic, cylindrical, terminal, integrated, percurrent,  $1.0-1.5\mu$  wide; collarettes lacking. *Phialoconidia* acrogenous, clavate to cylindrical,  $(2.5)4.0-6.0(7.5) \times (1.0)1.5-2.0(3.5)\mu$ , collecting in a globose slime droplet up to  $100\mu$  in diameter or hanging together to form a column up to four (or more) times the length of the synnema.

The comparison of *C. columnaris* and *C. ossiformis* is made elsewhere in this text (see discussion of *C. ossiformis*). The columnar masses of phialoconidia, which are produced abundantly in culture on wood, are a distinctive characteristic of this species (Fig. h, Plate XIII), which separates it from all other species examined in culture.

HOST: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)71-27, Sandilands Forest Reserve, Manitoba, Canada, July 17, 1971.

4. *Ceratocystis curvicollis* sp. nov. Plate XIV, Figs. a-n.

*Perithecia* globosa, atrobrunnea vel nigra,  $60-125\mu$  diam, hyphis pallido-brunneis, parietibus crassis, septatis, vel maxima  $100\mu$  longis et  $1.5-2.0\mu$  latis ad basim ornata; collum atrobrunneum vel nigrum, cylindricum vel contractum, curvatum vel arcuatum,  $(60)100-200\mu$  longum, ad basim  $(12)20-30\mu$  latum, ad apicem truncatum vel obtusum  $6.0-10\mu$  latum; hyphae ostiolaris hyalinae, ad apicem

truncatae, rectae vel tortae, parallelae vel divergentes, 2.0-10 $\mu$  longae, 0.7-1.0 $\mu$  diam; asci juveniles clavati, maturi subglobosi, 7.0-8.0  $\times$  3.0-4.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae et superne oblongae vel cylindricae cum extremis obtusis, ab extremo conspectae rotundae, (2.5)3.0-4.0(5.5)  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne ossiformis, ab extremo conspecta quadrangula, in medio tenuissima, in extremis 1.5 $\mu$  lata. Coloniae albae; hyphae 0.7-4.5 $\mu$  diam, hyalinae, immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia vel furcata; conidia hyalina, aseptata, acropleurogena, cylindrica vel clavata, (2.0)3.5-5.0(7.0)  $\times$  0.7-1.5(2.5) $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno *Abietis balsameae*.

*Perithecia* superficial on wood; in culture, developing on the surface of the agar on on aerial mycelium; bases dark brown to black, globose, 60-125 $\mu$  in diameter, usually ornamented with pale brown, thick-walled, septate, hair-like hyphal elements, 1.5-2.0 $\mu$  wide, up to 100 $\mu$  long; outer layer of the peridium composed of dark, irregularly-shaped cells, thick-walled in outline, (4.0)6.0-15(18) $\mu$  across; necks dark brown to black, tapered or nearly cylindrical, curved or arcuate, (60)100-200 $\mu$  long, (12)20-30 $\mu$  wide at the base, 6.0-10 $\mu$  at the tip, composed of parallel, septate, laterally fused, thick-walled hyphal

elements, 2.0-2.5 $\mu$  wide, which terminate in a truncate or obtuse apex; thick septations, more or less coincident in adjacent hyphal elements, give the neck an appearance of having dark bands alternating with lighter areas; ostiolar hyphae, when present, hyaline, blunt at the tips, straight or crooked, parallel or divergent, 6-10 in number, 2.0-10  $\times$  0.7-1.0 $\mu$ , develop as extensions of the cells comprising the outer layer of the neck. *Asci* 8-spored, evanescent, clavate when young, broadly clavate to sub-globose when mature, 7.0-8.0  $\times$  3.0-4.0 $\mu$ . *Ascospores* 1-celled, hyaline, oblong with obtuse ends to cylindrical in side and plan view, globose in end view, (2.5)3.0-4.0(5.5)  $\times$  0.7-1.0 $\mu$ , surrounded by a hyaline, gelatinous sheath; sheath ossiform or dumbbell-shaped in side and plan view, quadrangular in end view, very thin along the body of the spore and apparent only where it extends 0.2-0.7 $\mu$  beyond the ends of the spore and flares to a width of 1.5 $\mu$ . The spores collect at the tip of the neck in a hyaline droplet. Perithecia develop on autoclaved wood in 10-14 days.

*Colonies* effuse, hyaline or white on pabulum agar, compact on malt agar. *Mycelium* mostly immersed, agar not pigmented. *Hyphae* hyaline, septate, thin-walled, 0.7-4.5 $\mu$  wide. *Conidiophores* hyaline, macronematous or semi-macronematous, mononematous, unbranched or branched, branches in 1-3 series, stipe 4.0-12  $\times$  2.0-4.0 $\mu$ .

## PLATE XIV

*Ceratocystis curvicollis* WIN(M)70-25

Figs. a-c Perithecia from culture on wood ( $\times 250$ )

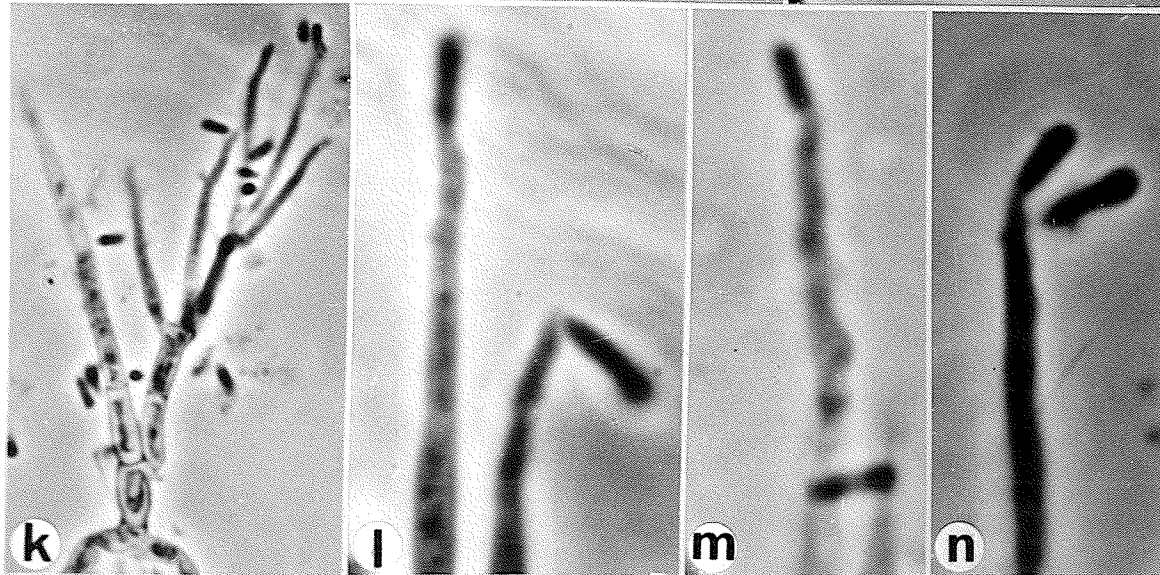
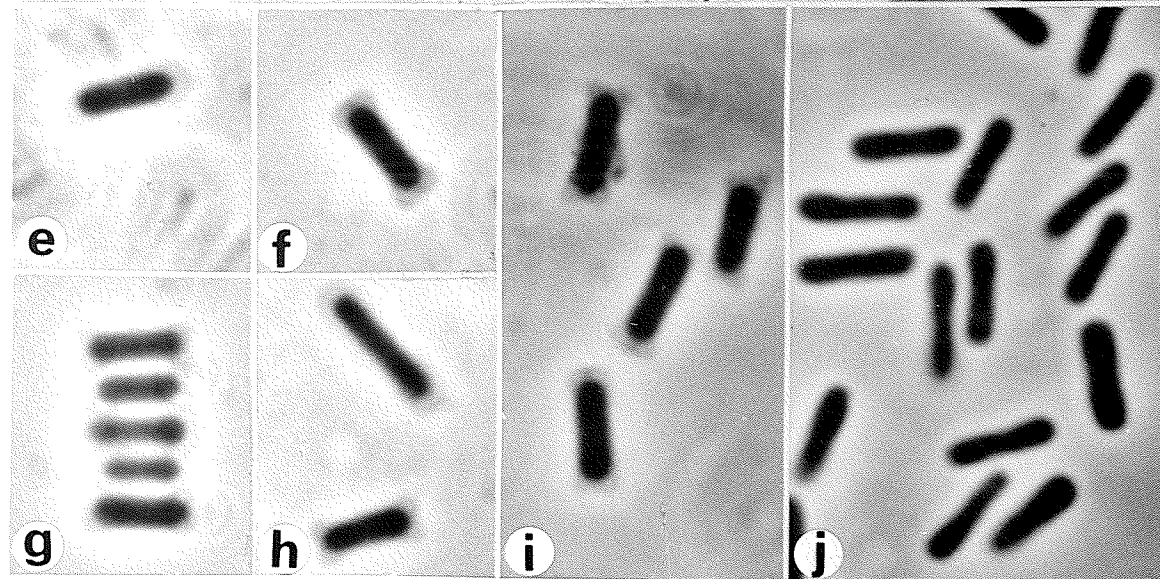
Fig. d Apex of perithecial neck ( $\times 1000$ )

Figs. e-i Ascospores ( $\times 4000$ )

Fig. j Conidia ( $\times 4000$ )

Fig. k Branching conidiophore ( $\times 1500$ )

Figs. l-n Conidiogenous cells ( $\times 4000$ )





*Conidiogenous cells* polyblastic, integrated, terminal, sympodial, subulate, approximately  $1\mu$  wide at the tip. *Conidia* acropleurogenous, cylindrical or clavate to broadly clavate,  $(2.0)3.5-5.0(7.0) \times 0.7-1.5(2.5)\mu$ , formed solitarily but becoming aggregated in a hyaline, slime droplet.

*C. curvicollis* is closely related to *C. nigra* with the two species having similar ascospores and conidial states. Separation of the two species is based mainly on the characteristics of the perithecial necks. Perithecia of *C. nigra* have necks which are straight or slightly curved, with upper portions tapering and terminating in obtuse apices. Perithecia of *C. curvicollis*, however, produce necks which are bent or coiled in a helicoid fashion, with upper portions that are nearly cylindrical and terminate in truncate apices. Also, the necks of *C. nigra* are wider; the average width of the mid point being twice that of *C. curvicollis*.

HOST: *Abies balsamea*

TYPE COLLECTION: WIN(M)70-25, Sandilands Forest Reserve, Manitoba, Canada, June 7, 1970.

ADDITIONAL SPECIMENS EXAMINED: Ontario: TRTC 45641, 45742.

5. *Ceratocystis deltoideospora* sp. nov. Plate XV Figs.a-k

Perithecia in cultura non evoluta, subglobosa vel globosa, atrobrunnea vel nigra,  $(75)100-125\mu$ , paucis spinulis pallido-brunneis  $5-30\mu$  longis et  $2.0\mu$  latis ad

basim ornata; collum atrobrunneum vel nigrum, pallidius versus apicem, contractum, rectum vel curvatum vel flexum, 80-150(180) $\mu$  longum, ad basim 20-40 $\mu$  latum, ad apicem obtusum 8.0-12 $\mu$  latum; hyphae ostiolaris hyalinae, septatae, cylindricae vel contractae, parallelae vel divergentes, vel maxima 30 $\mu$  longae, ad basim 1.0-2.0 $\mu$  diam; asci juveniles clavati, maturi sub-globosi, evanescentes, octospori, 6.0-7.0  $\times$  3.0-4.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae rotundae, (2.5)3.5-4.0(4.5)  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne ossiformis, ab extremo conspecta quadrangula, in medio 0.2 $\mu$  lata, in extremis 2.0 $\mu$  lata. Coloniae albae; hyphae 1.0-2.5 $\mu$  diam, hyalinae, parietibus tenuibus; conidiophora simplicia vel furcata; conidia hyalina, aseptata, ovoidea vel oblonga vel clavata vel T- vel Y- formia, 2.0-4.5  $\times$  1.0-2.5(3.0) $\mu$ .

Hab. in ligno *Pini banksianae*.

*Perithecia* superficial on wood, not produced in agar culture; bases dark brown to black, globose to subglobose, (75)100-125 $\mu$  wide, height slightly greater than width, occasionally ornamented with a few pale brown, thick-walled, septate spines, 5.0-30  $\times$  2.0 $\mu$ , outer layer of the peridium composed of dark cells, thick-walled in outline, vermiform or like the pieces of a jig-saw puzzle, minimum width 2.5 $\mu$ , maximum length 12.5 $\mu$ ; necks dark brown to black, lighter at the tip, tapered, straight, curved, or

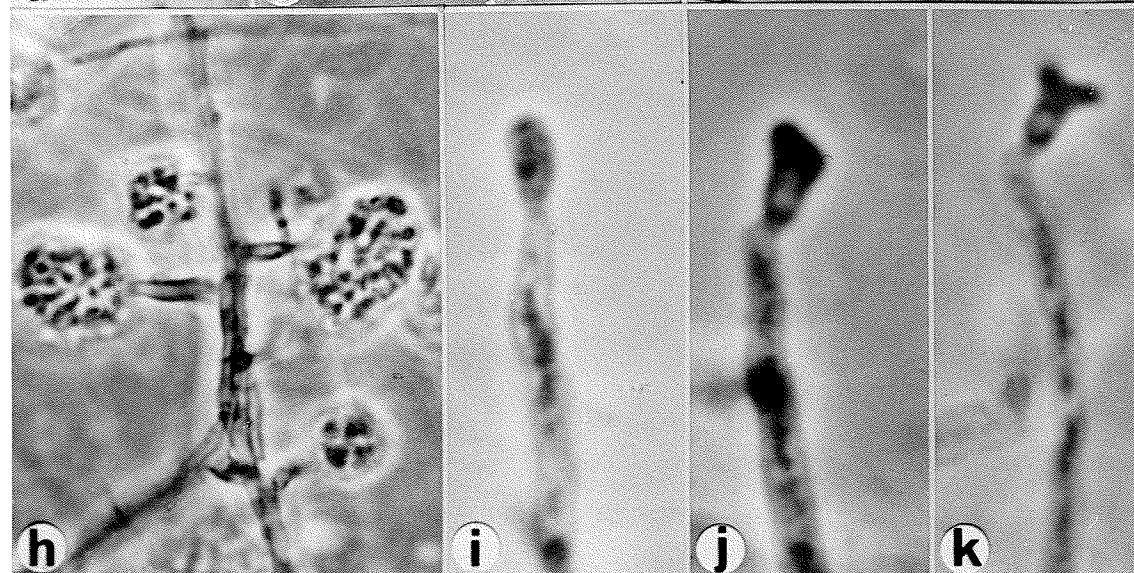
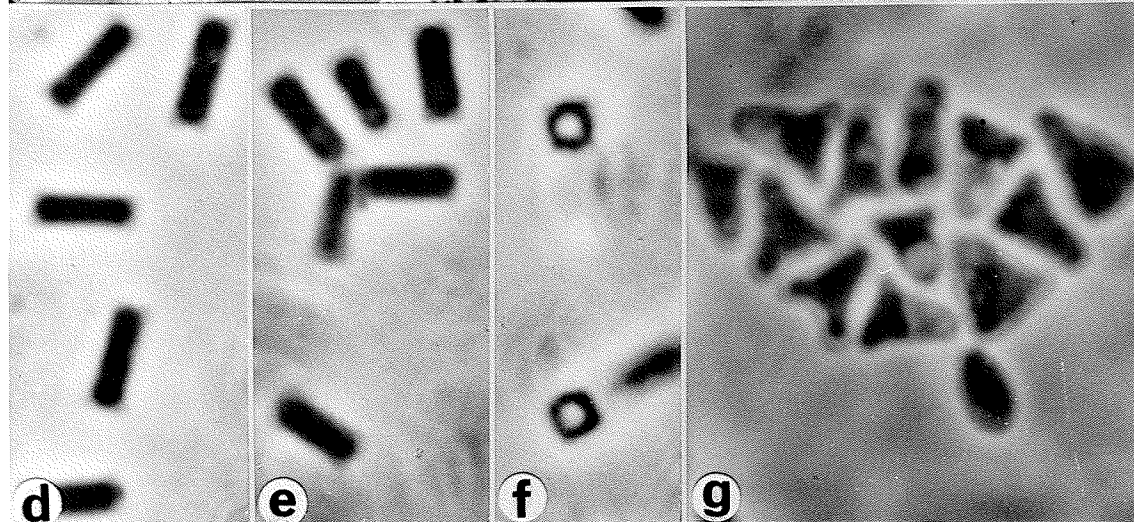
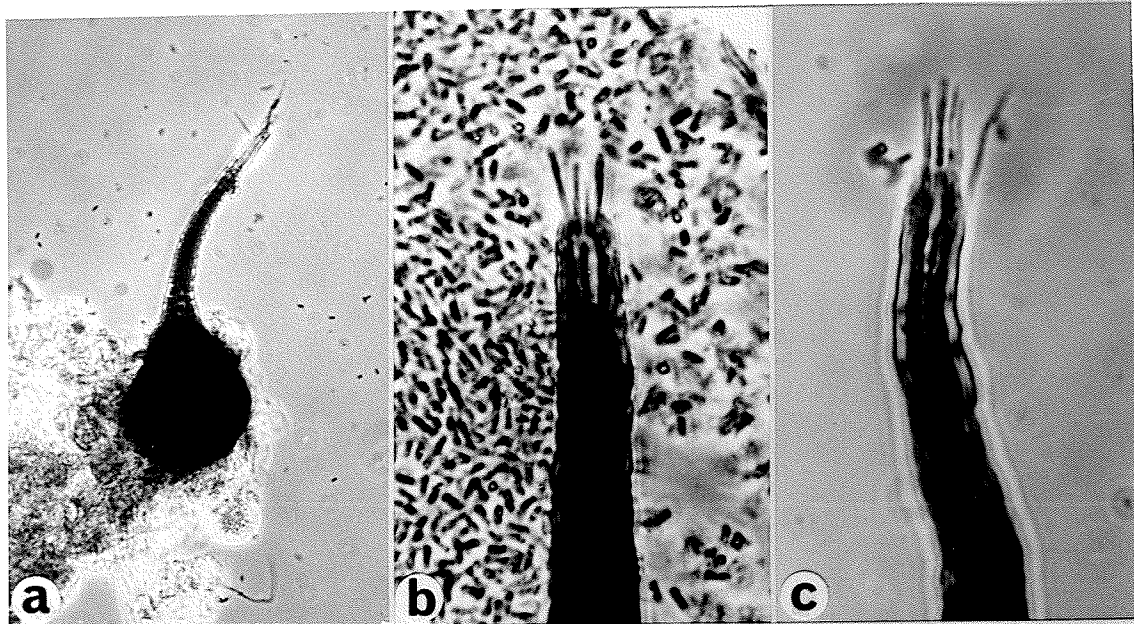
crooked, 80-150(180) $\mu$  long, 20-40 $\mu$  wide at the base, 8.0-12 $\mu$  at the tip, composed of parallel, septate, thick-walled, laterally-fused, hyphal elements, 2.0-2.5 $\mu$  wide, which terminate in an obtuse apex; thick septations, more or less coincident in adjacent elements give the neck an appearance of having dark bands alternating with lighter areas; ostiolar hyphae hyaline, septate, approximately 12 in number, cylindrical or tapered, parallel or divergent, 1.0-2.0 $\mu$  wide at the base, up to 30 $\mu$  long, develop as extensions of hyphal elements composing the outer layer of the neck. *Asci* 8-spored, evanescent, clavate when young, subglobose when mature, 6.0-7.0  $\times$  3.0-4.0 $\mu$ . *Ascospores* hyaline, 1-celled, cylindrical in side and plan view, globose in end view, (2.5) 3.5-4.0(4.5)  $\times$  0.7-1.0 $\mu$ , surrounded by a hyaline gelatinous sheath; sheath ossiform in side and plan view, quadrangular in end view, up to 0.3 $\mu$  thick and flared to a width of 2.0 $\mu$  at the ends of the spore. Perithecia not obtained on agar culture, but several perithecia developed on autoclaved wood in 1 month.

*Colonies* on agar compact. *Mycelium* mostly immersed, agar not pigmented. *Hyphae* hyaline, thin-walled, septate, 1.0-2.5 $\mu$  wide. *Conidiophores* semi-macronematous, mononematous, unbranched or branched, stipe 1-2-celled, 4-10  $\times$  2.5-5.0 $\mu$ , branches in 1-2 series. *Conidiogenous cells* polyblastic, integrated, terminal, sympodial,

## PLATE XV

*Ceratocystis deltoideospora* WIN(M) 71-26

- Fig. a Perithecium ( $\times 250$ )  
Figs. b-c Apices of perithecial necks ( $\times 1000$ )  
Figs. d-e Ascospores ( $\times 4000$ )  
Fig. f Ascospores in end view ( $\times 4000$ )  
Fig. g Conidia ( $\times 4000$ )  
Fig. h Conidiophores. WIN(M) 69-58 ( $\times 1500$ )  
Figs. i-k Conidiogenous cells ( $\times 4000$ )



subulate, 1.0-1.5 $\mu$  wide at the tip. *Conidia* hyaline, 1-celled, ovoid, oblong, clavate, T-, or Y-shaped, frequently giving rise to secondary conidia, 2.0-4.5  $\times$  1.0-2.5(3.0) $\mu$ .

Perithecia of *C. deltoideospora* resemble those of *C. nigra* but are distinguished from those of this species by the longer, and usually divergent, ostiolar hyphae. In culture, *C. deltoideospora* produces T-shaped, Y-shaped, or deltoid conidia which are unlike those of any other species in this group.

HOST OF TYPE: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)71-26, Sandilands Forest Reserve, Manitoba, Canada, May 8, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)69-58, 69-61, 69-57, 70-17 (all with *C. angusticollis*); 71-03 on *Pinus resinosa* (with *C. angusticollis*, *C. aequiva-ginata*, *C. tubicollis*); Ontario: TRTC 33028 on *P. resinosa*. 39552 on *P. strobus*.

6. *Ceratocystis ips* (Rumb.) C. moreau, Revue de Mycologie, Suppl. Colonial 17:22. 1952. Plate XIX, Fig. g  
 $\equiv$  *Ceratostomella ips* Rumb., Jour. Agr. Res. 43: 864, 1931.

$\equiv$  *Ophiostoma ips* (Rumb.) Nannf., Sv. Skogsvardsf. Tidskr. 32: 408, 1934.

*C. ips* has been well described in the literature, and Manitoba collections conform in all respects to the

characteristics already attributed to this species.

MANITOBA HOSTS: *Pinus banksiana*, *Picea mariana*.

SPECIMENS EXAMINED: Manitoba: WIN(M)71-10 (with 71-27 (with *C. columnaris*, *C. minuta*, *C. allantospora*) 71-26 (with *C. coronata*), all on *Pinus banksiana*; 67-11, 67-18, 67-20, 67-23, all on *Picea* sp. Ontario: MFB 7433, 7449, on *Pinus resinosa*, 7362 on *P. strobus*, 7368 on *P. banksiana*; TRTC 39549 on *Picea glauca*.

7. *Ceratocystis ossiformis* sp. nov. Plate XVI, Figs. a-m.

*Perithecia* globosa, brunnea vel nigra, (75)100-175 $\mu$  diam; collum nigrum, rectum, parvum contractum, 375-600 $\mu$  longum, ad basim 20-40 $\mu$ , ad apicem 12-16 $\mu$  latum, pileo hyalino tectum; hyphae ostiolaris non visae; asci clavati, evanescentes, octospori, vel maxima 10  $\times$  3.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae rotundae, 2.5-4.0  $\times$  1.2-1.5 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne ossiformis, ab extremo conspecta quadrangula, in medio 0.5 $\mu$  lata, in extremis 2.5 $\mu$  lata. Coloniae albae; hyphae 0.7-5.0 $\mu$  diam, hyalinae, septatae, parietibus crassis; conidiophora simplicia vel in synnemata aggregata; synnemata brunnea, pallidiora versus apices, 150 $\mu$  alta et 30 $\mu$  lata; phialoconidia acrogena, aseptata, clavata vel fusiformia, 3.5-7.0  $\times$  1.0-2.0(2.5) $\mu$ , in muco aggregata.

Hab. in ligno et cortice interno *Abietis balsameae*.

*Perithecia* superficial on wood, in culture developing

abundantly in 1-2 weeks on superficial mycelium or embedded in the agar; bases globose, mid brown to black, (75) 100-175 $\mu$  in diameter, outer layer of the peridium composed of irregularly-shaped cells, thick-walled in outline, up to 12 $\mu$  in diameter, or of interwoven, undifferentiated, thick-walled hyphal elements; necks black, straight, slightly tapered, 375-600 $\mu$  long, 20-40 $\mu$  wide at the base, 12-16 $\mu$  at the tip, composed of straight, multiseptate, laterally-fused hyphal elements, 1.5-2.0 $\mu$  wide, covered at the apex by a hyaline, gelatinous cap; ostiolar hyphae absent. *Asci* clavate, 8-spored, evanescent, up to 10  $\times$  3.0 $\mu$ . *Ascospores* hyaline, 1-celled, oblong with obtuse ends in side and plan view, globose in end view, 2.5-4.0  $\times$  1.2-1.5 , surrounded by a hyaline, gelatinous sheath; sheath ossiform in side and plan view, quadrangular in end view, up to 0.5 $\mu$  thick and flared to a width of 2.5 $\mu$  at the ends of the spore; the spores collect in a hyaline droplet at the tip of the neck.

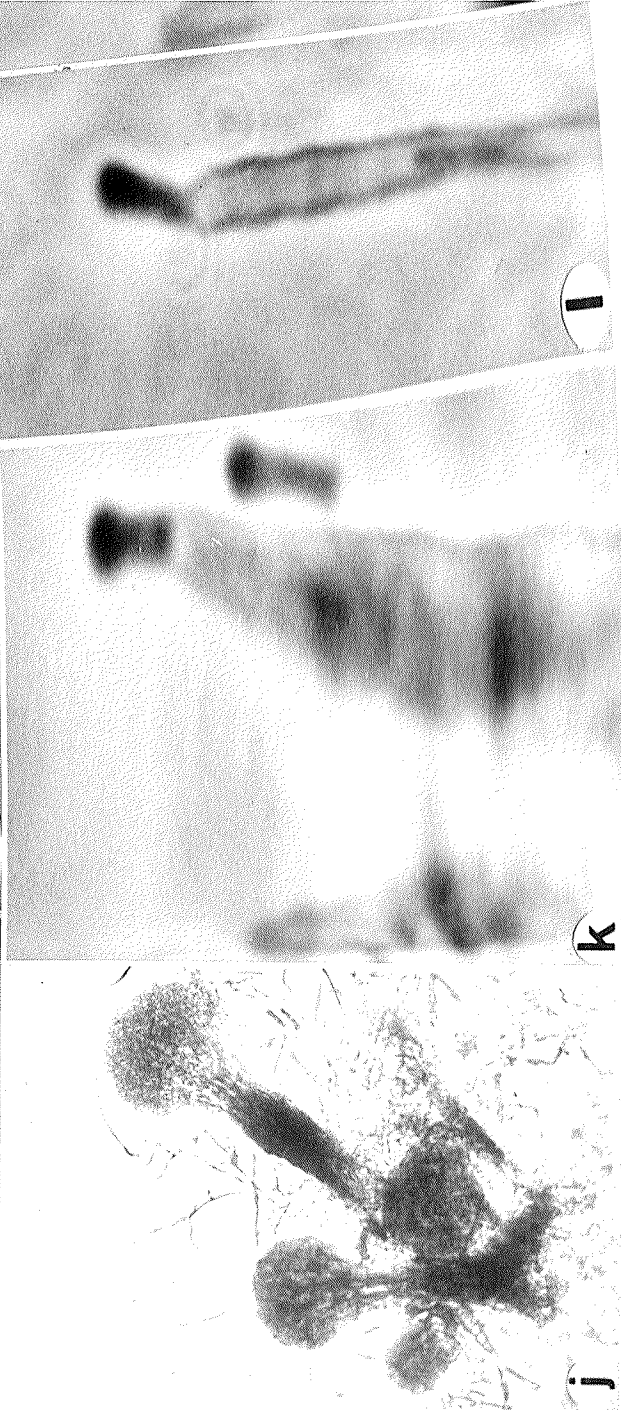
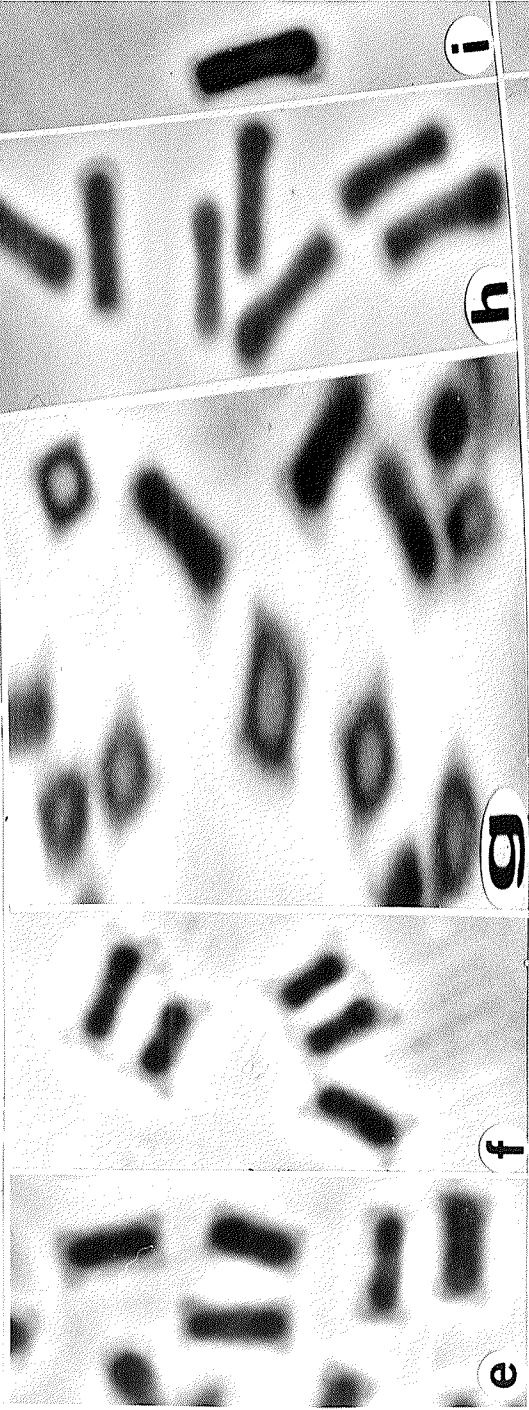
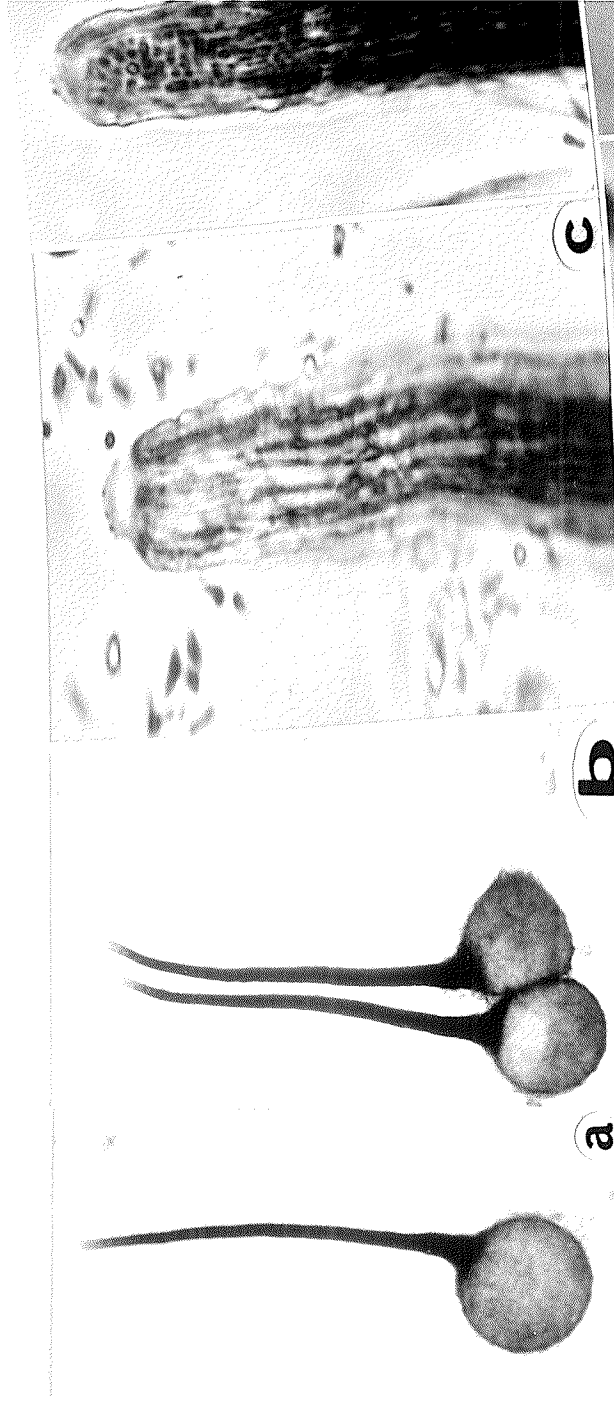
*Colonies* effuse; malt agar and pablum agar pigmented dark brown. *Mycelium* mostly immersed. *Hyphae* thin-walled, pale brown, septate, 0.7-5.0 $\mu$  wide. *Conidiophores* macronematous or semi-macronematous, mononematous or synnematous; synnematous conidiophores develop only on wood. *Synnemata* light brown, paler at the tip, solitary or cespitose, up to 150  $\times$  30 $\mu$ . *Conidiogenous cells* monophialidic, terminal, cylindrical, integrated, percurrent,



## PLATE XVI

*Ceratocystis ossiformis* WIN(M) 69-17

- Figs. a-b Perithecia ( $\times 100$ )  
Figs. c-d Apices of perithecial necks ( $\times 1000$ )  
Figs. e-g Ascospores ( $\times 4000$ )  
Figs. h-i Conidia ( $\times 4000$ )  
Fig. j Synnemata from wood culture ( $\times 250$ )  
Figs. k-m Conidiogenous cells ( $\times 4000$ )



0.7-1.0 $\mu$  wide; collarettes lacking. *Phialoconidia* acrogenous, clavate, 3.5-7.0  $\times$  1.0-2.0(2.5) $\mu$ , collecting in a globose slime droplet up to 100 $\mu$  in diameter.

The perithecia of *C. ossiformis* closely resemble those of *C. columnaris*. Although the perithecia of the latter species tend to be darker in color, this is not a reliable character for identification of field collections. In culture, the two species can be readily distinguished on the basis of pigmentation of the agar and the shape of the phialoconidia. The phialoconidia of *C. ossiformis* are clavate with a slight median constriction whereas those of *C. columnaris* are wider and lack a median constriction (compare Figs. h-i, Plate XVI and Fig. g, Plate XIII). The conidiogenous cells also differ in the two species, with the older phialides in *C. ossiformis* having crenulate margins (compare Figs l-m, Plate XVI and Figs. j-k, Plate XIII). The perithecia of *C. ossiformis* also closely resemble those of *C. ips* but the shape of the sheath surrounding the ascospores is quite different in these two species.

HOST: *Abie balsamea*.

TYPE COLLECTION: WIN(M)69-17, Duck Mountain Provincial Forest, Manitoba, Canada, May 21, 1969.

8. *Ceratocystis pseudonigra* sp. nov. Plate XVII Figs. a-j.

Perithecia globosa, atrobrunnea vel nigra, (70)120-175(250) $\mu$  diam; collum atrobrunneum vel nigrum, rectum

vel curvatum, cylindricum vel contractum, 175-270 $\mu$  longum, ad basim (15)30-50 $\mu$  latum, ad truncatum apicem (7)10-25 $\mu$  latum; hyphae ostiolaris hyalinae, rectae vel flexuosae, contractae, divergentes, 30 $\mu$  longae, ad basim 1.0-2.0 $\mu$  diam; asci juveniles clavati, maturi subglobosi, evanescentes, octospori, 6.0-7.0  $\times$  3.0-4.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae et superne oblongae cum extremis obtusis, ab extremo conspectae rotundae, 2.0-2.5(3.0  $\times$  1.0-1.2 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne ossiformis, ab extremo conspecta quadrangula, 2.5-4.0 $\mu$  longa, in extremis 2.0-2.5 $\mu$  lata. Coloniae albae; hyphae 0.7-2.0 $\mu$  diam, hyalinae, septatae, parietibus tenuibus; conidiophora simplicia vel penicillate furcata; conidia hyalina, aseptata, clavata, (2.5)3.0-4.0(6.0)  $\times$  1.0-2.0(2.5) $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno et cortice interno *Piceae marianae*.

*Perithecia* superficial on wood or on the cambium side of bark; bases globose, dark brown to black, (70)120-175(250) $\mu$  in diameter, outer layer of the peridium composed of irregularly-shaped, thick-walled, interlocking cells, 5.0-18  $\times$  2.0-12 $\mu$ ; necks dark brown to black, straight or curved, nearly cylindrical or tapered, 175-275(750) $\mu$  long, (15)30-50 $\mu$  thick at the base, (7)10-25 $\mu$  at the tip, composed of laterally-fused, thick-walled, septate hyphal elements, which terminate in a truncate

apex; ostiolar hyphae hyaline, straight or flexuous, divergent, tapered towards the tips, 1.0-2.0 $\mu$  wide at the base, up to 30 $\mu$  long. *Asci* 8-spored, evanescent, clavate when young, clavate to subglobose when mature, 6.0-7.0  $\times$  3.0-4.5 $\mu$ . *Ascospores* hyaline, 1-celled, oblong to slightly constricted in the middle in side and plan views, globose in end view, 2.0-2.5(3.0)  $\times$  1.0-1.2 $\mu$ , enclosed in a hyaline gelatinous sheath; sheath ossiform in side and plan views, quadrangular in end view, 2.5-4.0 $\mu$  long, 2.0-2.5 $\mu$  wide at the ends.

Perithecia develop on autoclaved wood in 2-3 weeks.

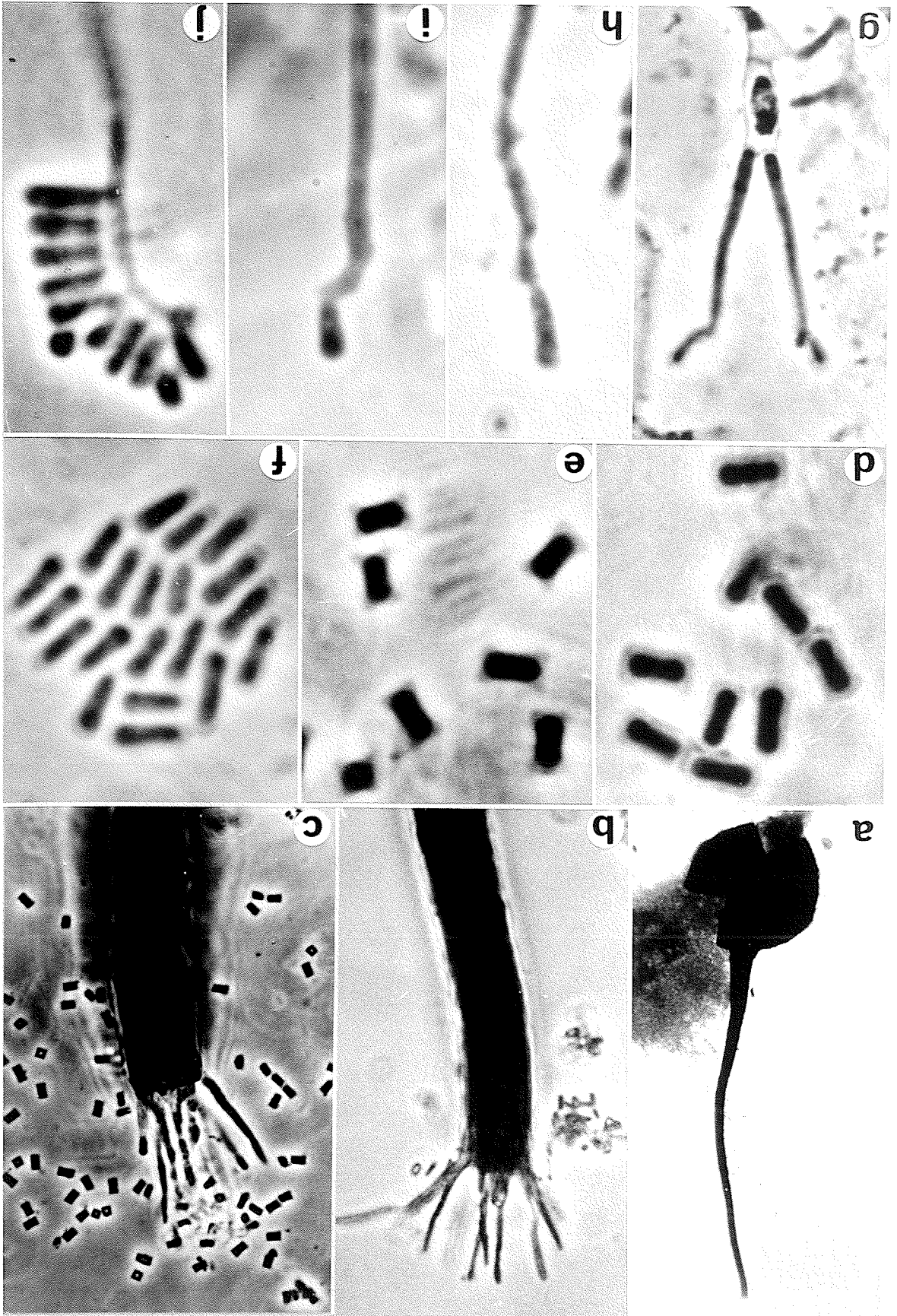
*Colonies* on agar hyaline to white; agar not pigmented; growth rate intermediate. *Mycelium* aerial, superficial, and immersed. *Hyphae* hyaline, thin-walled, septate, 0.7-2.0 $\mu$  wide. *Conidiophores* macronematous, mononematous, unbranched or penicillately branched. *Conidiogenous cells* polyblastic, terminal, integrated, cylindrical, sympodial, 0.7-1.0 $\mu$  wide. *Conidia* hyaline, 1-celled, clavate, narrowed at point of attachment, (2.5)3.0-4.0 (6.0)  $\times$  1.0-2.0(2.5) $\mu$ , formed solitarily but become aggregated in slimy heads.

Except for the fact that they possess ostiolar hyphae, the perithecia of *C. pseudonigra* are similar to those of *C. ossiformis* and *C. columnaris*. The latter two species, however, have a Graphium-like conidial state. Although the conidial state of *C. pseudonigra* is similar to that of

## PLATE XVII

*Ceratocystis pseudonigra* WIN(M) 69-18

- Fig. a Perithecium ( $\times 100$ )
- Fig. b Apex of perithecial neck ( $\times 1000$ )
- Fig. c Apex of perithecial neck. WIN(M) 71-13 ( $\times 1000$ )
- Fig. d Ascospores ( $\times 4000$ )
- Fig. e Ascospores. WIN(M) 71-13 ( $\times 4000$ )
- Fig. f Conidia ( $\times 4000$ )
- Fig. g Branched conidiophore ( $\times 2000$ )
- Figs. h-j Conidiogenous cells ( $\times 4000$ )



*C. nigra*, these two species are readily separated on their perithecial morphology. Also, it cannot be confused with *C. brunneocrinita* which has a very distinctive neck apex with far more robust ostiolar hyphae.

*C. pseudonigra* shows two forms which appear to have different nutritional requirements for perithecial production. One form, which occurs on inner bark tissue, produces slightly shorter ascospores (Fig. e, Plate XVII) than the form which occurs on wood (Fig. d, Plate XVII). The form that occurs on bark produces cultures with appressed growth on pablum agar and no perithecia, while perithecia develop in cultures on wood only when bark has been included. The form that occurs on wood produces cultures with cottony growth and some perithecia on pablum agar, and abundant perithecia are produced on autoclaved pieces of wood whether bark has been included or not.

Since at the moment it is unsure whether these differences justify separating these two forms or not, they are being considered as variations of one species.

HOST: *Picea mariana*.

TYPE COLLECTION: WIN(M)69-18, Duck Mountain Provincial Forest, Manitoba, Canada, May 22, 1969.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)71-13 (with *C. cainii*, *C. allantospora*, *C. europhioides*, *C. pseudoeurophioides*).



9. *Ceratocystis tubicollis* sp. nov. Plate XVIII, Figs. a-1

*Perithecia* nec in culturo agarō nec in ligno sterili evoluta, globosa, nigra et opaca, (75)100-150 $\mu$  diam, spinulis pallido-brunneis, parietibus crassis, 7.0-25 $\mu$  longis et 1.5-2.0 $\mu$  latis ad basim ornata; collum atrobrunneum vel nigrum, ad basim latum, contractum dein cylindricescens, rectum vel curvatum, (40)60-85(100) $\mu$  longum, ad basim 25-45 $\mu$  latum, ad apicem dilatatum 14-18 $\mu$  latum; hyphae ostiolarēs non visae; asci juveniles fusiformes, maturi clavati, evanescentes, usque ad 18  $\times$  7.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae et superne oblongae cum extremis obtusis, ab extremo conspectae rotundae, biguttulatae, (2.5)3.0-4.5  $\times$  1.0-1.5 $\mu$ , cum vagina gelatinosa; vagina a latere conspecta et superne rectangula, ab extremo conspecta quadrangula, tenuissima. Coloniae albae; hyphae 0.7-2.0 $\mu$  diam, hyalinae, immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia vel furcata; conidia hyalina, aseptata, acropleurogena, cylindrica vel clavata, (2.0)2.5-4.0(5.5)  $\times$  (0.7)1.0-2.0 $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno *Pini banksianae*.

*Perithecia* superficial on wood, not developing in agar culture; bases black and opaque in transmitted light, cellular detail visible only when the perithecia are bleached, globose, (75)100-150 $\mu$  in diameter, ornamented

with pale brown, thick-walled, septate spines, mostly  $7.0-25 \times 1.5-2.0\mu$ , outer layer of the peridium composed of dark, irregularly-shaped cells, thick-walled in outline,  $2.5-10\mu$  in diameter; necks dark brown to black, broad at the base becoming cylindrical or slightly tapered, but flaring slightly at the tip, straight or curved,  $(40)60-85(100)\mu$  long,  $25-45\mu$  wide at the base,  $14-18\mu$  wide near the tip, composed of dark, laterally-fused, thick-walled, septate, hyphal elements,  $2.0-2.5\mu$  wide, thick septations, more or less coincident in adjacent hyphal elements give the neck an appearance of having dark bands alternating with lighter areas; discrete ostiolar hyphae lacking, except for a few neck cells which may bend sharply inwards to partly enclose the ostiole. *Asci* 8-spored, evanescent, fusiform when very young, approximately  $2.0\mu$  wide, becoming broadly clavate at maturity, up to  $18 \times 7.5\mu$ . *Ascospores* hyaline, 1-celled, oblong with obtuse ends in side and plan view, globose in end view, usually 2-guttulate,  $(2.5)3.0-4.5 \times 1.0-1.5\mu$ , surrounded by a very thin gelatinous sheath, rectangular in side and plan view, quadrangular in end view, dimensions not measurably greater than those of the spore; the spores collect in a hyaline or milky droplet at the tip of the neck. Perithecia not obtained in culture.

*Colonies* on agar compact, cottony, or glistening

due to conidial slime droplets. *Mycelium* mostly immersed, agar not pigmented. *Hyphae* hyaline, thin-walled, septate, 0.7-2.0 $\mu$  wide. *Conidiophores* hyaline, semi-macronematous, mononematous, unbranched or branched, stipe usually composed of 1-4 cells, up to 12  $\times$  2.5 $\mu$ . *Conidiogenous cells* polyblastic, integrated, terminal, sympodial, usually subulate, up to 2.0 $\mu$  wide, tapered to approximately 1.0 $\mu$ . *Conidia* acropleurogenous, 1-celled, cylindrical, clavate, or broadly clavate, (2.0)2.5-4.0 (5.5)  $\times$  (0.7)1.0-2.0 $\mu$ , formed solitarily but becoming aggregated in a slimy head.

The dark, globose bases and short cylindrical necks readily distinguish the perithecia of *C. tubicollis* from all other species in this group.

Although perithecia were not produced in culture, numerous transfers of ascospores from field collections have always yielded cultures with the same characteristics. It is therefore reasonably certain that the conidial state described here is that of *C. tubicollis*.

HOST OF TYPE: *Pinus banksiana*.

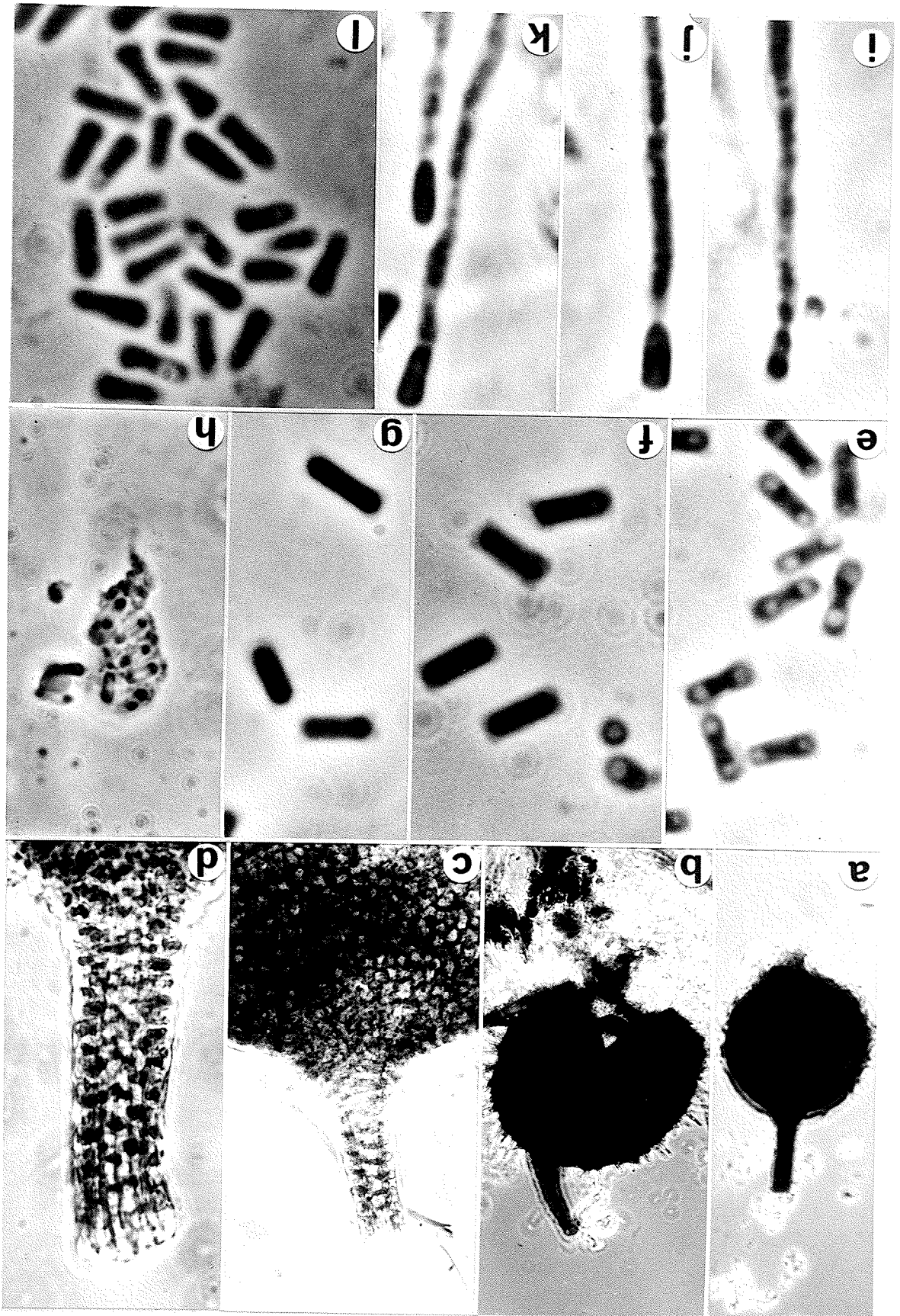
TYPE COLLECTION: WIN(M)71-10, Sandilands Forest Reserve, Manitoba, Canada, April 10, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)71-03 on *Pinus resinosa* (with *C. deltoideospora*), 71-09 on *Picea mariana*, 71-21 on *Abies balsamea*. Ontario: TRTC 33702 on *Pinus resinosa*.

## PLATE XVIII

*Ceratocystis tubicollis* WIN(M) 71-10

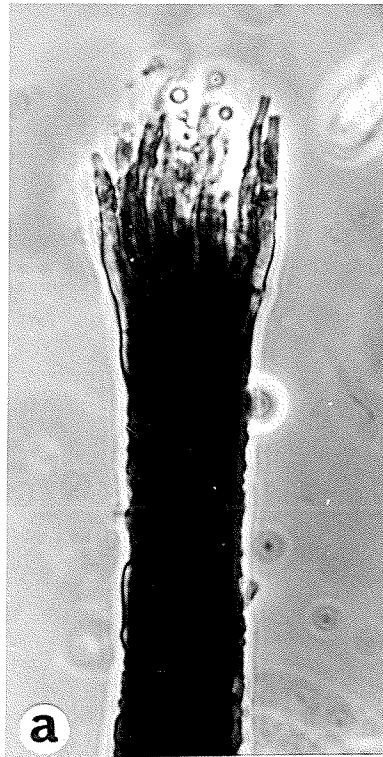
- Figs. a-b Perithecia ( $\times 250$ )  
Fig. c Perithecium, bleached to show detail ( $\times 500$ )  
Fig. d Perithecial neck, bleached ( $\times 1000$ )  
Figs. e-g Ascospores ( $\times 4000$ )  
Fig. h Ascus ( $\times 2000$ )  
Figs. i-k Conidiogenous cells ( $\times 4000$ )  
Fig. l Conidia ( $\times 4000$ )



## PLATE XIX

Additional illustrations of *Ceratocystis* spp.  
of the Ips Group

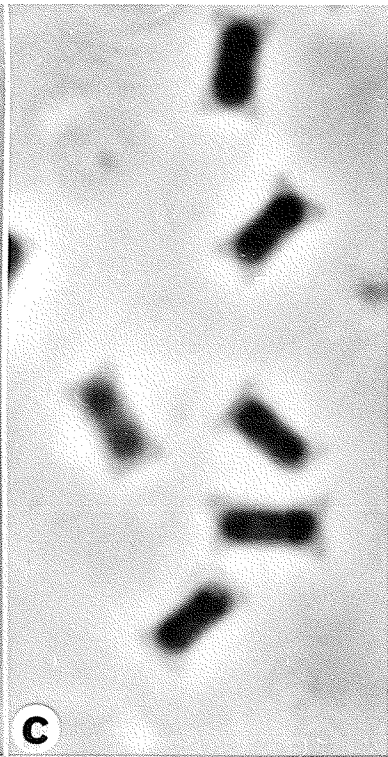
- Figs. a-b *C. brunneocrinita* WIN(M) 71-28. Perithecial necks ( $\times 1000$ )
- Fig. c *C. brunneocrinita* WIN(M) 71-28. Ascospores ( $\times 4000$ )
- Fig. d *C. nigra* BPI-FP 70804. Perithecial neck ( $\times 1000$ )
- Figs. e-f *C. nigra* BPI-FP 70804. Ascospores ( $\times 4000$ )
- Fig. g *C. ips* WIN(M) 71-10. Ascospores ( $\times 4000$ )



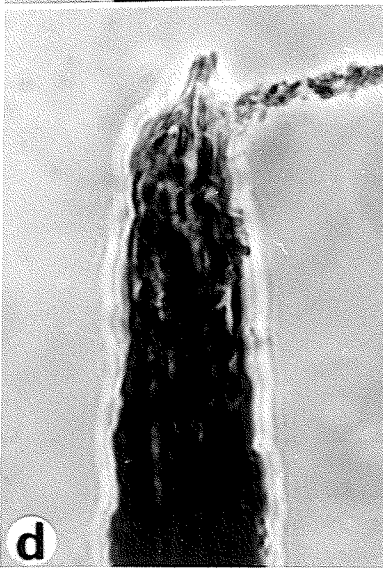
**a**



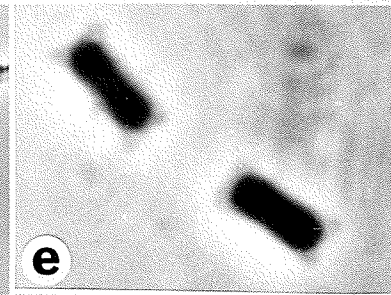
**b**



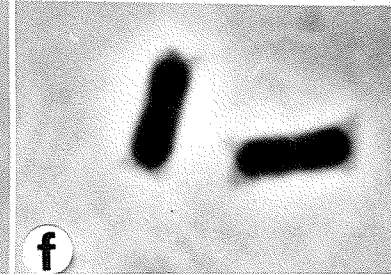
**c**



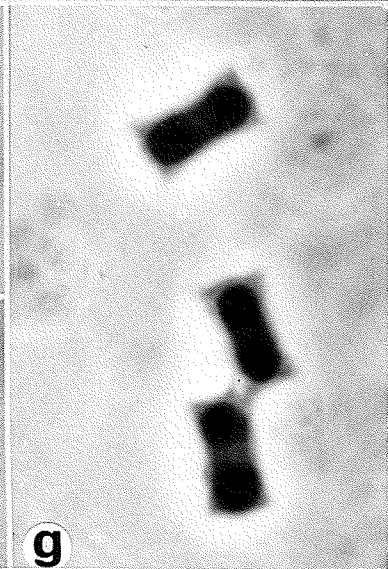
**d**



**e**



**f**



**g**

The following species have not been found in Manitoba but have been examined for purposes of comparison and are considered to belong to the Ips Group:

*Ceratocystis bicolor* (Davids. and Wells) Davidson, Mycologia 47:63. 1955. SPECIMENS EXAMINED: Ontario: TRTC 34581, 45768; Colorado: BPI-FP 70711.

*Ceratocystis montia* (Rumb.) Hunt, Lloydia 19:45. 1956. SPECIMEN EXAMINED: CFB R-572 (conidial state only)

*Ceratocystis nigra* Davidson, Mycologia 50:662. 1958. Plate XIX, Figs. d-f. SPECIMEN EXAMINED: BPI-FP 70804.

The following species have not been examined but, from the descriptions appearing in the literature, are probably referable to the Ips Group:

*Ceratosystis autographa* Bakshi, Ann. Bot. n.s. 15: 55. 1951.

*Ceratocystis seticollis* Davidson, Mycopathol. Mycol. Appl. 28:282. 1966.

*Ceratocystis sparsa* Davidson, Mycologia 63:14. 1971.



## KEY TO THE SPECIES OF THE FIMBRIATA GROUP

1. Ostiolar hyphae present
  2. Ostiolar hyphae developing from a sharply defined apex
    3. Ascospores (including sheath) more than  $6\mu$  long
      4. Average diameter of perithecial bases less than  $350\mu$ .....*C. adiposa*
      4. Average diameter of perithecial bases more than  $350\mu$ .....*C. major*
    3. Ascospores (including sheath) less than  $6\mu$  long
      5. Sheath cucullate in side view...8.*C. populicola*
      5. Sheath lunate or orange-section-shaped in side view
        6. Base of perithecium more than  $300\mu$  in diameter.....*C. magnifica*
        6. Base of perithecium less than  $300\mu$  in diameter
          7. Imperfect state Graphium-like
            8. Ostiolar hyphae hyaline.....  
.....11.*C. torticiliata*
            8. Ostiolar hyphae brown.....*C. clavata*
          7. Imperfect state not Graphium-like.....  
..... 1. *C. aequivaginata*
2. Hyphal elements comprising neck extending into ostiolar hyphae; neck apex not sharply defined
  9. Ascospore sheath forming a single or double brim, appearing hat-shaped or cucullate in side view

10. Ascospore sheath forming a single brim, hat-shaped in side view
11. Base of perithecium ornamented with conical spines.....*C. moniliformis*
11. Base of perithecium unornamented.....  
.....5. *C. fimbriata*
10. Ascospore sheath forming a double brim, cucullate in side view
12. Brims positioned so that sheath appears triangular in end view.....7. *C. olivacea*
12. Brims positioned so that sheath appears quadrangular in end view....10. *C. sagmatospora*
9. Ascospore sheath uniform, or nearly so, not forming a brim
13. Conidiophores synnematosus; conidiogenous cells phialidic.....3. *C. davidsonii*
13. Conidiophores mononematosus; conidiogenous cells sympodial..... *C. brevicollis*
1. Ostiolar hyphae absent
14. Ascospore sheath forming a double brim; cucullate in side view
15. Ascospores (excluding sheath) less than 2 $\mu$  wide
16. Brims positioned so that sheath appears triangular in end view.....6. *C. huntii*
16. Brims positioned so that sheath appears quadrangular in end view.....2. *C. cainii*

15. Ascospores (excluding sheath) more than  $2\mu$  wide
17. Conidiogenous cells sympodial; conidia curved  
        ..... 9. *C. pseudoeurophioides*
17. Conidiogenous cells phialidic; conidia not  
        curved..... 4. *C. europhioides*
14. Ascospore sheath uniform, or nearly so, lunate or  
    orange-section-shaped in side view... *C. magnifica*

1. *Ceratocystis aequivaginata* sp. nov. Plate XX, Figs. a-k.

*Perithecia* globosa, atrobrunnea vel nigra, 50-150 $\mu$  diam; collum atrobrunneum vel nigrum, pallidius versus apicem, ad apicem contractum, rectum vel flexuosum, 150-650 $\mu$  longum, ad basim 15-25 $\mu$ , ad truncatum apicem 6.0-11 $\mu$  latum; hyphae ostiolaris hyalinae, cylindricae vel contractae, rectae vel flexuosae, parallelae vel divergentes, 5.0-25 $\mu$  longae, ad basim 0.7-1.2 $\mu$  diam; asci clavati, evanescentes, octospori, 5.0-5.5  $\times$  2.5-3.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae lunatae cum extremis obtusis, superne fusiformes vel ellipticae, ab extremo conspectae rotundae, 1.5-2.5(4.0)  $\times$  0.7-1.0(1.2) $\mu$ , cum vagina gelatinosa aequabili usque 0.5 $\mu$  crassa. Coloniae albae; hyphae 0.5-2.0 $\mu$  diam, septatae, superficiales vel immersae, parietibus tenuibus vel crassis granularibusque extra; conidiophora hyalina, simplicia vel penicillate furcata; conidia hyalina, aseptata, clavata vel ellipsoidea vel subglobosa, 2.5-5.0(9.0)  $\times$  1.2-2.0(2.5) $\mu$ .

Hab. in ligno *Pinus banksianae*.

*Perithecia* superficial on wood, in culture, developing on superficial mycelium or embedded in the agar medium; bases globose, dark brown to black, 50-150 $\mu$  in diameter, outer layer of the peridium composed of thick-walled, interlocking cells, 2.0-3.0 $\mu$  wide; necks dark brown to black, paler and tapering towards the apex, straight

or crooked, 150-650 $\mu$  long, 15-25 $\mu$  wide at the base, 6.0-11 $\mu$  at the tip, composed of straight, thick-walled, laterally-fused, hyphal elements which terminate in a rounded or truncate apex; ostiolar hyphae, when present, hyaline, cylindrical or tapered, straight or crooked, parallel or divergent, 5.0-25 $\mu$  long, 0.7-1.2 $\mu$  wide at the base. *Asci* 8-spored, evanescent, clavate, 5.0-5.5  $\times$  2.5-3.5 $\mu$ . *Ascospores* hyaline, 1-celled, crescent-shaped with obtuse ends in side view, fusiform to elliptical in plan view, globose in end view, 1.5-2.5(4.0)  $\times$  0.7-1.0(1.2) $\mu$ , surrounded by a more or less uniform hyaline, gelatinous sheath up to 0.5 $\mu$  thick.

Perithecia develop on agar in 3-4 weeks.

*Colonies* on agar hyaline to white, glistening due to masses of conidia in slime; agar not pigmented, growth rate slow to intermediate. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.5-2.0 $\mu$  wide; in some cultures, becoming thick-walled with a granular coating, 1.5-2.5 $\mu$  wide, in areas of developing perithecia. *Conidiophores* macronematous, semi-macronematous, or micronematous, mononematous, hyaline, unbranched or penicillately branched; up to 60 $\mu$  long, including conidial head. *Conidiogenous cells* polyblastic, terminal, discrete, cylindrical, sympodial, 0.5-1.0 $\mu$  wide. *Conidia* hyaline, 1-celled, clavate, ellipsoidal, or subglobose, 2.5-5.0(9.0)  $\times$  1.2-2.0(2.5) $\mu$ .

As herein treated, *C. aequivaginata* is a somewhat variable species with differences being noted between collections from different host substrates, and within different collections from a single host substrate. Perithecia found on balsam fir are generally smaller than those found on pine or spruce and cultures derived from the perithecia found on fir produce a yeast-like growth on agar, whereas cultures obtained from perithecia found on pine or spruce produce either an appressed, or cottony type of growth on agar. Also, in some cultures derived from perithecia found on pine, perithecia develop from dark brown hyphae which become detached from the perithecial bases when the perithecia mature, whereas in other cultures perithecia develop from hyaline mycelium.

The ascospores of *C. aequivaginata* resemble those of *C. acericola*, but its perithecia differ from those of the latter species in having ostiolar hyphae and lacking swellings or annuli along the perithecial necks. The perithecia of *C. aequivaginata* resemble those of *C. populicola*, but these two species are readily separated on the basis of the shape of the sheaths which surround the ascospores.

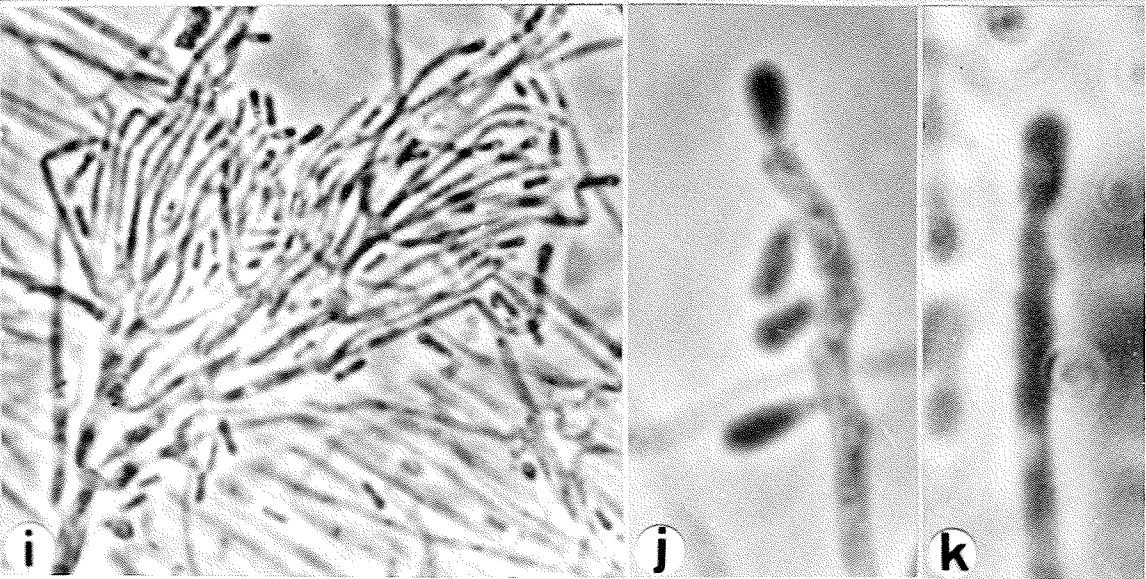
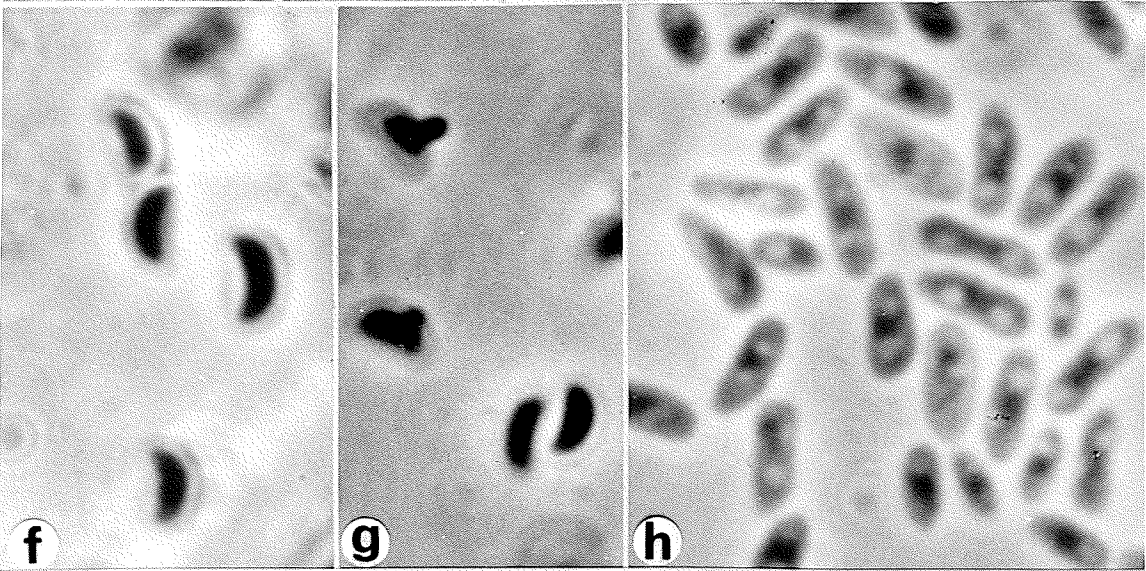
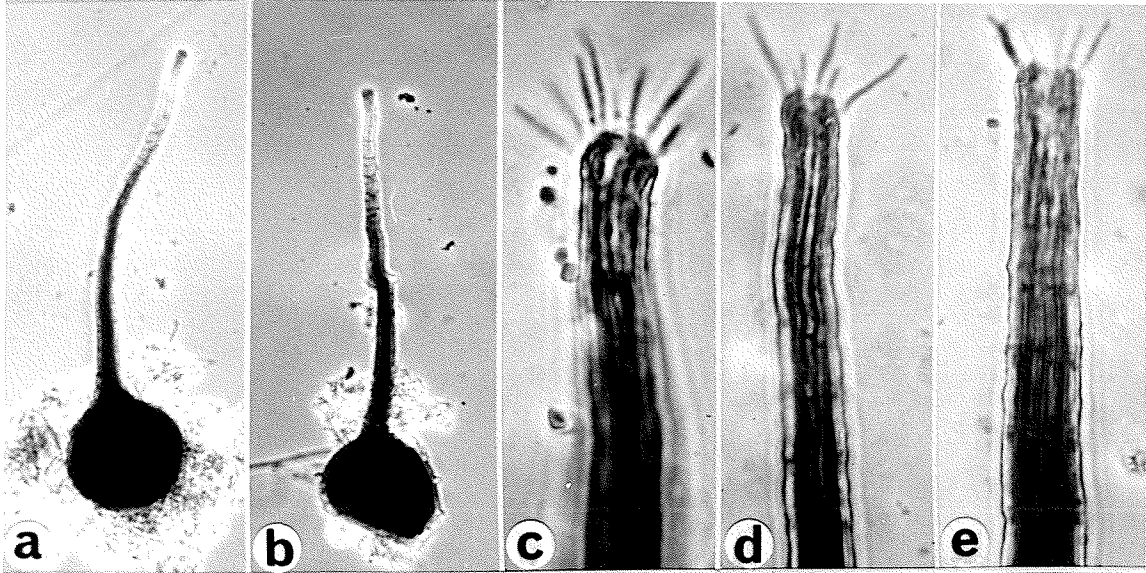
HOST OF TYPE: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)69-37, Sandilands Forest Reserve, Manitoba, Canada, June 6, 1969.

## PLATE XX

*Ceratocystis aequivaginata* WIN(M)71-01

- Figs. a-b Perithecia. WIN(M)71-21 ( $\times 250$ )  
Figs. c-e Apices of perithecial necks ( $\times 1000$ )  
Figs. f-g Ascospores ( $\times 4000$ )  
Fig. h Conidia ( $\times 4000$ )  
Fig. i Branching conidiophore ( $\times 1500$ )  
Figs. j-k Conidiogenous cells ( $\times 4000$ )





ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M) 69-54, 69-57, 71-01, 71-07, 71-10, all on *P. banksiana*; 71-03, on *P. resinosa*; 71-09, on *Picea mariana*; 71-21, on *Abies balsamea*.

2. *Ceratocystis cainii* sp. nov. Plate XXI, Figs. a-s

Perithecia in agaro non evoluta, in ligno sterili evoluta, globosa, nigra et opaca, 125-375 $\mu$  diam; collum nigrum, vel cylindricum et ad apicem contractum vel omnino contractum, rectum vel curvatum, 270-850 $\mu$  longum; hyphae ostiolaris non visae; asci juveniles clavati, maturi subglobosi, evanescentes, 10-15  $\times$  6.0-10 $\mu$ ; ascospores hyalinae, aseptatae, a latere conspectae reniformes et concavae, superne oblongae cum extremis obtusis, ab extremo conspectae ovoideae, 2.0-3.5  $\times$  1.0-1.5 $\mu$ , cum vagina gelatinosa; vagina duo labra asymmetrica formans. Coloniae albae; hyphae 1.0-8.0 $\mu$  diam; conidiophora in synnemata aggregata; synnemata in ligno brunnea, cylindrica, 300-650 $\mu$  alta et 40-150 $\mu$  lata; synnemata in agaro flabellata omnia ex una cellula evoluta, vel maxima 250 $\mu$  alta et 200 $\mu$  lata; conidia clavata, vel oblonga cum extremis obtusis, vel subglobosa, 2.5-7.5(10)  $\times$  (1.0)1.5-2.5 $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno et cortice interno *Piceae marianae*.

*Perithecia* black, cellular detail visible only when the perithecia are bleached, superficial on wood or embedded in inner bark, not produced in agar culture; bases

globose, 125-375 $\mu$  in diameter, outer layer of the peridium composed of dark, thick-walled, irregularly-shaped cells, 5.0-15 $\mu$  in diameter; necks black, cylindrical, tapered gradually or abruptly at the apex, straight or curved, 270-850 $\mu$  long, 30-50 $\mu$  wide at the base, 25-40 $\mu$  near the tip, composed of dark, rectangular cells, 7.5-12  $\times$  2.5-4.0 $\mu$ , terminating in a tapered or obtuse apex; ostiolar hyphae absent. *Asci* 8-spored, evanescent, clavate when young, subglobose when mature, 10-15  $\times$  6.0-10 $\mu$ . *Ascospores* hyaline, 1-celled, broadly reniform and deeply concave in side view, oblong with obtuse ends in plan view, ovoid in end view, 2.0-3.5  $\times$  1.0-1.5 $\mu$ , enclosed in a hyaline, gelatinous sheath, 0-0.5 $\mu$  thick on the convex side of the spore, 1.0-1.5 $\mu$  on the concave side, having two asymmetrically-placed brims, 4.5-5.5 $\mu$  long, appearing cucullate, campanulate, or hat-shaped in side view, quadrangular in plan view; in end view appearing quadrangular with the brims converging, but not meeting, below the concave surface of the spore and spreading from the convex surface. The spores are extruded from the ostiole in a thick whitish mass. Perithecia develop on autoclaved wood in 3-4 weeks.

*Colonies* on agar hyaline, appressed. *Mycelium* mostly immersed; pabulum agar not pigmented, malt agar pigmented light brown. *Hyphae* hyaline, thin-walled, septate, 1.0-8.0 $\mu$  wide. *Conidiophores* macronematous, syn-

nematous. *Synnemata* on wood mid-brown, cylindrical, 300-650 × 40-150 $\mu$ ; on agar usually developing from a single cell into a fan-shaped structure up to 250 $\mu$  high and 200 $\mu$  wide at the broadest part; individual threads 2.5-3.5 $\mu$  wide. *Conidiogenous cells* of two types: (1) hyaline, polyblastic, integrated, sympodial, cylindrical, 1.5-2.0 $\mu$  wide, and (2) hyaline, terminal, monophialidic, integrated, percurrent, cylindrical, 1.5-2.5 $\mu$  wide. *Conidia and phialoconidia* clavate, oblong with obtuse ends, rarely subglobose, 2.5-7.5(10) × (1.0)1.5-2.5 $\mu$ , produced solitarily but becoming aggregated in cream-colored slimy heads.

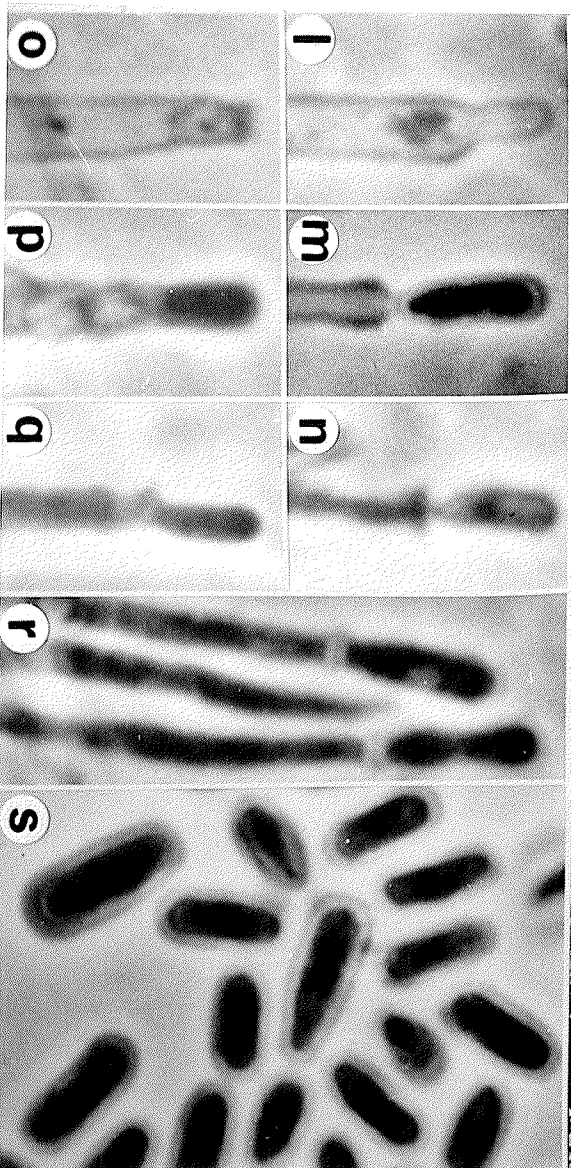
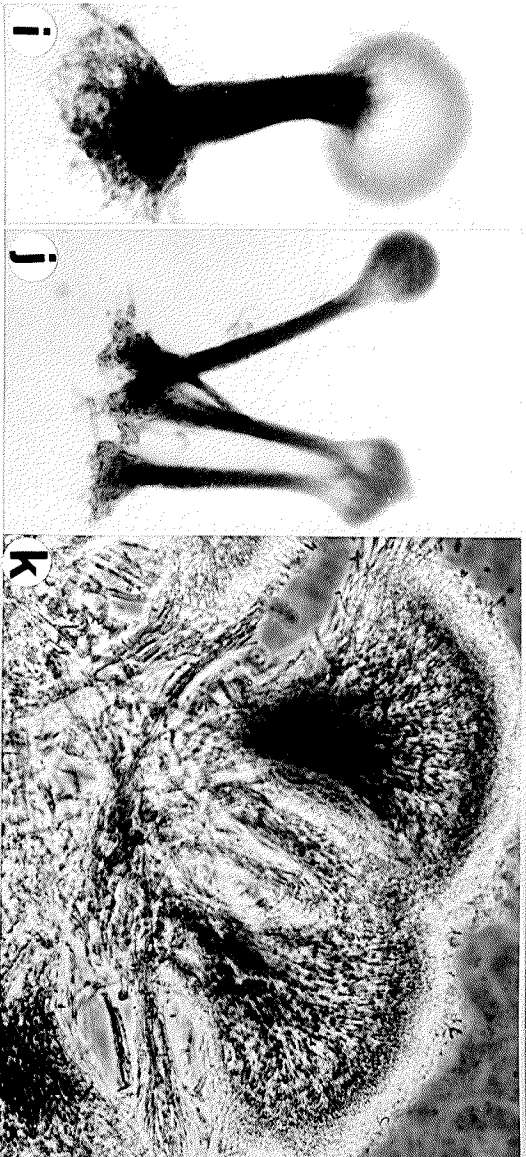
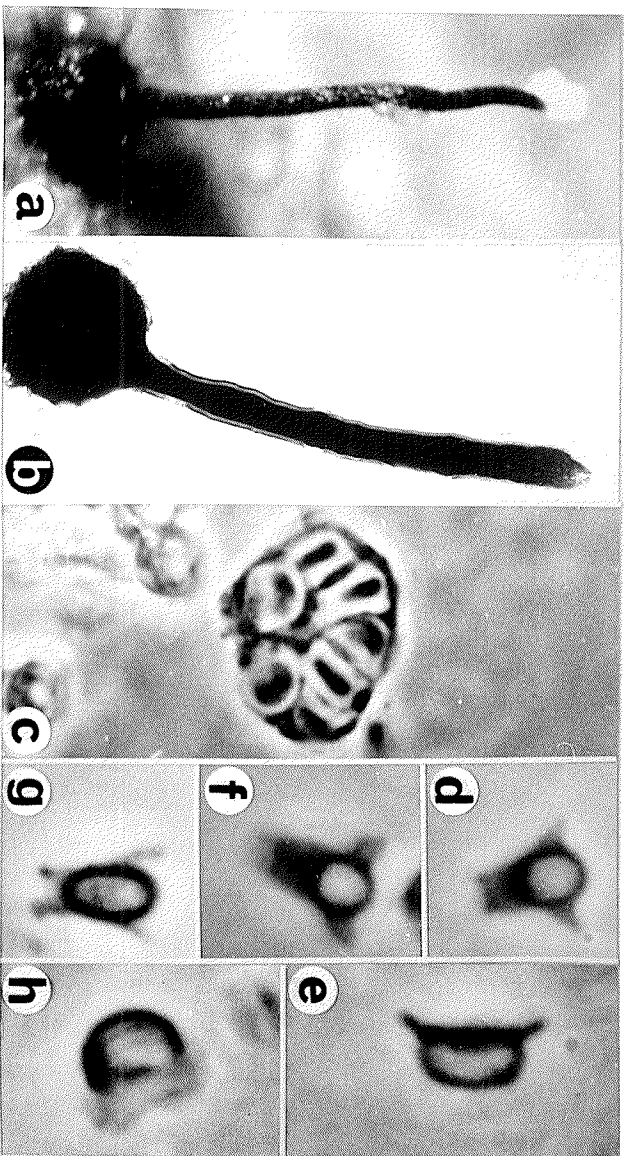
*C. cainii* is similar to *C. huntii* and *C. europhioides* in perithecial morphology. The ascospores are much smaller than those of *C. europhioides* and more nearly approximate the dimensions of those of *C. huntii*. The ascospores differ from those of *C. huntii*, however, in that they possess a sheath which resembles the sheath associated with ascospores of *C. sagmatospora*, i.e., the sheath is extended in a double brim that does not converge either below or above the spore itself (compare figs. d-h, Plate XXI and fig.d, Plate XXVI).

In the conidial state, *C. cainii* produces Graphium-like conidiophores similar to those of *C. sagmatospora*. In agar culture, however, true synnemata are not produced, but rather, fan-shaped conidiophores develop from a single

## PLATE XXI

*Ceratocystis cainii* WIN(M) 71-13

- Fig. a Perithecium on wood ( $\times 150$ )
- Fig. b Perithecium on wood. WIN(M) 69-18 ( $\times 100$ )
- Fig. c Ascus ( $\times 2000$ )
- Figs. d-h Ascospores ( $\times 4000$ )
- Figs. i-j Synnemata on wood ( $\times 250$ )
- Fig. k Synnemata on agar. WIN(M) 69-18 ( $\times 250$ )
- Figs. l-o Conidiogenous cells from cultures on wood ( $\times 4000$ )
- Figs. p-r Conidiogenous cells from cultures on agar ( $\times 4000$ )
- Fig. s Conidia ( $\times 4000$ )



basal cell (see fig. k, Plate XXI). This type of development is more nearly representative of a *Leptographium* conidial state than that of a *Graphium*. In this respect, the conidial state is closely related to the imperfect states of *C. huntii* and *C. europhioides*, since the conidia of these latter two species are produced on mononematous *Leptographium*-like conidiophores.

*C. cainii* thus appears to be intermediate between *C. huntii* and *C. sagmatospora*, since it possesses some of the characteristics of each of these species in both its perfect and imperfect states.

HOST: *Picea mariana*.

TYPE COLLECTION: WIN(M)71-13, Sandilands Forest Reserve, Manitoba, Canada, April 24, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)69-18 (with *C. dolominuta*, *C. europhioides*, *C. pseudonigra*).

3. *Ceratocystis davidsonii* sp. nov. Plate XXII, Figs. a-j.

Perithecia globosa, spadicea vel brunnea, 60-90 $\mu$  diam; collum atrobrunneum, rectum, cylindricum vel subcylindricum, 225-350 $\mu$  longum (cum hyphis ostiolaribus), ad basim 25-35 $\mu$  ad apicem 15-20 $\mu$  latum; hyphae ostiolares ad basim brunneae, pallidae vel hyalinae versus apicem, contractae, septatae, 20-125 $\mu$  longae, ad basim 2.0-2.5 $\mu$  diam, ad apicem 1.0-1.5 $\mu$  diam; asci juveniles clavati, maturi subglobosi, octospori, evanescentes, usque ad 13  $\times$  9.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere con-

spectae lunatae cum extremis obtusis, superne ellipsoideae, ab extremo conspectae rotundae,  $3.5-4.5(5.0) \times 1.5-2.0\mu$ , cum vagina gelatinosa aequabili  $1.0-1.5\mu$  crassa; vagina a latere conspecta cum figura segmenti pomi citri vel depresse obovata, superne ellipsoidea vel transverse elliptica, ab extremo conspectae rotundae vel ovatae.

Coloniae albae; hyphae  $1.0-3.0\mu$  diam, hyalinae, septatae, parietibus tenuibus; conidiophora in synnemata aggregata; synnemata olivaceo-brunnea, solitaria vel cespitosa, ad basim tumida,  $125-250\mu$  alta et  $7-25\mu$  lata (in agaro malto usque  $200\mu$  lata); phialoconidia transverse elliptica vel obovata, hyalina, semi-endogena,  $2.5-7.5 \times 1.5-3.0\mu$ , in muco aggregata.

Hab. in ligno *Pseudotsugae menziesii*.

*Perithecia* superficial on wood or on surface mycelium in agar culture; bases yellowish brown to medium brown, globose,  $60-90\mu$  in diameter, outer layer of the peridium composed of irregularly-shaped interlocking cells, thick-walled in outline, maximum length  $8.0\mu$ , minimum width  $2.0\mu$ ; necks dark brown, straight, nearly cylindrical,  $225-350\mu$  long (including ostiolar hyphae),  $25-35\mu$  wide at the base,  $15-20\mu$  near the tip, composed of thick-walled, septate, laterally-fused hyphal elements,  $2.0-2.5\mu$  wide, separating at the apex and extending into ostiolar hyphae; ostiolar hyphae brown at the base, light brown to hyaline at the tip, tapered, septate, irregular in length,  $2.0-$

2.5 $\mu$  wide at the base, 1.0-1.5 $\mu$  at the tip, 20-125 $\mu$  long, or 60-125 $\mu$  long collectively. *Asci* 8-spored. evanescent, clavate when young, subglobose when mature, maximum dimensions at maturity 13  $\times$  9.0 $\mu$ . *Ascospores* hyaline, 1-celled, crescent-shaped with obtuse ends in side view, ellipsoidal in plan view, globose in end view, 3.5-4.5(5.0)  $\times$  1.5-2.0 $\mu$ , enclosed by a nearly-uniform, hyaline, gelatinous sheath; sheath 1.0-1.5 $\mu$  thick, orange-section-shaped to hemispherical in side view, ellipsoidal to oval in plan view, globose to ovoid in end view. The spores are extruded in a hyaline to pale yellow cirrhous through the ostiole. Perithecia develop on wood or agar in 3-4 weeks.

*Colonies* on agar effuse. *Mycelium* mostly immersed, agar pigmented grayish brown. *Hyphae* hyaline, thin-walled, septate, 1.0-3.0 $\mu$  wide. *Conidiophores* macronematous, mononematous or synnematous, usually branched at the apex. *Synnemata* olivaceous brown, solitary or cespitose, usually swollen at the base, 125-250  $\times$  7-25 $\mu$  (up to 200 $\mu$  wide on malt agar). *Conidiogenous cells* hyaline, monophialidic, terminal, discrete, determinate; phialides cylindrical, straight or curved, 5.0-15  $\times$  2.0-2.5 $\mu$ , with a well-defined collarette. *Phialoconidia* semi-endogenous or acrogenous, oval or obovate, 2.5-7.5  $\times$  1.5-3.0 $\mu$ , collecting in a hyaline or grayish slime droplet.

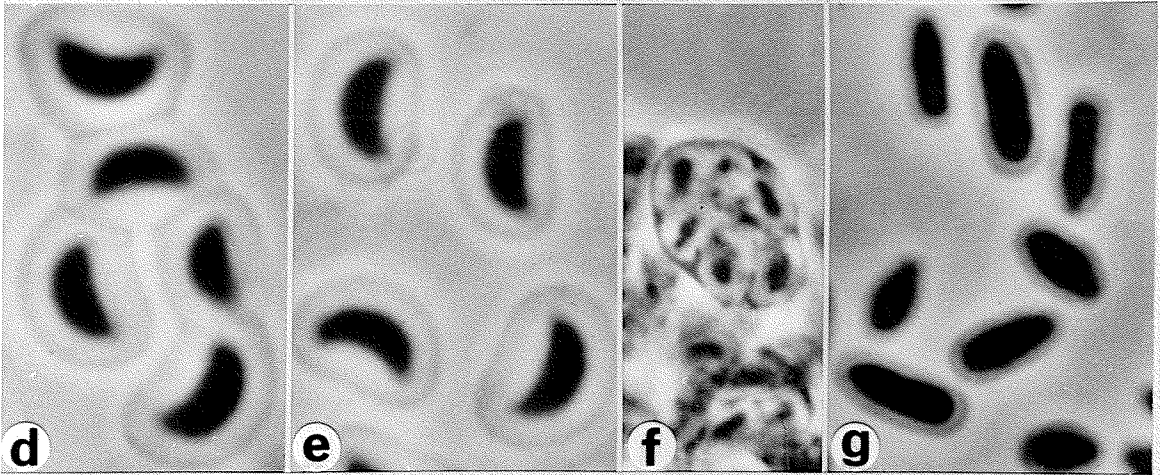
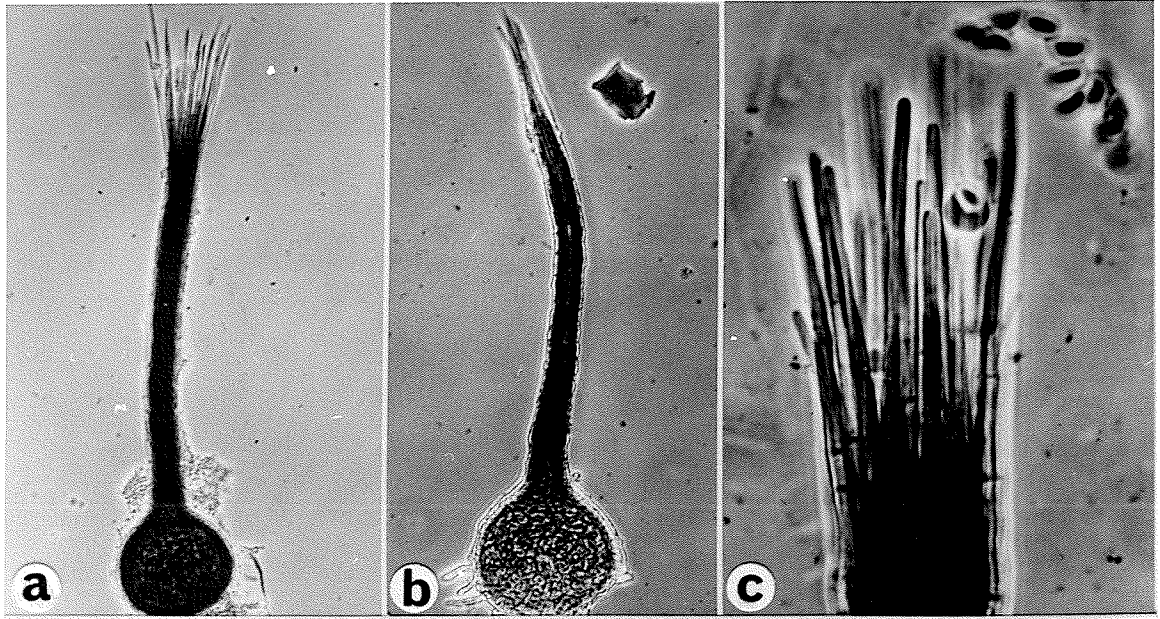
The perithecia of *C. davidsonii* resemble those of



## PLATE XXII

*Ceratocystis davidsonii* WIN(M)71-30

- Figs. a-b Perithecia ( $\times 250$ )
- Fig. c Apex of perithecial neck ( $\times 1000$ )
- Figs. d-e Ascospores ( $\times 4000$ )
- Fig. f Ascus ( $\times 2000$ )
- Fig. g Conidia ( $\times 4000$ )
- Fig. h Synnemata ( $\times 250$ )
- Fig. i Phialide ( $\times 4000$ )
- Fig. j Phialides, showing arrangement on conidiophore ( $\times 4000$ )



*C. brevicollis*, *C. olivacea*, and *C. sagmatospora*, but its curved ascospores with broad, uniform, gelatinous sheaths readily distinguish *C. davidsonii* from these species except *C. brevicollis*. The ascospores of the latter species also possess a uniform gelatinous sheath but are more elongate in appearance (compare Figs. d-e, Plate XXII and Fig. f, Plate XXVI).

The conidial state of *C. davidsonii* is very similar to that of *C. olivacea* in that their phialides are similar in morphology (compare Figs. i-j, Plate XXII and Fig. a, Plate XXVI), and in their arrangement on the individual stalks which comprise the synnemata. It cannot be confused with *C. brevicollis*, since the latter species has a *Verticicladiella*-like conidial state with sympodial conidiogenous cells (see Fig. e, Plate XXVII).

HOST: *Pseudotsuga menziesii*.

TYPE COLLECTION: WIN(M)71-30, Seymour Arm, British Columbia, Canada, August 26, 1971 (with *C. allantospora*,

*C. europhioides*, *C. fasciata*, *C. olivacea*, *C. pseudominor*).

4. *Ceratocystis europhioides* Wright and Cain, Can. J. Bot. 39: 1222. 1961. Figs. b and d, Plate XXVII; Fig. b, Plate XXVI.

Wright and Cain (18), in their description of *C. europhioides*, referred to the conidial state as a *Leptographium* and to the conidia as phialospores, while Robinson-Jeffrey (16), in comparing the conidial states of *C. huntii* and

*C. europhioides*, concluded that the two species have a *Verticicladiella* imperfect state. Examination of cultures from Manitoba collections, as well as type material (TRTC 33700) indicates that the conidiogenous cells of *C. europhioides* are not readily identifiable as either sympodulae or phialides but are an intermediate type, and in this study, are referred to as *percurrent phialides*. Cultures obtained from type material of *C. huntii* and from Manitoba collections of this species also produce conidiophores with percurrent phialides (compare Figs. a & b, Plate XXVII).

*C. pseudoeurophioides*, a newly-described species in this study has a *Verticicladiella* imperfect state, and this character is used to separate it from *C. europhioides*.

MANITOBA HOSTS: *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M)69-18 (with *C. dolominuta*, *C. cainii*, *C. olivacea*), 69-13, 71-13 (with *C. cainii*, *C. pseudoeurophioides*), 71-18, 69-02, 69-30 (with *C. crenulata*), all on *Picea mariana*; 69-35 (with *C. sagmatospora*, *C. huntii*, *C. alba*, *C. dolominuta*), on *Pinus banksiana*. Ontario: TRTC 33700, 45762, on *Picea mariana*; 45761 on *Pinus banksiana*; 36278 on *Picea glauca*; 34598b on *Pinus resinosa*.

5. *Ceratocystis fimbriata* Ell. and Halst., N.J. Agr.

Expt. Sta. Bul. 76: 14. 1890 and Jour. Mycol.7:1.1891.

Plate XXVI, Fig. e.

≡*Sphaeronaema fimbriatum* (Ell. and Halst.) Sacc., Syll.  
Fung. 10:215. 1923.

≡*Ophiostoma fimbriatum* (Ell. and Halst.) Nannf., Sv.  
Skogsvardsf. Tidskr. 32:408. 1934

≡*Endoconidiophora fimbriata* (Ell. and Halst.) Davids.,  
Jour. Agr. Res. 50:800. 1935

=*Rostrella coffeae* Zimm., Buitenzorg L'Institut Bot.  
Bull. 4:19. 1900.

*C. fimbriata* is readily distinguished by its ascospores which are surrounded by a sheath that is hat-shaped in side view and oval in plan view (see Fig. e, Plate XXVI). In Manitoba, this species has been found on the inner bark of trembling aspen and on wood of paper birch.

MANITOBA HOSTS: *Populus tremuloides*, *Betula papyrifera*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-03 on *Betula papyrifera*; 71-12 (with *C. pallidobrunnea*), on *Populus tremuloides*. Ontario: MFB 7415 on *P. tremuloides*. British Columbia: WIN(M) 71-32 (with *C. pilifera*), on *P. tremuloides*.

6. *Ceratocystis huntii* Robinson-Jeffrey, Can. J. Bot.

42:528. 1964. Fig. c, Plate XXVI and Fig. a Plate XXVII.

The similarity of the conidial states of *C. huntii* and *C. europhioides* has already been discussed (see discussion of *C. europhioides*). The ascospores of *C. huntii*, however, are much smaller than those of *C. europhioides* and are the basis for the separation of these two species.

MANITOBA HOSTS: *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-01, 70-05, 69-35 (with *C. alba*, *C. dolominuta*, *C. minuta*, *C. europhioides*), all on *Pinus banksiana*; 69-02 (with *C. europhioides*, *C. olivacea*), on *Picea mariana*. British Columbia: CFB R-577 (sub-culture from TYPE).

7. *Ceratocystis olivacea* (Mathiesen) Hunt, *Lloydia*, 19:29.

1956. Fig.a, Plate XXVI.

=*Ophiostoma olivaceum* Mathiesen, *Sv. Bot. Tidskr.* 45: 212. 1951.

=*Ceratocystis vesca* Davidson, *Mycologia* 50:666. 1958.

*C. olivacea* resembles *C. sagmatospora*, *C. davidsonii*, and *C. brevicollis* in perithecial morphology. It is easily distinguished from all these species by its ascospores which are surrounded by a double-brimmed sheath that converges to a point above the dorsal surface of the spore. The sheath appears cucullate in side view and triangular in end view.

MANITOBA HOST: *Picea mariana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-24 (with *C. dolominuta*), 69-18 (with *C. cainii*, *C. dolominuta*, *C. europhioides*), 71-18 (with *C. europhioides*); Ontario: TRTC 34649, 45747 on *Picea mariana*; 33696 on *Pinus sylvestris*.

8. *Ceratocystis populicola* sp. nov. Plate XXIII, Figs. a-k.

Perithecia globosa, atrobrunnea vel nigra, 75-125 $\mu$

diam; collum atrobrunneum vel nigrum, rectum vel curvatum, ad apicem gradatim contractum, 75-175 $\mu$  longum, ad basim 20-30(40) $\mu$ , ad truncatum apicem 7.0-10 $\mu$  latum; hyphae ostiolaris hyalinae, cylindricae, rectae vel tortuosae, parallelae vel divergentes, 5.0-10 $\mu$  longae, 0.5 $\mu$  diam; asci juveniles clavati, maturi clavati vel subglobosi, evanescentes, 7.0-9.0  $\times$  4.0-5.0 $\mu$ ; ascospores hyalinae, aseptatae, a latere conspectae lunatae cum extremis obtusis, superne cylindricae cum extremis obtusis, ab extremo conspectae rotundae, 2.5-3.5  $\times$  1.0-2.0 $\mu$ , cum vagina gelatinosa; vagina cucullata a latere conspecta, superne elliptica, ab extremo conspecta tri-radians. Coloniae albae; hyphae 0.5-2.0 $\mu$  diam, hyalinae, immersae vel superficiales, parietibus tenuibus; conidiophora simplicia; conidia hyalina, aseptata, cylindrica vel clavata, recta vel curvata, 2.5-4.5(5.0)  $\times$  1.0-1.5 $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno et cortice interno *Populi tremuloidis*.

*Perithecia* superficial on wood or on the cambium side of bark; in culture, developing on superficial mycelium or embedded in the agar medium; bases globose, dark brown to black, 75-125 $\mu$  in diameter, outer layer of the peridium composed of thick-walled, irregularly-shaped cells, 2.0-8.0 $\mu$  in diameter; necks dark brown to black, straight or curved, tapered towards the apex, 75-175 $\mu$  long, 20-30(40) $\mu$  wide at the base, 7.0-10 $\mu$  at the tip, composed

of thick-walled, laterally-fused, septate hyphal elements, 1.5-2.5 $\mu$  thick, which terminate in a truncate apex; thick septa, which are more or less coincident in adjacent elements, give the neck an appearance of having dark bands alternating with lighter areas; ostiolar hyphae hyaline, cylindrical, straight or crooked, parallel or divergent, 5.0-10  $\times$  0.5 $\mu$ . *Asci* 8-spored, evanescent, clavate when young, clavate to subglobose when mature, 7.0-9.0  $\times$  4.0-5.0 $\mu$ . *Ascospores* hyaline, 1-celled, lunate with obtuse ends in side view, cylindrical with obtuse ends in plan view, globose in end view, 2.5-3.5  $\times$  1.0-1.2 $\mu$ ; enclosed in a hyaline gelatinous sheath appearing cucullate or hat-shaped in side view, elliptical in plan view, tri-radiate in end view; sheath dimensions in side view: 3.5-5.0  $\times$  2.0-2.5 $\mu$ .

Perithecia produced sparingly in agar culture in approximately 4 weeks.

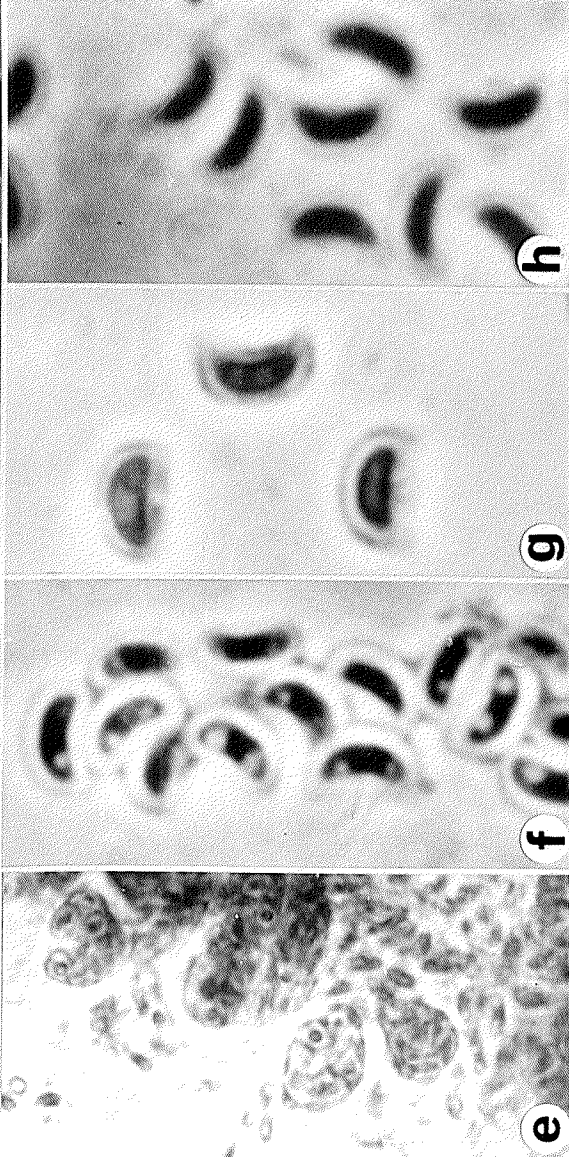
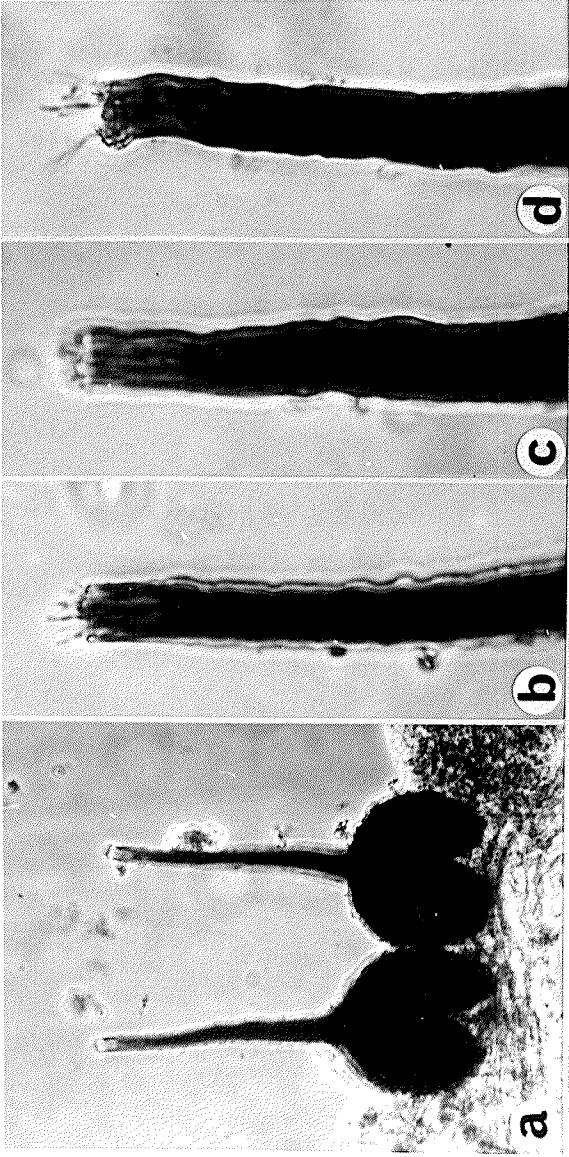
*Colonies* on agar hyaline to white, glistening due to masses of conidia in slime; agar not pigmented; growth rate slow. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.5-2.0 $\mu$  wide. *Conidiophores* semi-macronematous, mononematous, unbranched, up to 10 $\mu$  long. *Conidiogenous cells* polyblastic, terminal, integrated, cylindrical, sympodial, denticulate, 0.7-1.0 $\mu$  wide; denticles 0.5 $\mu$  long. *Conidia* hyaline, 1-celled, cylindrical or clavate,



PLATE XXIII

*Ceratocystis populicola* WIN(M) 69-19

- Fig. a Perithecia (×250)
- Figs. b-d Perithecial necks (×1000)
- Fig. e Asci (×2000)
- Figs. f-h Ascospores (×4000)
- Fig. i Conidia (×4000)
- Figs. j-k Conidiogenous cells (×4000)



straight or curved,  $2.5-4.5(5.0) \times 1.0-1.5\mu$ , produced singly but become aggregated in slimy heads.

The perithecia of *C. populicola* are superficially similar to those of *C. aequivaginata* and *C. acericola*. However, the perithecial necks of *C. populicola* are consistently shorter than those of *C. aequivaginata* and these two species can be separated on this basis. Also, *C. populicola* has ostiolar hyphae which *C. acericola* lacks and it does not have the swellings or annuli along the necks which are always present in *C. acericola*.

In the conidial state, *C. populicola* produces conidia which are curved and unlike those of *C. aequivaginata* (compare Fig. i, Plate XXIII and Fig. h, Plate XX). The conidial state cannot be compared with that of *C. acericola* since the latter species was described on the basis of the perfect state only and has not been isolated in culture.

HOST: *Populus tremuloides*.

TYPE COLLECTION: WIN(M) 69-19, Duck Mountain Provincial Forest, Manitoba, Canada, May 22, 1969.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M) 69-33, 70-23.

9. *Ceratocystis pseudoeurophioides* sp. nov. Plate XXIV, Figs. a-k

Perithecia globosa, nigra, 125-300 $\mu$  diam; collum nigrum, cylindricum, rectum vel curvatum, 300-850 $\mu$  longum,

ad basim 35-50 $\mu$  latum, ad apicem gradatim vel abrupte contractum, 25-45 $\mu$  latum; hyphae ostiolaris non visae; asci juveniles clavati, maturi clavati vel late elliptici, evanescentes, 17-20  $\times$  6.0-10 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspecta reniformes, superne ellipticae, ab extremo conspectae ovaes, 4.5-5.0  $\times$  2.0-2.5 $\mu$ , cum vagina gelatinosa; vagina cucullata vel campanulata a latere conspecta, superne quadrangula, ab extremo conspecta triradians. Coloniae atrovirentes; hyphae 0.7-10 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus vel crassis; conidiophora brunnea, penicillate furcata; conidia hyalina, aseptata, acropleurogena, curvata vel clavata, 2.5-5.0  $\times$  1.0-1.5(2.0) $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno et cortice interno *Piceae marianae*.

*Perithecia* black, cellular detail visible only when the perithecia are bleached, superficial on wood or embedded in inner bark, developing mostly on superficial mycelium in agar culture; bases globose, 125-300 $\mu$  in diameter, outer layer of the peridium composed of dark, thick-walled, irregularly-shaped cells, 4.0-18 $\mu$  in diameter; necks nearly cylindrical, straight or curved, gradually or abruptly tapered near the apex, 300-850 $\mu$  long, 35-50 $\mu$  wide at the base, 25-45 $\mu$  near the tip; chiefly composed of dark rectangular cells, 7.5-14  $\times$  3.5-5.5 $\mu$ , but towards the apex, of thick-walled, angular,

more or less isodiametric cells 2.5-10 $\mu$  in diameter; ostiolar hyphae absent. *Asci* 8-spored, evanescent, clavate when young, clavate or broadly clavate to globose when mature, 17-20  $\times$  6.0-10 $\mu$ . *Ascospores* hyaline, 1-celled, reniform in side view, broadly ellipsoid in plan view, oval in end view, 4.5-5.0  $\times$  2.0-2.5 $\mu$ , enclosed in a hyaline gelatinous sheath, up to 0.5 $\mu$  thick on the convex side of the spore, extending into a retrorse brim 6.5-7.5 $\mu$  across and up to 2.5 $\mu$  thick on the concave side, appearing cucullate or campanulate in side view of the spore, quadrangular in plan view, tri-radiate in end view; the spores are extruded from the ostiole in a thick whitish mass.

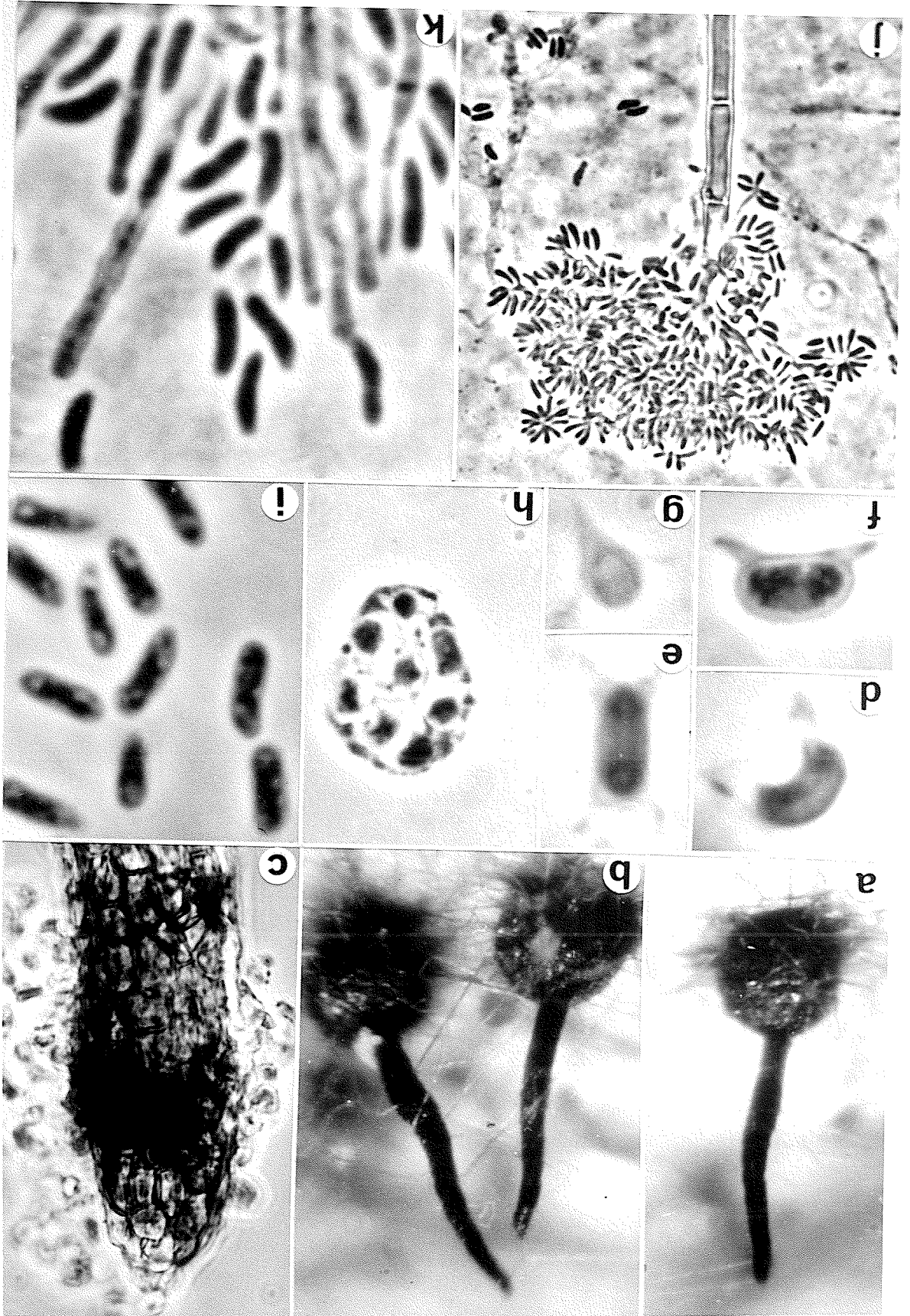
Perithecia develop on autoclaved wood in 2-3 weeks, in agar culture in 3-4 weeks. Frequently, the venters of perithecia produced in culture are densely ornamented by dematiaceous hyphae within which the perithecia developed.

*Colonies* on agar blackish green. *Mycelium* partly immersed, partly superficial. *Hyphae* hyaline, thin- or thick-walled, 0.7-10 $\mu$  wide. *Conidiophores* macronematous, mononematous, branched towards the apex forming a stipe and head; stipe straight, mid to dark brown, 150-500 $\mu$  long, 8.0-12 $\mu$  thick at the base, 4.0-6.0 $\mu$  just below the head; branches usually in 2-4 series. *Conidiogenous cells* polyblastic, discrete, arranged penicillately

## PLATE XXIV

*Ceratocystis pseudoeurophioides* WIN(M) 71-13

- Figs. a-b Perithecia on wood ( $\times 75$ )
- Fig. c<sup>s</sup> Apex of perithecial neck, bleached to show cell detail ( $\times 1000$ )
- Figs. d-g Ascospores ( $\times 4000$ )
- Fig. h Ascus ( $\times 2000$ )
- Fig. i Conidia ( $\times 4000$ )
- Fig. j Conidiophore apex of *Verticicladiella* state ( $\times 1000$ )
- Fig. k Conidia and conidiogenous cells ( $\times 4000$ )



on branches, sympodial, cylindrical, 0.7-1.2 $\mu$  thick. *Conidia* formed solitarily but becoming aggregated in slimy heads, acropleurogenous, usually curved, often clavate, 2.5-5.0  $\times$  1.0-1.5(2.0) $\mu$ .

The perithecia and ascospores of *C. pseudoeurophioides* are indistinguishable from those of *C. europhioides*. Separation of the two species is based on differences in their conidial states. *C. pseudoeurophioides* has a *Verticicladiella* imperfect state with sympodial conidiogenous cells which produce curved conidia, whereas *C. europhioides* has a *Leptographium* imperfect state with percurrent phialides which produce straight phialoconidia (compare Figs. i, j, & k, Plate XXIV; Fig. b, Plate XXVI; and Figs. b & d, Plate XXVII)

HOST: *Picea mariana*.

TYPE COLLECTIONL WIN(M)71-13, Sandilands Forest Reserve, Manitoba, Canada, April 24, 1971 (with *C. cainii*, *C. olivacea*, *C. pseudonigra*).

10. *Ceratocystis sagmatospora* Wright and Cain, Can. J. Bot., 39:1226. 1961. Fig. d, Plate XXVI and Fig. c, Plate XXVII.

This species is very similar in general appearance to *C. olivacea* and *C. davidsonii*, but is distinguished by the sheath which surrounds the ascospores. The ascospores of *C. sagmatospora* possess a sheath with a double brim which does not converge either above or below the



spore itself.

MANITOBA HOSTS: *Picea mariana* *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-50 (with *C. europheoides*), 69-35 (with *C. alba*, *C. dolominuta*, *C. europheoides*, *C. huntii*, *C. minuta*), 69-02 (with *C. europheoides*). Ontario: TRTC 36247 (TYPE), 36263, 39559, all on *Picea mariana*; 39555, 36265, 36245, 36264, all on *Pinus strobus*; 34600 on *P. resinosa*. British Columbia: WIN(M) 71-30 (with *C. allantospora*, *C. davidsonii*, *C. europheoides*, *C. fasciata*, *C. pseudominor*) on *Pseudotsuga menziesii*. 71-29 (with *C. allantospora*, *C. pilifera*) on *Thuja occidentalis*.

11. *Ceratocystis torticiliata* sp. nov. Plate XXV,  
Figs. a-l.

Perithecia in agar non evoluta, in ligno sterili evoluta, globosa, nigra et opaca, 150-250 $\mu$  diam; collum nigrum, rectum vel curvatum, (400)700-1500 $\mu$  longum, ad basim 35-60 $\mu$  ad truncatum apicem 18-25 $\mu$  latum; hyphae ostiolaris hyalinae, cylindricae, tortuosae, usque ad 135 $\mu$  longae, 1.0-1.5 $\mu$  diam; asci juveniles clavati, maturi clavati vel subglobosi, 7.0-9.0  $\times$  4.0-5.0 $\mu$ ; ascosporeae hyalinae, a latere conspectae lunatae, superne transverse ellipticae, ab extremo conspectae rotundae, 2.0-2.5  $\times$  0.7-1.0 $\mu$ , cum vagina gelatinosa; vagina in pagina convexa ascosporeae 0.3 $\mu$  lata, in pagina concava ascosporeae 0.3-0.5 $\mu$  lata convexaque. Coloniae

albae; hyphae 0.5-2.0 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiphora in synnemata aggregata; synnemata olivaceo-brunnea, pallidiora versus apicem, solitaria vel cespitosa, usque ad 1000 $\mu$  longa et 75 $\mu$  lata, ad apicem iterum atque iterum prolificantia ut apices secundarios et tertiarios formunt; conidia hyalina, aseptata, clavata vel ovoidea vel oblonga cum extremis obtusis, 2.5-4.0  $\times$  1.2-2.0 $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno *Populi balsamiferae*.

*Perithecia* black, cellular detail visible only when the perithecia are bleached; superficial or partly embedded on wood, not developing in agar culture; bases globose, 150-250 $\mu$  in diameter, outer layer of the peridium composed of thick-walled, more or less isodiametric cells, 3.0-10 $\mu$  in diameter; necks cylindrical, straight or curved, (400)700-1500 $\mu$  long, 35-60 $\mu$  wide at the base, 18-25 $\mu$  at the tip, composed of laterally-fused, thick-walled, septate hyphal elements 1.5-3.0(5.0) $\mu$  wide, which terminate in a truncate apex; ostiolar hyphae hyaline, cylindrical, flexuous, divergent, 1.0-1.5 $\mu$  thick, up to 135 $\mu$  long. *Asci* 8-spored, evanescent, clavate when young, clavate to subglobose when mature, 7.0-9.0  $\times$  4.0-5.0 $\mu$ . *Ascospores* hyaline, 1-celled, lunate in side view, elliptical in plan view, globose in end view, 2.0-2.5  $\times$  0.7-1.0 $\mu$ , surrounded by a hyaline, gelatinous sheath, 0.3 $\mu$

thick on the convex side of the spore, 0.3-0.5 $\mu$  thick and convex on the concave side of the spore.

Perithecia develop on autoclaved wood in 4-5 weeks.

*Colonies* on agar hyaline to white, cottony, conidiophores abundant; agar not pigmented; growth rate intermediate. *Mycelium* aerial, superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.5-2.0 $\mu$  wide. *Conidiophores* macronematous, mononematous or synnematos, solitary or cespitose. *Synnemata* olivaceous brown at the base, becoming paler towards the apex, up to 1000 $\mu$  long, up to 75 $\mu$  thick at the base, capped by a slimy head; the central portion remaining meristematic, frequently growing out of the conidial head to produce secondary and tertiary heads. *Conidiogenous cells* polyblastic, terminal, integrated, cylindrical, sympodial, 0.7-1.0 $\mu$  thick. *Conidia* hyaline, 1-celled, clavate, ovoid, or oblong with obtuse ends, 2.5-4.0  $\times$  1.2-2.0 $\mu$ , formed solitarily but becoming aggregated in slimy heads.

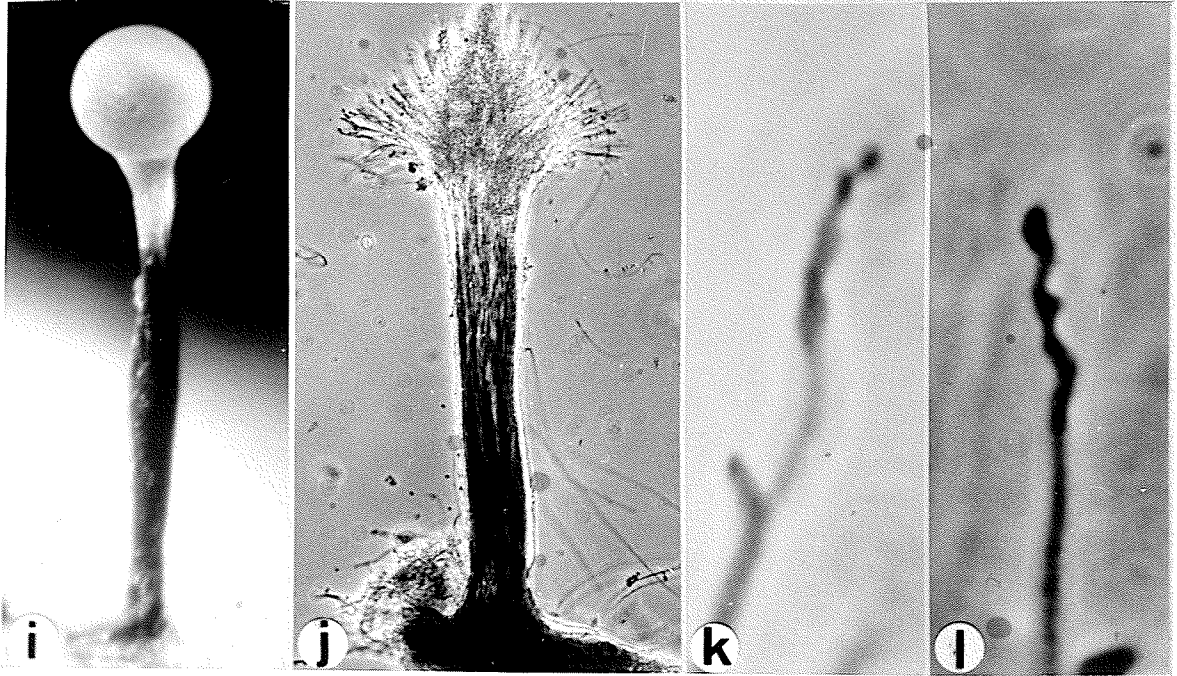
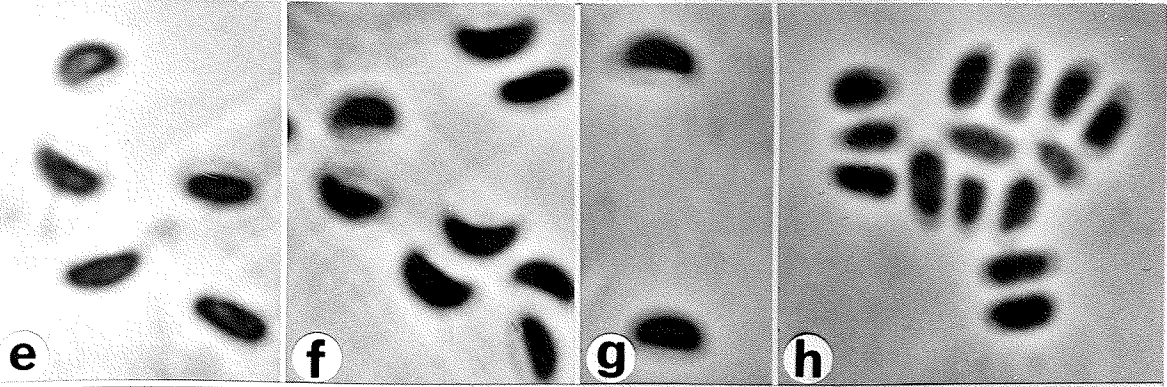
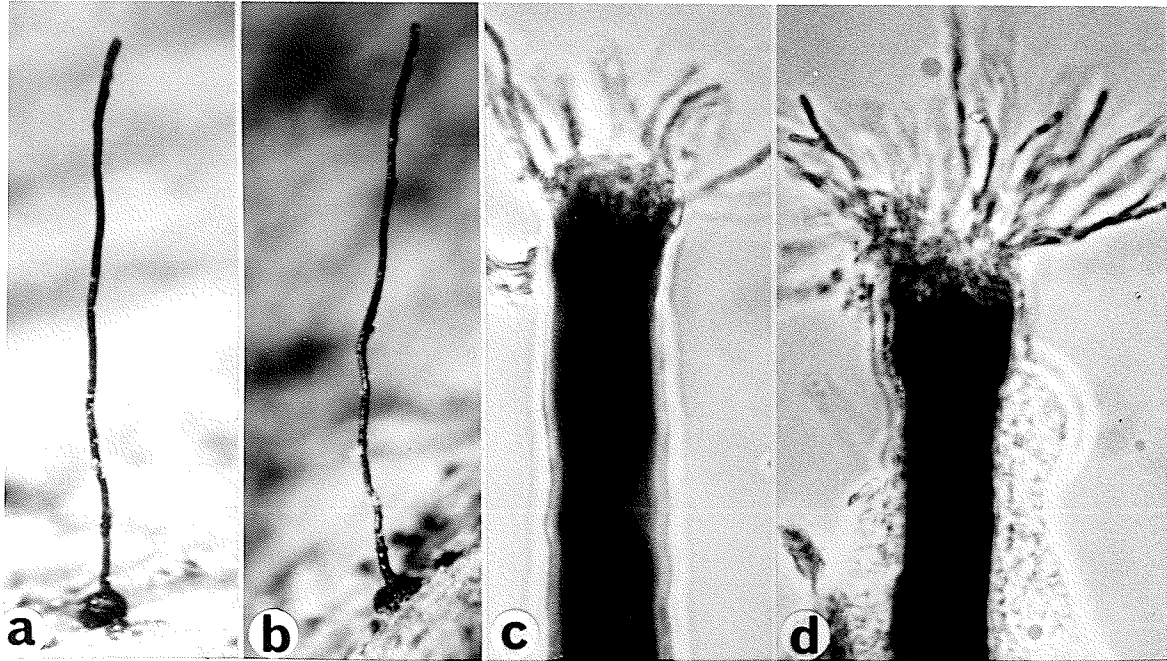
*C. torticiliata* resembles *C. clavata* more closely than any other species of *Ceratocystis*. However, the necks of *C. torticiliata* are longer than is reported for those of *C. clavata* and *C. clavata* has slightly larger ascospores. Also, the ostiolar hyphae of *C. torticiliata* are hyaline and flexuous while those of *C. clavata* are brown and spirally curved.

In the conidial state, both species produce similar

## PLATE XXV

*Ceratocystis torticiliata* WIN(M)70-15

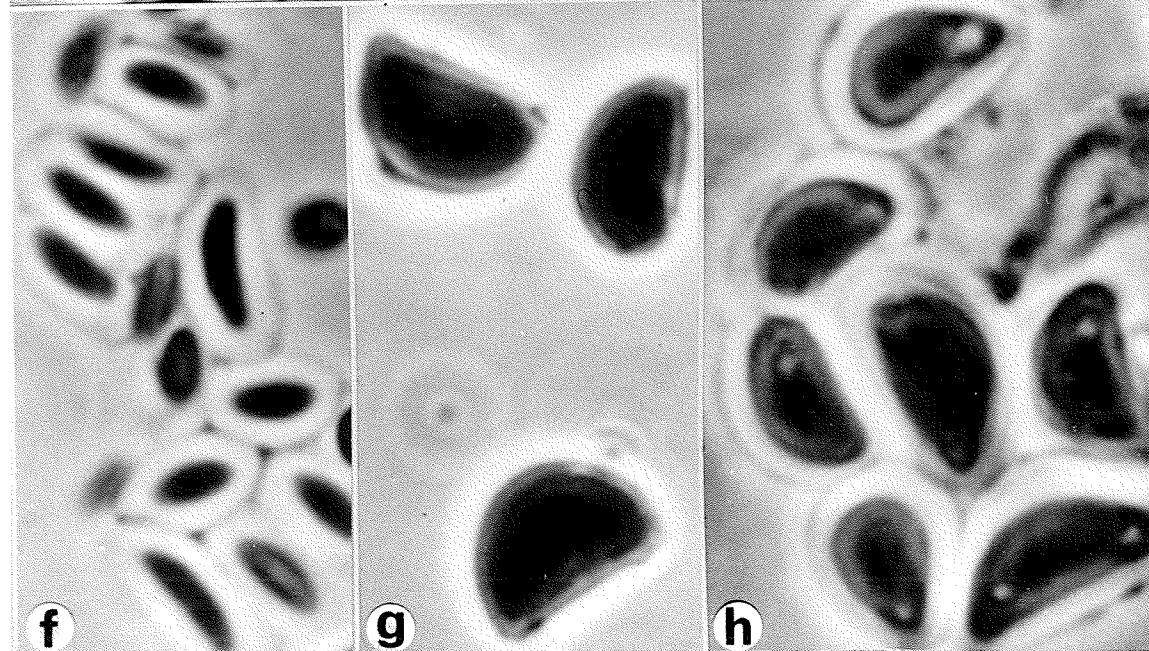
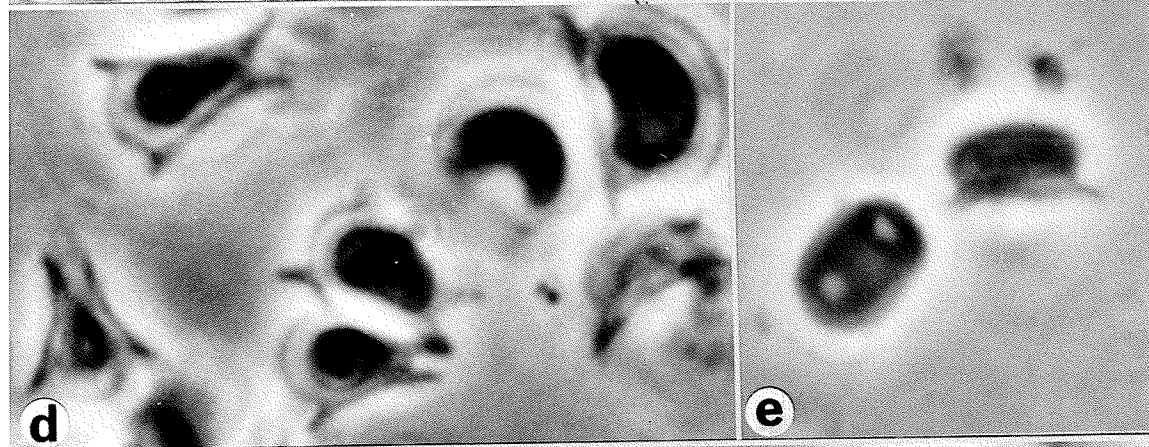
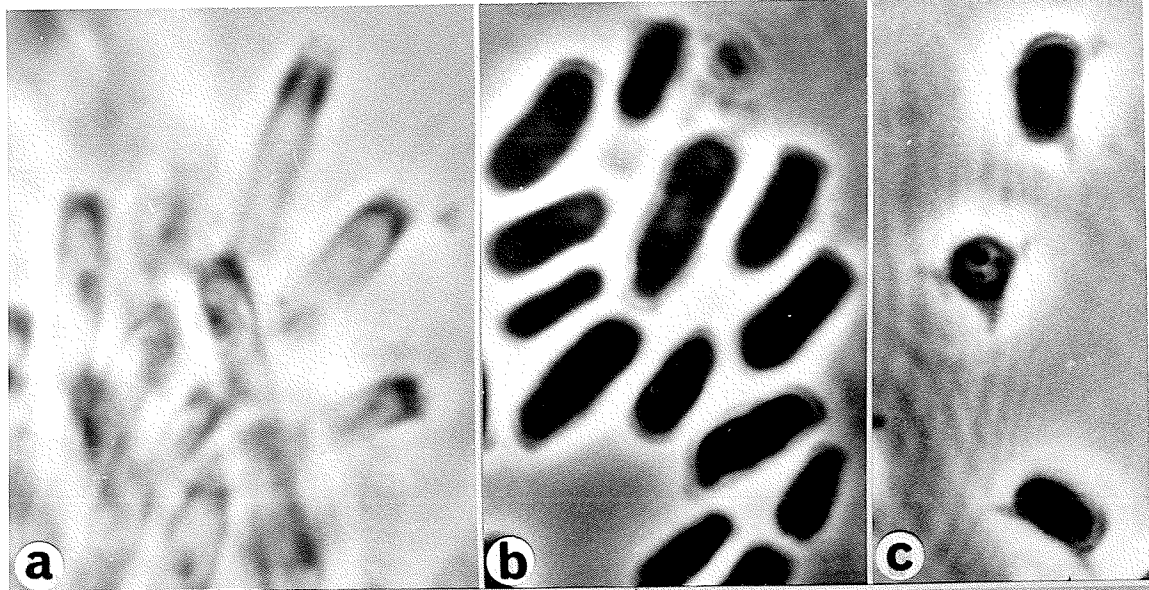
- Figs. a-b Perithecia on wood ( $\times 60$ )  
Figs. c-d Apices of perithecial necks ( $\times 750$ )  
Figs. e-g Ascospores ( $\times 4000$ )  
Fig. h Conidia ( $\times 4000$ )  
Fig. i Synnema on wood ( $\times 250$ )  
Fig. j Synnema, slide preparation ( $\times 250$ )  
Figs. k-l Conidiogenous cells ( $\times 4000$ )



## PLATE XXVI

Additional illustrations of *Ceratocystis* spp.  
of the Fimbriata Group

- Fig. a      *C. olivacea* WIN(M)71-13. Phialides (×4000)  
Fig. b      *C. europhioides* WIN(M)69-02. Conidia (×4000)  
Fig. c      *C. huntii* WIN(M)70-05. Ascospores (×4000)  
Fig. d      *C. sagmatospora* WIN(M)71-09. Ascospores (×4000)  
Fig. e      *C. fimbriata* WIN(M)68-03. Ascospores (×4000)  
Fig. f      *C. brevicollis* ATCC 12971. Ascospores (×4000)  
Fig. g      *C. adiposa* TRTC Culture. Ascospores (×4000)  
Fig. h      *C. major* CFB-R562. Ascospores (×4000)

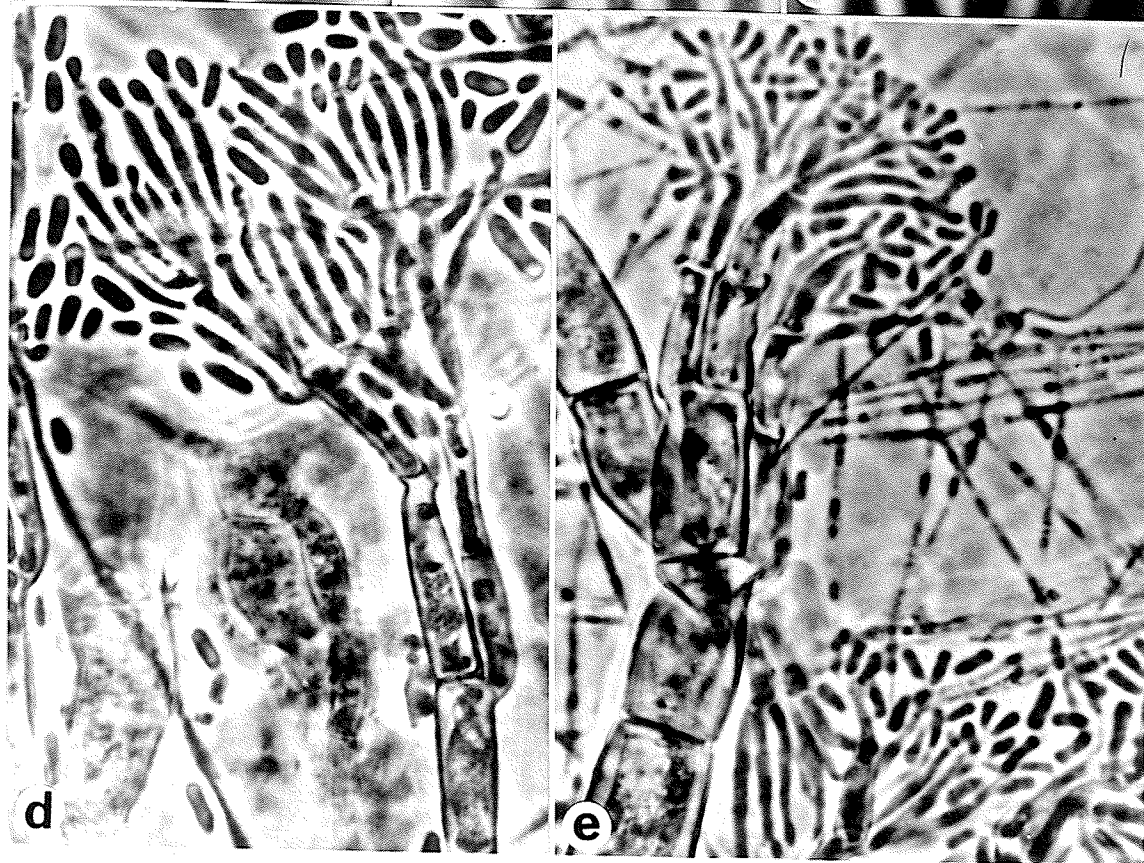
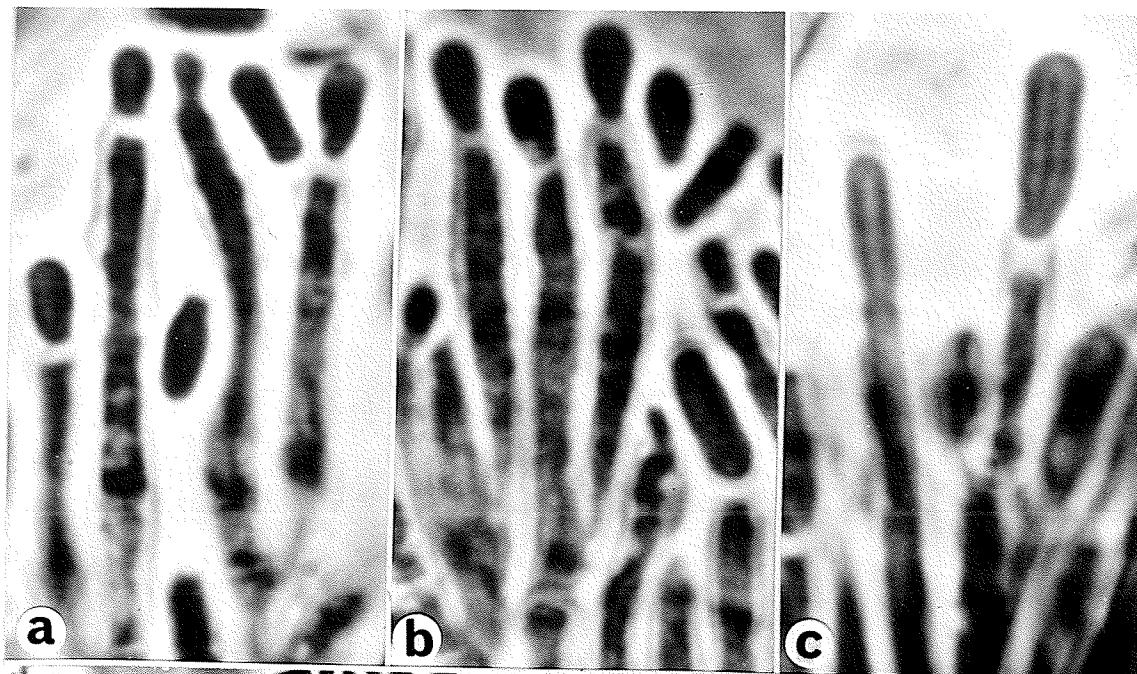


## PLATE XXVII

Additional illustrations of *Ceratocystis* spp.  
of the Fimbriata Group

- Fig. a *C. huntii* WIN(M)70-05. Conidiogenous cells  
(×4000)
- Fig. b *C. europhioides* WIN(M)69-02. Conidiogenous  
cells (×4000)
- Fig. c *C. sagmatospora* WIN(M)71-09. Conidiogenous  
cells (×4000)
- Fig. d *C. europhioides* WIN(M)69-02. Conidiophores  
and conidia (×1500)
- Fig. e *C. brevicollis* ATCC 12971. Conidiophores and  
conidia (×1500)





appearing synnemata, but the conidia of *C. torticiliata* are smaller than those of *C. clavata*.

HOST: *Populus balsamifera*.

TYPE COLLECTION: WIN(M)70-15, Sandilands Forest Reserve, Manitoba, Canada, May 24, 1970.

The following species have not been found in Manitoba but have been examined for purposes of comparison and are considered to belong to the Fimbriata Group:

*Ceratocystis adiposa* (Butl.) C. Moreau, *Revue de Mycologie, Suppl. Colonial* 17:22. 1952. Plate XXVI, Fig. g. SPECIMEN EXAMINED: BPI-FP 46664.

*Ceratocystis acericola* Griffin, *Can. J. Bot.* 46:694. 1968. SPECIMEN EXAMINED: MFB 7593

*Ceratocystis brevicollis* Davidson, *Mycologia* 50:667. 1958. Plate XXVI, Fig. f; Plate XXVII, Fig. e. SPECIMEN EXAMINED: ATCC 12971.

*Ceratocystis clavata* (Mathiesen) Hunt, *Lloydia* 19:37. 1956. SPECIMEN EXAMINED: AM-K 1-7-56 (imperfect state only).

*Ceratocystis major* (van Beyma) C. Moreau, *Revue de Mycologie, Suppl. Colonial* 17:22. 1952. SPECIMEN EXAMINED: CFB R-562. Plate XXVI, Fig. h.

*Ceratocystis moniliformis* (Hedgc.) C. Moreau, *Revue de Mycologie, Suppl. Colonial* 17:22. 1952. SPECIMEN EXAMINED: ATCC 12861.

*Ceratocystis magnifica* Griffin, Can. J. Bot. 46:704.  
1968. SPECIMEN EXAMINED: MFB 7637 (=TRTC 36287).

The following species have not been examined but, from the descriptions appearing in the literature, are probably referable to the Fimbriata Group:

*Ceratocystis brunneo-ciliata* (Mathiesen-K) Hunt,  
Lloydia 19:32. 1956.

*Ceratocystis dryocoetidis* Kendrick and Molnar,  
Can. J. Bot. 43:39. 1965.

*Ceratocystis francke-grosmanniae* Davidson,  
Mycologia 63:6. 1971.

*Ceratocystis leptographioides* (Davids.) Hunt,  
Lloydia 19:28. 1956

*Ceratocystis olivaceapini* Davidson, Mycologia  
63:7. 1971

*Ceratocystis rostrocyllindrica* (Davids.) Hunt,  
Lloydia 19:26. 1956.

*Ceratocystis variospora* (Davids.) C. Moreau,  
Revue de Mycologie, Suppl. Colonial 17:22. 1952.

## KEY TO THE SPECIES OF THE PILIFERA GROUP

1. Ostiolar hyphae absent
  2. Base of perithecium more than 100 $\mu$  in diameter
    3. Ascospores lunate or orange-section-shaped; contents of venter bright yellow; imperfect state synnematosus..... 7. *C. introcitrina*
    3. Ascospores allantoid or ellipsoid; imperfect state mononematous
      4. Ascospores allantoid..... 2. *C. allantospora*
      4. Ascospores ellipsoid..... 10. *C. narcissi*
  2. Base of perithecium less than 100 $\mu$  in diameter
    - ..... 3. *C. angusticollis*
1. Ostiolar hyphae present
  5. Ostiolar hyphae nearly cylindrical, arising from a sharply defined apex
    6. Necks usually more than 200 $\mu$  long.....
      - ..... 6. *C. coronata*
    6. Necks usually less than 200 $\mu$  long
      7. Ascospores more than 1.5 $\mu$  wide.. 4. *C. capitata*
      7. Ascospores less than 1.5 $\mu$  wide
        8. Ascospores less than 4 $\mu$  long.....
          - ..... 14. *C. pseudominor*
          8. Ascospores more than 4 $\mu$  long..... 9. *C. minor*
    5. Ostiolar hyphae tapered, developing as continuations of hyphal elements comprising the neck; apex not sharply defined

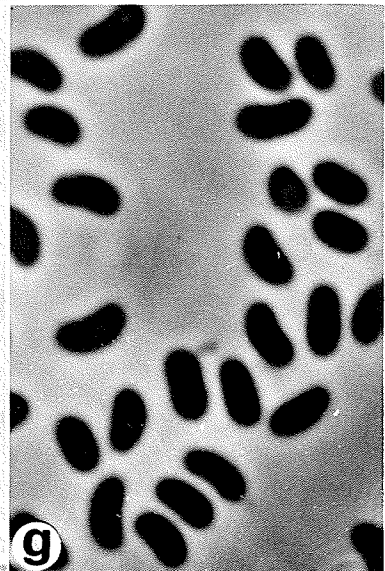
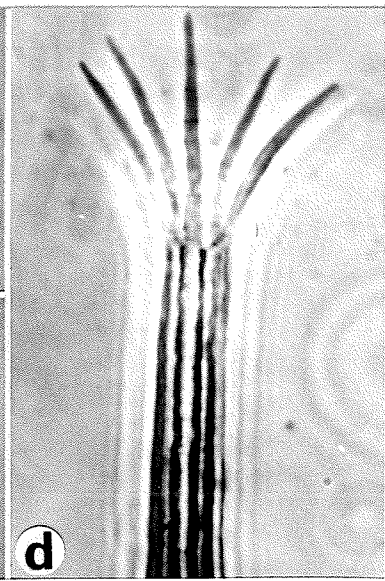
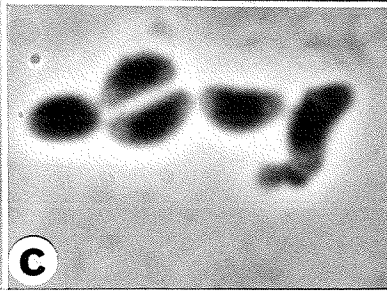
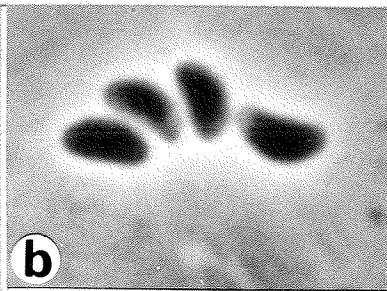
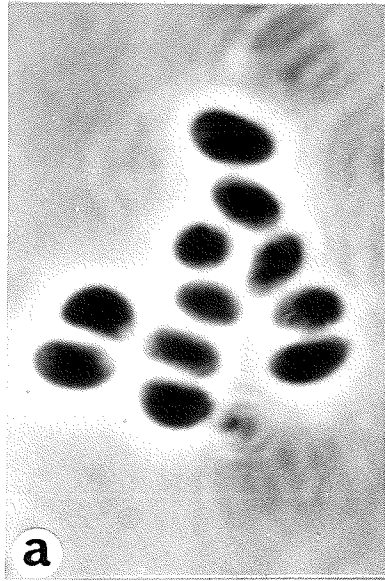
- 9. Ascospores less than 4 $\mu$  long
    - 10. Perithecia hyaline..... 8. *C. leucocarpa*
    - 10. Perithecia brown to black
      - 11. Ascospores allantoid..... *C. tetropii*
      - 11. Ascospores lunate to orange-section-shaped
        - 12. Cultures on agar hyaline to white; agar not pigmented
          - 13. Ascospores less than 3 $\mu$  long.....  
..... *C. stenoceras*
          - 13. Ascospores more than 3 $\mu$  long.....  
..... 1. *C. albida*
        - 12. Cultures on agar buff-colored; agar pigmented brown..... *C. megalobrunnea*
9. Ascospores more than 4 $\mu$  long
  - 14. Imperfect state endoconidial... 5. *C. coerulescens*
  - 14. Imperfect state not endoconidial
    - 15. Imperfect state Graphium-like
      - 16. Necks rarely exceeding 400 $\mu$  in length.....  
..... *C. ulmi*
      - 16. Necks up to 1000 $\mu$  long..... 12. *C. piceae*
    - 15. Imperfect state not Graphium-like
      - 17. Base of perithecium paler than the neck.....  
..... 11. *C. perfecta*
      - 17. Base of perithecium brown to black, essentially concolorous with the neck

18. Cultures on agar hyaline to white; agar not pigmented
19. Necks usually more than 750 $\mu$  long.....
- ..... 13. *C. pilifera*
19. Necks less than 750 $\mu$  long..... 15. *C. tenella*
18. Cultures on agar brown to buff
20. Malt agar pigmented yellow, pablum agar pigmented  
pale brown..... 16. *C. tremulo-aurea*
20. Malt agar pigmented brown..... *C. brunnea*

## PLATE XXVIII

Additional illustrations of *Ceratocystis* spp.  
of the Pilifera Group

- Fig. a *C. albida* TRTC Culture. Ascospores ( $\times 4000$ )
- Figs. b-c *C. albida* WIN(M) 69-53. Ascospores ( $\times 4000$ )
- Fig. d *C. albida* WIN(M) 69-53. Perithecial neck  
( $\times 1000$ )
- Fig. e *C. angusticollis* WIN(M) 71-32. Perithecium  
( $\times 100$ )
- Fig. f *C. angusticollis* WIN(M) 71-32. Perithecial  
neck ( $\times 1000$ )
- Fig. g *C. angusticollis* WIN(M) 71-32. Ascospores  
( $\times 4000$ )
- Fig. h *C. angusticollis* WIN(M) 71-03. Conidiophore  
and conidia ( $\times 1500$ )
- Figs. i-j *C. angusticollis* WIN(M) 71-32. Conidiogenous  
cells ( $\times 4000$ )
- Fig. k *C. angusticollis* WIN(M) 71-32. Conidia ( $\times 4000$ )





1. *Ceratocystis albida* (Mathiesen-K) Hunt, *Lloydia* 19: 49. 1956. Plate XXVIII, Figs. a-d.

=*Ophiostoma albidum* Mathiesen-K., Meddel. Statens Skogsforskningsinst., Sweden, 43(4):50. 1953.

*C. albida* is readily identified by its small, orange-section-shaped ascospores and prominent divergent ostiolar hyphae which are usually curved outwards. A single collection of this species has been made in Manitoba from elm. Comparisons with cultures of *C. albida*, as well as with the description in the literature, show that the Manitoba material resembles *C. albida* in all respects except that the necks tend to be almost twice the length of those produced by *C. albida*. The cultural characteristics and the conidial state do not differ from those of *C. albida*. I therefore consider the Manitoba collection to represent *C. albida* with the following emendation to the original description of this species: necks 340-1000 $\mu$  long.

MANITOBA HOST: *Ulmus americana*.

SPECIMENS EXAMINED: Manitoba: WIN(M)69-53. Sweden: TRTC culture from Mathiesen-Käärik (no numerical designation).

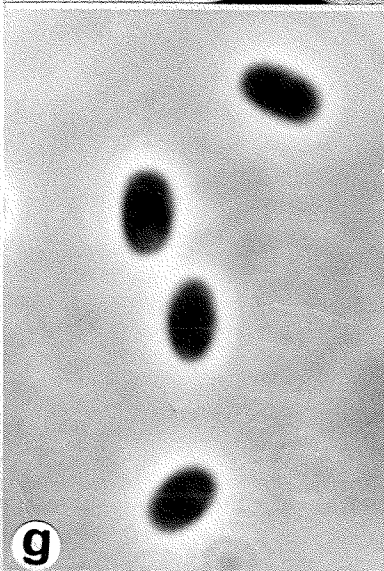
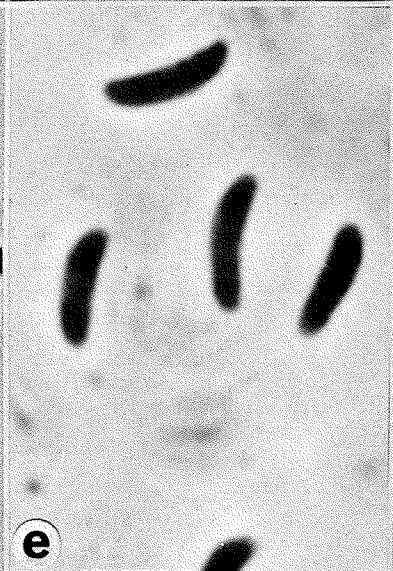
2. *Ceratocystis allantospora* Griffin, *Can. J. Bot.* 46: 694. 1968. Plate XXIX, Fig. a.

*C. allantospora* is easily recognized by its allantoid ascospores and the lack of ostiolar hyphae. Griffin, in his description of the species, referred to the asco-

## PLATE XXIX

Additional illustrations of ascospores of  
*Ceratocystis* spp. of the Piliifera Group

- Fig. a      *C. allantospora* WIN(M) 69-56.    (×4000)  
Fig. b      *C. tenella* WIN(M) 71-07.    (×4000)  
Fig. c      *C. tenella* BPI-FP 70809.    (×4000)  
Fig. d      *C. minor* WIN(M) 71-10.    (×4000)  
Fig. e      *C. perfecta* WIN(M) 71-27.    (×4000)  
Fig. f      *C. pilifera* WIN(M) 71-12.    (×4000)  
Fig. g      *C. narcissi* WIN(M) 69-55.    (×4000)  
Fig. h      *C. tremulo-aurea* ATCC 15459.    (×4000)  
Fig. i      *C. capitata* WIN(M) 69-16.    (×4000)



spores as being surrounded by a thin hyaline sheath. However, examinations during this study failed to show the presence of a sheath.

MANITOBA HOSTS: *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-06, 71-09, 71-30, 71-18, 70-22, 70-24, all on *Picea mariana*; 69-56, 71-10, 71-26, all on *Pinus banksiana*. Ontario: TRTC 36278, 45770, 45772; MFB 7601, 7602, 7604, 7609, 7611. British Columbia: WIN(M) 71-29 on *Thuja occidentalis*, 71-30 on *Pseudotsuga menziesii*.

3. *Ceratocystis angusticollis* Wright and Griffin, Can.

J. Bot. 46:697. Plate XXVIII, Figs. e-k.

*C. angusticollis* was first described on the basis of the perfect state but was not grown in culture. Isolates have been obtained from Manitoba collections which resemble type material of this species in all respects. On this basis, the conidial state of *C. angusticollis* is described as follows:

*Colonies* on agar hyaline to white, glistening due to masses of conidia in slime; agar not pigmented; growth rate slow. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.5-1.5 $\mu$  wide. *Conidiophores* micronematous, mononematous. *Conidiogenous cells* polyblastic, terminal, integrated, cylindrical, denticulate, 0.7-1.0 $\mu$  wide; denticles 0.1 $\mu$  wide, up to 0.5 $\mu$  long. *Conidia* hyaline, 1-celled, clavate, ovoid,

or arcuate,  $2.5-5.0(6.0) \times 1.0-1.2(2.0)\mu$ , formed solitarily but becoming aggregated in a slimy head.

The apices of the perithecial necks of *C. angusticollis* are usually swollen, and capped by a hyaline gelatinous pad (see Fig. f, Plate XXVIII). This feature, which is characteristic of this species, is usually not seen since the neck tends to fracture below the ostiole prior to, or at the time of, the release of the ascospores.

MANITOBA HOSTS: *Pinus resinosa*, *P. banksiana*, *Abies balsamea*, *Picea mariana*.

SPECIMENS EXAMINED: WIN(M) 71-03, 71-23, all on *Pinus resinosa*; 69-44, 69-57, 70-13 all on *P. banksiana*; 71-11 71-21 all on *Abies balsamea*; 71-09 on *Picea mariana*.

Ontario: TRTC 34647, 34663, 34669, 36292, 39570, 45769; MFB 7590. British Columbia: WIN(M) 71-29 on *Thuja occidentalis*; 71-32 on *Pseudotsuga menziesii*.

4. *Ceratocystis capitata* Griffin, Can. J. Bot. 46:699.

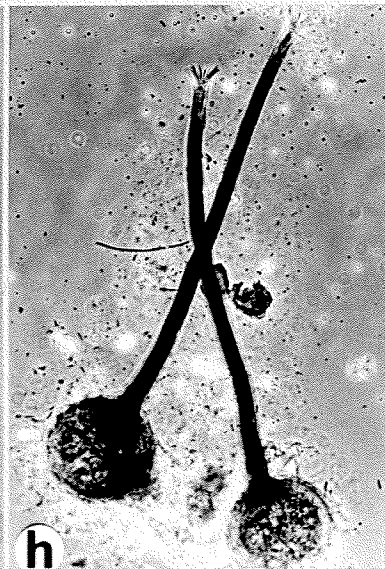
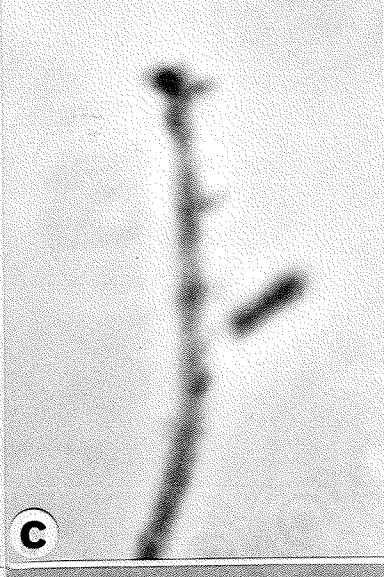
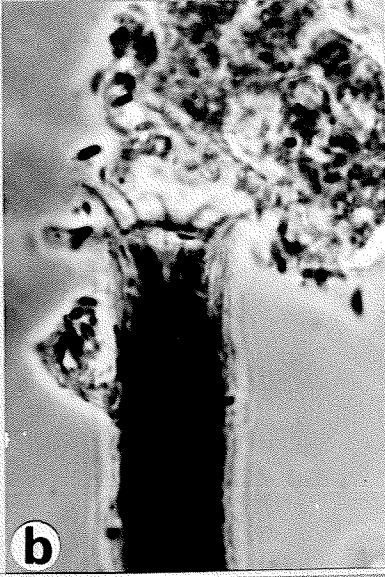
1968. Plate XXIX, Fig. i; Plate XXX, Figs. a-c.

Manitoba collections of *C. capitata* show no significant variation from the original description of this species. The truncate apices, with narrow, cylindrical, divergent ostiolar hyphae, and the presence of a hyaline gelatinous pad, are characteristic of *C. capitata* as well as *C. tremulo-aurea* and *C. coronata*. Denticulate conidiogenous cells and large clavate conidia are also features

## PLATE XXX

Additional illustrations of *Ceratocystis* spp.  
of the Pilifera Group

- Figs. a-b *C. capitata* WIN(M)69-16. Apices of perithe-  
cial necks ( $\times 1000$ )
- Fig. c *C. capitata* WIN(M)69-16. Denticulate conidio-  
phore with conidium ( $\times 4000$ )
- Figs. d-e *C. tenella* WIN(M)71-27. Perithecial neck  
apices ( $\times 1000$ )
- Fig. f *C. tenella* WIN(M)71-27. Conidia ( $\times 4000$ )
- Fig. g *C. perfecta* WIN(M)71-27. Perithecial neck  
apex ( $\times 1000$ )
- Fig. h *C. perfecta* WIN(M)71-27. Perithecia ( $\times 150$ )
- Fig. i *C. perfecta* WIN(M)71-27. Conidia ( $\times 4000$ )





shared by these three species.

MANITOBA HOST: *Populus tremuloides*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-16, 69-39.

Ontario: TRTC 45763, 39548, 36262; MFB 7613, 7616, 7617, 7621, 7623, 7625.

5. *Ceratocystis coerulescens* (Münch) Bakshi, Brit.

Mycol. Soc. Trans. 33:114. 1950.

=*Endoconidiophora coerulescens* Münch, Naturw. Ztschr. f. Forst. u Landw. 5:564. 1907.

=*Ophiostoma coerulescens* (Münch) Nannf., Sv. Skogsvardef. Tidskr. 32:408. 1934.

=*Endoconidiophora virescens* Davids., Mycologia 36: 301. 1944.

A single collection of *C. coerulescens* has been made in Manitoba. Although there is a thin gelatinous sheath associated with the ascospores, it is frequently not seen, and for this reason *C. coerulescens* is included in this group.

MANITOBA HOST: *Picea mariana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-11 (with *C. piceae*).

Alberta: CFB R-584 (culture).

6. *Ceratocystis coronata* sp. nov. Plate XXXI Figs. a-1.

Perithecia globosa, atrobrunnea vel nigra, 45-110 (160) $\mu$ ; collum atrobrunneum vel nigrum, pallidius versus apicem, cylindricum, flexum vel tortuosum, 100-450(600) $\mu$  longum, ad basim 20-30(40) $\mu$  latum, ad apicem obtusum



6.0-10 $\mu$  latum pileo hyalino tectum; hyphae ostiolarum hyalinae, rectae, cylindricae vel contractae, divergentes et coroniformes, 10-30 $\mu$  longae, ad basim 0.7-1.0 $\mu$  diam; asci juveniles clavati, maturi subglobosi, evanescentes, octospori, 3.5-10  $\times$  2.5-5.0 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae allantoideae, superne oblongae cum extremis obtusis, ab extremo conspectae rotundae, (2.5)3.5-4.5  $\times$  1.0-1.2 $\mu$ , vagina nulla. Coloniae albae; hyphae 0.5-5.0 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiophora hyalina, simplicia vel furcata; conidia hyalina, aseptata, clavata, 2.0-8.0  $\times$  1.0-2.5 $\mu$ .

Hab. in ligno *Pini banksianae*.

*Perithecia* superficial on wood, developing on superficial mycelium or embedded in the agar medium in culture; bases dark brown to black, globose, 45-110(160) $\mu$  in diameter, outer layer of the peridium composed of thick-walled, polygonal cells, (2.5)5.0-10 $\mu$  in diameter; necks dark brown to black, paler near the apex, nearly cylindrical, usually bent or crooked, 100-450(600) $\mu$  long, 20-30(40) $\mu$  wide at the base, 6.0-10 $\mu$  at the tip, composed of dark, thick-walled, laterally-fused, septate, hyphal elements, 1.0-2.5 $\mu$  wide, which terminate in an obtuse to truncate apex covered by a hyaline gelatinous pad; ostiolar hyphae, when present, hyaline, straight, cylindrical or tapered, divergent, up to 30 in number, 10-30 $\mu$  long,

0.7-1.0 $\mu$  wide at the base, develop as extensions of the hyphal elements composing the outer layer of the neck. *Asci* 8-spored, evanescent, clavate when young, subglobose when mature, 3.5-10  $\times$  2.5-5.0 $\mu$ . *Ascospores* hyaline, 1-celled, allantoid in side view, oblong with obtuse ends in plan view, globose in end view, (2.5)3.5-4.5  $\times$  1.0-1.2 $\mu$ ; the spores are extruded from the ostiole in a hyaline droplet, which becomes amber with age.

Perithecia develop on agar and on autoclaved wood in 1-2 weeks.

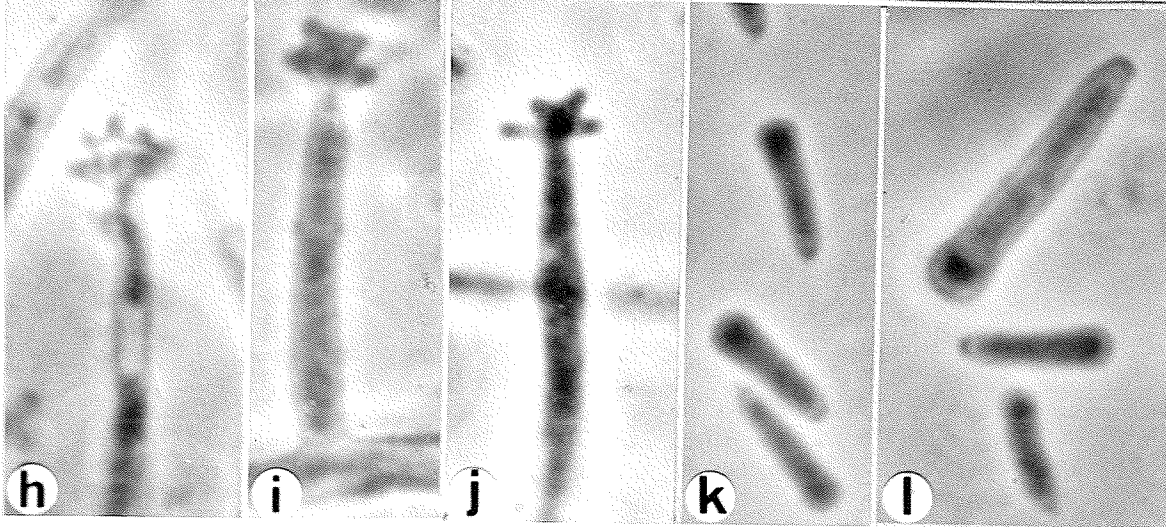
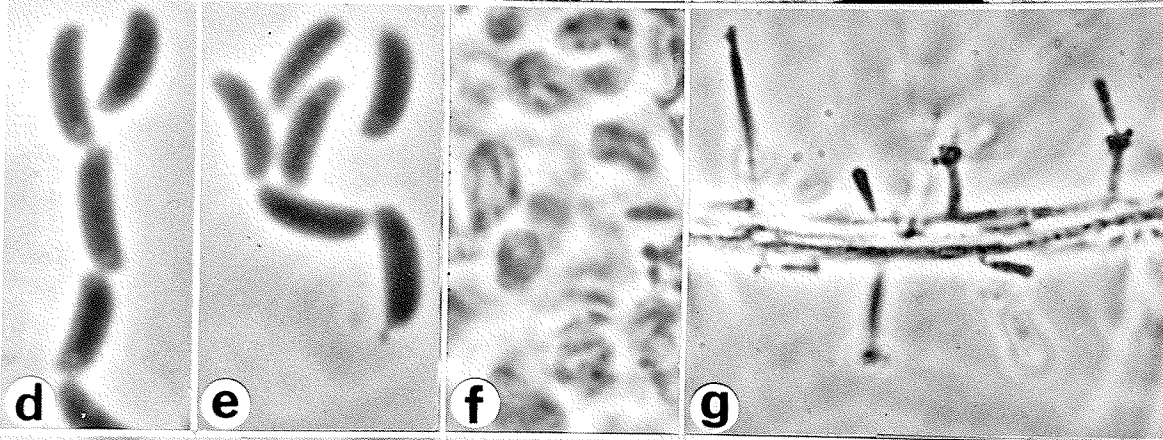
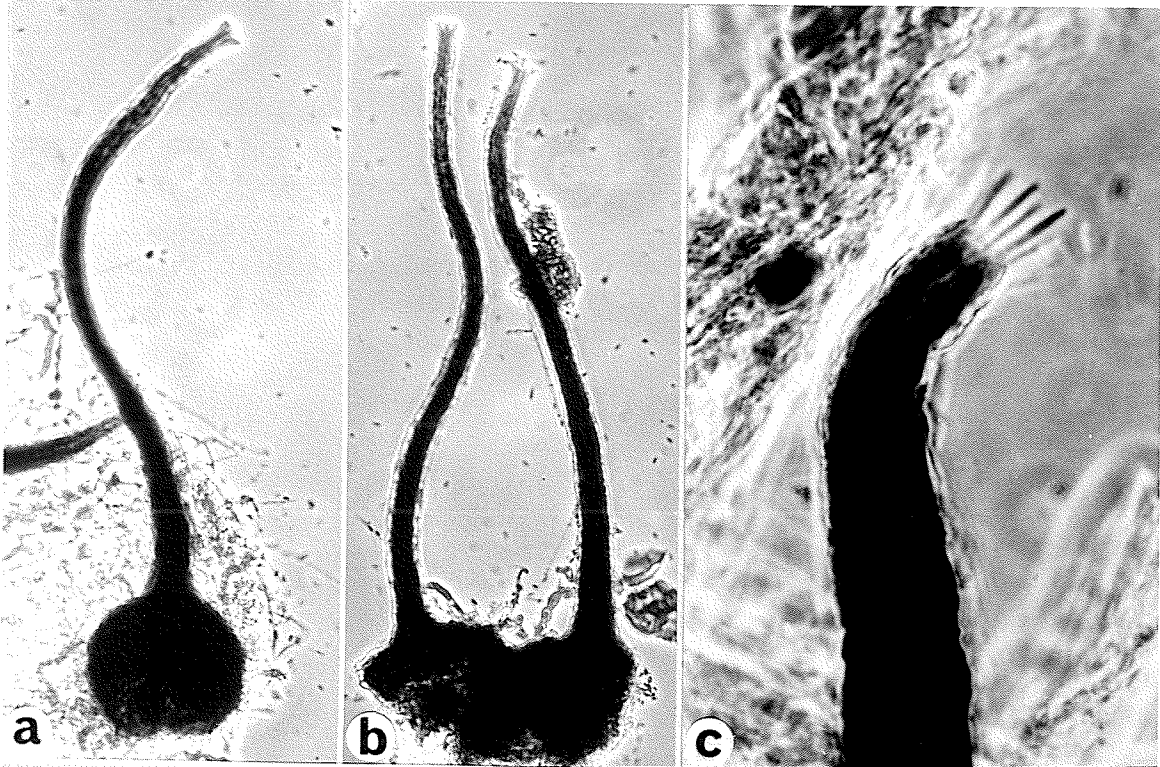
*Colonies* on agar dense, cottony, white. *Mycelium* superficial and immersed, agar pigmented dark gray. *Hyphae* hyaline, thin-walled, septate, 0.5-5.0 $\mu$  wide. *Conidiophores* micronematous or semi-macronematous, mononematous, hyaline, unbranched or branched. *Conidiogenous cells* polyblastic, integrated, terminal or intercalary, determinate but swelling as lateral conidia develop, denticulate; denticles numerous, tapered, 1.0-1.5 $\mu$  wide at the base, 0.7 $\mu$  at the tip, 0.5-1.5 $\mu$  long. *Conidia* hyaline, 1-celled, clavate, narrower at point of attachment, 2.0-8.0 $\mu$  long, 1.0-2.5 $\mu$  thick at the broadest part; first formed conidium terminal, subsequent ones lateral.

Since the perithecia of *C. coronata* and *C. tenella* are similar in size and their ascospores have similar dimensions, these two species could be confused if only

## PLATE XXXI

*Ceratocystis coronata* WIN(M)71-26

- Figs. a-b Perithecia ( $\times 250$ )
- Fig. c Apex of perithecial neck ( $\times 1000$ )
- Figs. d-e Ascospores ( $\times 4000$ )
- Fig. f Asci ( $\times 2000$ )
- Fig. g Mycelium with unbranched conidiophores  
( $\times 1500$ )
- Figs. h-j Tips of conidiogenous cells ( $\times 4000$ )
- Figs. k-l Conidia ( $\times 4000$ )



these characters are considered. However, the ascospores of *C. coronata* have obtuse ends while those of *C. tenella* are more attenuated and thus resemble those of *C. pilifera* (compare Figs. d,e, Plate XXXI and Figs. c & f, Plate XXIX). Further separation of these two species is based on the fact that the ostiolar hyphae of *C. coronata* are narrow and cylindrical while those of *C. tenella* are similar to those of *C. pilifera* in having a wider base and tapering towards narrow tips.

The conidial state of *C. coronata* closely resembles that of *C. capitata* in that cylindrical to clavate conidia are produced on large denticles, which occur laterally, or are terminally clustered, on unbranched conidiophores. The conidial state of *C. tenella*, however, is quite different since conidia are not produced in abundance, are more nearly ovoid in shape, are very narrow at the point of attachment, and in the dried culture of *C. tenella* (BPI-FP-70809) which was examined, denticles do not appear to be present.

Griffin (8) reported on several Ontario collections of a *Ceratocystis* species which had perithecia similar to those of *C. pilifera* except that they were consistently of smaller size. He assumed these represented a slightly variant form of *C. tenella* Davidson (4) and to accommodate them, he in fact emended Davidson's diagnosis of this taxon. The collections to which Griffin referred have

been examined and they are identical to *C. coronata* in all respects. Since, as noted above, *C. coronata* and *C. tenella* are readily separable, Griffin's emendment of the diagnosis of *C. tenella* is considered superfluous and his collections are referred to *C. coronata*.

HOST OF TYPE: *Pinus banksiana*.

TYPE COLLECTION: WIN(M)71-26, Sandilands Forest Reserve, Manitoba, Canada, May 8, 1971.

ADDITIONAL SPECIMENS EXAMINED: Manitoba: WIN(M)67-26 on *Picea mariana*. Ontario: TRTC 34659, 34660 on *P. mariana*, 34599, 39652 on *Pinus strobus*; MFB 7503 on *P. resinosa*, 7504, 7505 on *P. strobus*, 7511 on *P. banksiana*.

7. *Ceratocystis introcitrina* sp. nov. Plate XXXII,

Figs. a-k.

Perithecia in cultura non evoluta, globosa, nigra et opaca, 125-250 $\mu$  diam, centris citrinis; collum nigrum, rectum vel flexuosum, contractum, 300-500 $\mu$  longum, ad basim 35-65 $\mu$  latum, ad apicem 20-25 $\mu$  latum spinulis usque 7.5 $\mu$  longis et 1.0-2.0 $\mu$  diam ornatum; hyphae osti-olares non visae; asci clavati, evanescentes, octospori, 6.5-7.5  $\times$  2.5-3.5 $\mu$ ; ascosporae hyalinae, aseptatae, a latere conspectae lunatae vel cum figura segmenti pomi citri, superne et ab extremo non visae, vagina nulla. Coloniae albae; hyphae 0.7-2.5 $\mu$  diam, hyalinae, superficiales vel immersae, septatae, parietibus tenuibus; conidiophora in synnemata aggregata; synnemata hyalina,

recta, usque 1000 $\mu$  longa et ad basim 225 $\mu$  lata, contracta dein ad apices dilatata; conidia hyalina, oblonga cum extremis obtusis vel clavata, 2.0-3.5(4.0)  $\times$  0.7-1.2(2.0) $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno *Betulae papyriferae*.

*Perithecia* black, cellular detail visible only when the perithecia are bleached, superficial on wood, not produced in agar culture; bases globose, 125-250 $\mu$  in diameter, outer layer of the peridium composed of dark, thick-walled, more or less isodiametric cells, 2.5-7.5 $\mu$  in diameter; contents of venter bright yellow; necks straight or flexuous, tapered, 300-500 $\mu$  long, 35-65 $\mu$  wide at the base, 20-25 $\mu$  at the tip, composed of parallel ascending hyphae, 1.0-2.0(3.0) $\mu$  wide, frequently turning outward at their apices to appear as terminal cells protruding as hyaline cylindrical hairs or spines, up to 7.5 $\mu$  long and 1.0-2.0 $\mu$  wide, especially pronounced at the apex of the neck. *Asci* clavate, 8-spored, evanescent, 6.5-7.5  $\times$  2.5-3.5 $\mu$ . *Ascospores* hyaline, 1-celled, lunate or shaped like the sections of an orange, 2.5-3.5(5.0)  $\times$  1.0-1.5(1.7) $\mu$ ; gelatinous sheath absent. The spores are extruded from the ostiole in a thick whitish mass.

*Colonies* on agar compact, cottony; agar not pigmented. *Mycelium* superficial and immersed. *Hyphae* hyaline, thin-walled, septate, 0.7-2.5 $\mu$  wide. *Conidiophores*

macronematous, synnematous. *Synnemata* hyaline, straight, up to 1000 $\mu$  long, up to 225 $\mu$  wide at the base, tapering upwards then splaying out and capped by a cream-colored slimy head; individual threads 1.5-2.0 $\mu$  wide. *Conidigenous cells* polyblastic, integrated, sympodial, cylindrical, 0.7-1.0 $\mu$  wide. *Conidia* hyaline, oblong with obtuse ends or clavate, 2.0-3.5(4.0)  $\times$  0.7-1.2(2.0) $\mu$ , formed solitarily but becoming aggregated in a slimy head.

The lemon yellow contents of the perithecial venters of *C. introcitrina* readily distinguish this species from all other species of *Ceratozystis*. Although the contents of the venters of the perithecia of *C. magnifica* are also yellow in color, it is a much paler yellow, and this, coupled with the fact that the average diameter of the perithecial bases of *C. magnifica* is more than twice that found in *C. introcitrina*, prevents confusion between these two species.

In the conidial state, *C. introcitrina* produces Graphium-like conidiophores with hyaline synnemata, which are unlike those of any other species of *Ceratozystis* studied to date.

HOST: *Betula papyrifera*.

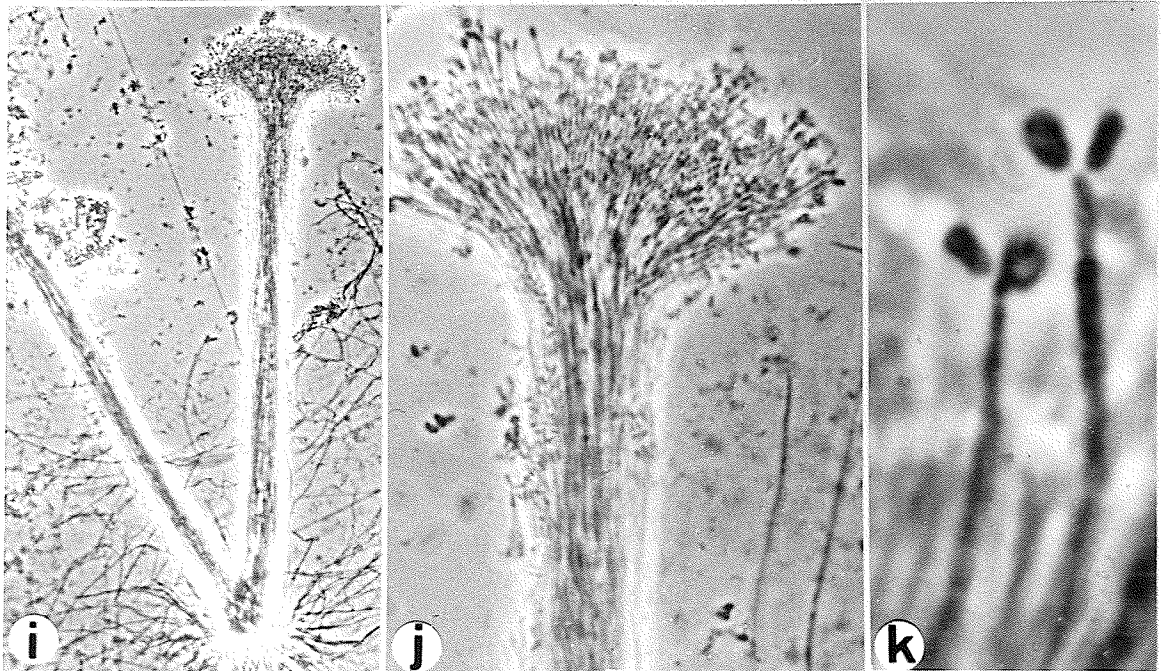
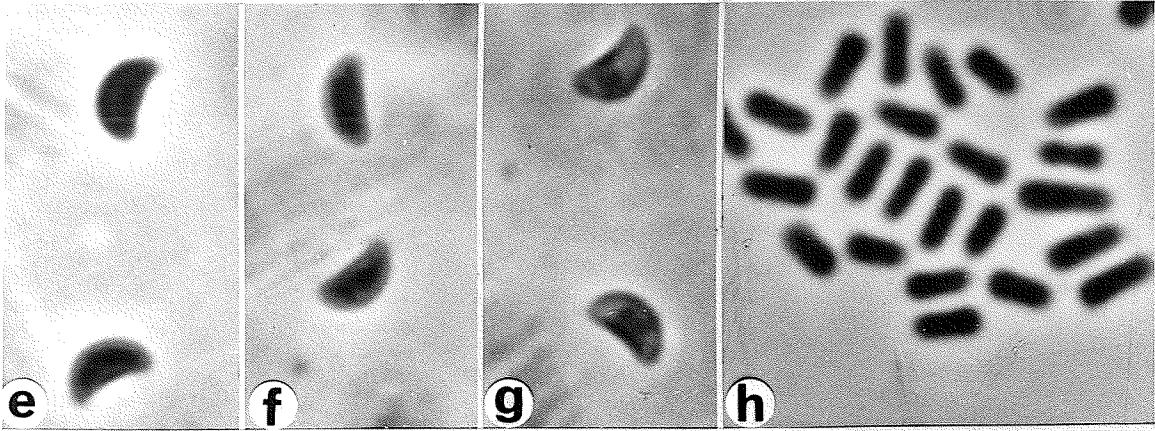
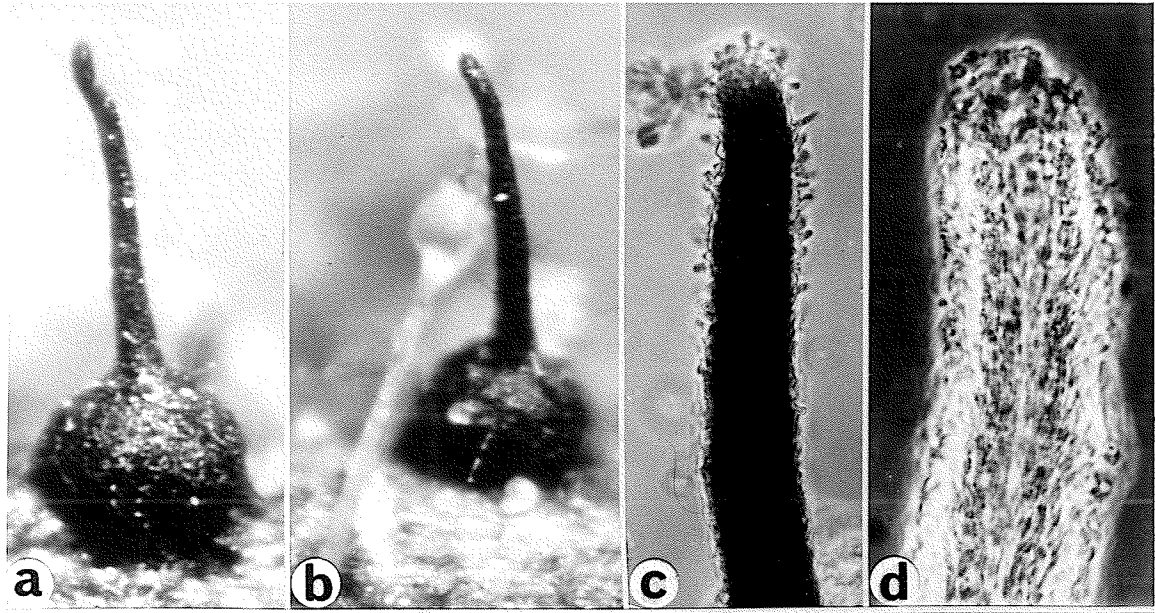
TYPE COLLECTION: WIN(M), Sandilands Forest Reserve, Manitoba, Canada, June 9, 1969.



## PLATE XXXII

*Ceratocystis introcitrina* WIN(M) 69-47

- Fig. a Perithecium on wood ( $\times 75$ )
- Fig. b Perithecium on wood, with hyaline coremium  
in foreground ( $\times 75$ )
- Fig. c Perithecial neck ( $\times 500$ )
- Fig. d Perithecial neck, bleached to show cell  
detail ( $\times 1000$ )
- Figs. e-g Ascospores ( $\times 4000$ )
- Fig. h Conidia ( $\times 4000$ )
- Fig. i Hyaline synnemata ( $\times 250$ )
- Fig. j Apex of synnema ( $\times 500$ )
- Fig. k Conidiogenous cells ( $\times 4000$ )



8. *Ceratocystis leucocarpa* Davidson, Mycopathol.

Mycol. Appl. 28:276. 1966.

MANITOBA HOSTS: *Abies balsamea*, *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-17 on *Abies balsamea*, 69-30 on *Picea mariana*, 71-10 on *Pinus banksiana*.

British Columbia: WIN(M) 71-30 on *Pseudotsuga menziesii*.

9. *Ceratocystis minor* (Hedgc.) Hunt, Lloydia 19:47. 1956.

Fig. d, Plate XXIX.

=*Ceratostomella minor* Hedgc., Mo. Bot. Gard. Ann.

Rpt. 17:74. 1906.

=*Ophiostoma minus* (Hedgc.) H. & P. Sydow, Ann. Mycol.

17:43. 1919.

=*Ceratostomella exigua* Hedgc., Mo. Bot. Gard. Ann.

Rpt. 17:76. 1906.

=*Ceratostomella pini* Münch, Naturw. Ztschr. f Forst.

u Landw. 5:541. 1907.

=*Ceratostomella pseudotsugae* Rumb., Jour. Agr. Res.

52:431. 1936.

The small perithecia with short conical necks, the crescent-shaped ascospores, and the intense blue-black stain associated with this species on conifers all facilitate rapid diagnosis. In Manitoba, *C. minor* is an early colonizer of recently-felled jack pine and is probably the most important blue-staining organism.

MANITOBA HOSTS: *Abies balsamea*, *Picea mariana*, *Pinus*

*banksiana*, *P. resinosa*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-15, 69-43, 70-02, 71-03, 71-07, 71-09, 71-17, 71-21, 71-10. Ontario: TRTC 39557, 39565, 39563, 39535, 39567, 36269, 36270, 36271; MFB 7369, 7375, 7382, 7423, 7431.

10. *Ceratocystis narcissi* (Limber) Hunt, *Lloydia* 19:

50. 1956. Fig. g, Plate XXIX.

=*Ophiostoma narcissi* Limber, *Phytopath.* 40:493. 1950.

A single collection of *C. narcissi* has been made by the author from daffodil bulbs grown in Manitoba. This species is readily identified by its broadly ellipsoid ascospores and by the fact that it appears to be specific to narcissus bulbs. This fungus grows well on pabulum agar and on autoclaved birch, producing an abundance of perithecia on both media.

MANITOBA HOST: *Narcissus* sp.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-55.

11. *Ceratocystis perfecta* Davidson, *Mycologia* 50:665.

1958. Fig. e, Plate XXIX; Figs. g-i, Plate XXX.

The ascospores of *C. perfecta* are similar in size and morphology to those of *C. pilifera*. The smaller perithecia with light-colored bases serve to separate *C. perfecta* from *C. pilifera*. The two species also differ in their conidial states: *C. perfecta* produces large clavate conidia with a broad base on sympodial conidiogenous cells, whereas *C. pilifera* produces large

clavate conidia, which are narrow at their point of attachment, on denticulate conidiogenous cells which are swollen at the tips.

MANITOBA HOST: *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 71-27. United States: ATCC 15458, 12969.

12. *Ceratocystis piceae* (Münch) Bakshi, Brit. Mycol. Soc. Trans. 33:113. 1950.

≡ *Ceratostomella piceae* Münch, Naturw. Ztschr. f. Forst. u. Landw. 5:547. 1907.

≡ *Ophiostoma piceae* (Münch) H. & P. Sydow, Ann. Mycol. 17:43. 1919.

= *Ceratostomella querci* Georgew., Acad. des Sci. Compt. Rend., Paris, 183:759. 1926.

The constant association between the perithecia and the *Graphium* state of *C. piceae* is a diagnostic aid in identification.

MANITOBA HOSTS: *Picea mariana*, *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-04, 68-06, 69-11, 69-13, 69-35. Ontario: MFB 7414, 7422, 7427.

13. *Ceratocystis pilifera* (Fries) C. Moreau, Revue de Mycologie, Suppl. Colonial 17:22. 1952. Fig. f, Plate XXIX.

≡ *Sphaeria pilifera* Fries, Syst. Mycol. 2:472. 1822.

≡ *Ceratostoma piliferum* (Fries) Fuckel, Symb. Mycol., p. 128. 1869.

- ≡*Ceratostomella pilifera* (Fries) Winter, Rabenh.  
Kryptogamen-Flora 1:252. 1887.
- ≡*Linostoma piliferum* (Fries) von Höhnelt, Ann. Mycol.  
16:91. 1918.
- ≡*Ophiostoma piliferum* (Fries) H. & P. Sydow, Ann.  
Mycol. 17:43. 1919.
- =*Ceratostomella coerulea* Münch. Naturw. Ztschr. f.  
Forst. u. Landw. 5:561. 1907.
- =*Ceratostomella echinella* Ell. & Ev. emend Hedgc.,  
Mo. Bot. Gard. Ann. Rpt. 17:69. 1906.
- [For further synonymy see Griffin (8)]

*C. pilifera* occurs widely on both coniferous and deciduous tree species. A thorough discussion of *C. pilifera* appears in Griffin's paper on the genus *Ceratocystis* in Ontario (8).

MANITOBA HOSTS: *Abies balsamea*, *Populus tremuloides*,  
*Picea mariana*, *Pinus banksiana*, *Thuja occidentalis*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 68-22, 68-26, 69-12,  
69-14, 69-24, 69-26, 69-28, 69-17, 70-06. Ontario: MFB  
7513, 7514, 7528.

14. *Ceratocystis pseudominor* sp. nov. Plate XXXIII,  
Figs. a-k.

Perithecia globosa, atrobrunnea vel nigra, 65-120 $\mu$   
diam, spinulis pallido-brunneis usque 75 $\mu$  longis et 2.0-  
2.5 $\mu$  latis ad basim ornata; collum atrobrunneum vel  
nigrum pallidius versus apicem, contractum, rectum vel

curvatum, 65-125 $\mu$  longum, ad basim 15-35 $\mu$ , ad truncatum apicem 6.0-8.5 $\mu$  latum; hyphae ostiolaris hyalinae, rectae vel curvatae, divergentes, 5.0-20 $\mu$  longae, ad basim 1.0-1.5 $\mu$  diam; asci non visi; ascosporae hyalinae, aseptatae, a latere conspectae lunatae cum extremis obtusis, superne oblongae vel contractae cum extremis obtusis, ab extremo non visae, 2.5-4.0(4.5)  $\times$  0.7-1.2 $\mu$ , vagina nulla. Coloniae albae; hyphae in agar 0.7-10 $\mu$  diam, hyalinae, superficiales vel immersae, in ligno 0.7-8.0 $\mu$  diam, brunneae vel ochraceae; conidiophora in agar hyalina, in ligno ochracea, simplicia vel furcata; conidia hyalina, aseptata, acropleurogena, clavata vel pyriformia vel ampulliformia, 2.5-5.5(8.0)  $\times$  1.5-4.0(4.5) $\mu$ , solitaria dein in muco aggregata.

Hab. in ligno *Pseudotsugae menziesii*.

*Perithecia* superficial on wood, in culture developing on superficial mycelium or embedded in the agar medium; bases dark brown to black, globose, 65-120 $\mu$  in diameter, usually ornamented with a few light brown spines up to 75 $\mu$  long, blunt at the tips, 2.0-2.5 $\mu$  wide at the base; outer layer of the peridium composed of dark, thick-walled, polygonal cells, 3.0-10 $\mu$  in diameter; necks dark brown to black, paler near the apex, tapered, straight or curved, 65-125 $\mu$  long, 15-35 $\mu$  wide at the base, 6.0-8.5 $\mu$  at the tip, composed of thick-walled, laterally-fused, septate hyphal elements, 2.0-2.5 $\mu$  wide

which terminate in a truncate apex; ostiolar hyphae, when present, hyaline, tapered, straight or curved, divergent, 6-12 in number, 5.0-20 $\mu$  long. *Asci* not seen. *Ascospores* hyaline, 1-celled, lunate with obtuse ends, 2.5-4.0(4.5)  $\times$  0.7-1.2 $\mu$ ; the spores are extruded from the ostiole in a hyaline droplet.

Perithecia develop on autoclaved wood and on agar media in 1-2 weeks.

*Colonies* on agar effuse. *Mycelium* superficial and immersed, agar unevenly pigmented pale to dark brown. *Hyphae* in agar culture hyaline, thin-walled, septate, 0.7-10 $\mu$  wide; on wood, mid brown to ochraceous, thick-walled, septate, 1.0-8.0 $\mu$  wide. *Conidiophores* microne-matous or semi-macronematous, mononematous, unbranched or branched, hyaline on agar, ochraceous on wood, tapered, 2.0-3.0 $\mu$  wide at the base, up to 60 $\mu$  long, including the conidial head. *Conidiogenous cells* hyaline, polyblastic, integrated, sympodial, subulate, 0.7-2.0 $\mu$  wide at the tip. *Conidia* hyaline, acropleurogenous, clavate, pyriform, or ampulliform, 2.5-5.5(8.0)  $\times$  1.5-4.0(4.5) $\mu$ , approximately 1.0 $\mu$  thick at point of attachment, formed solitarily but becoming aggregated in a slime droplet.

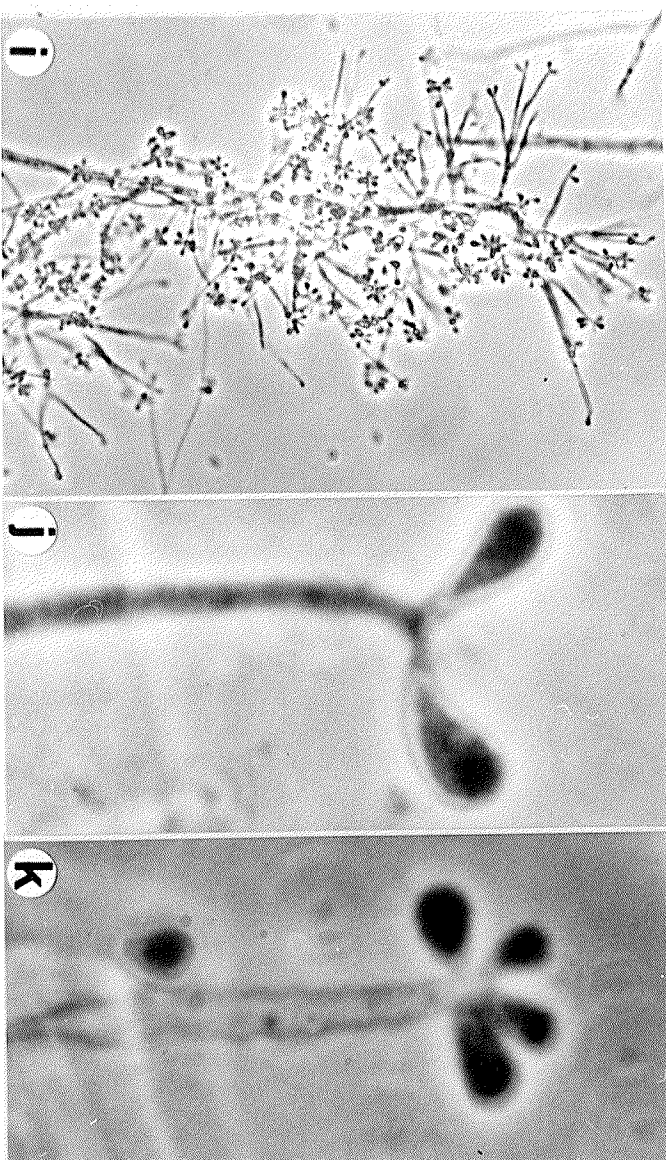
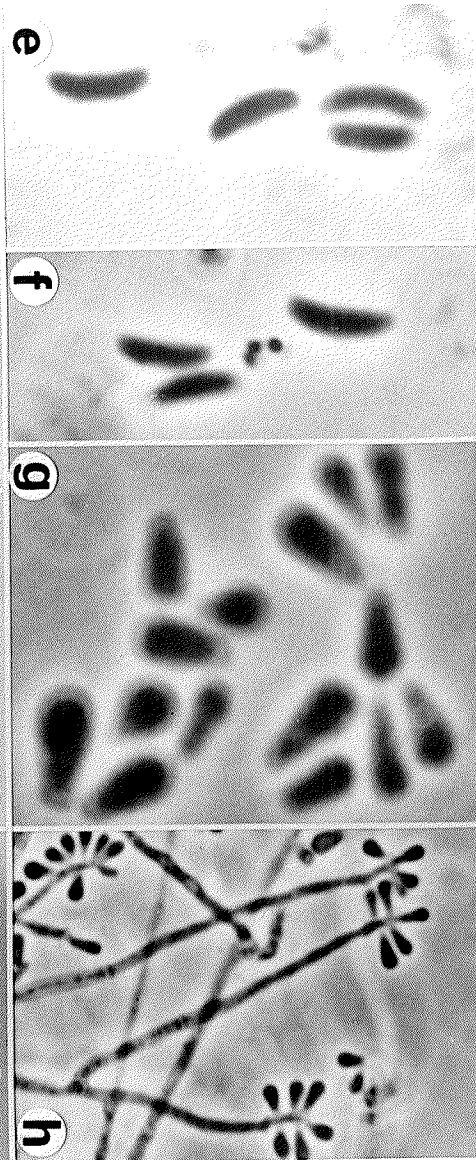
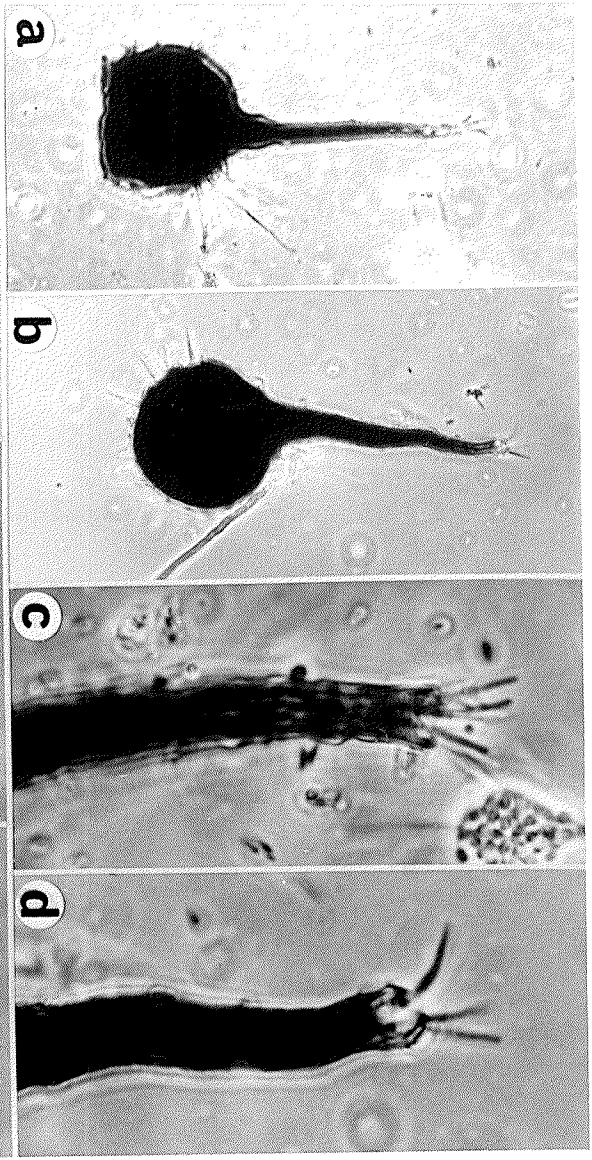
Shorter ascospores with obtuse ends distinguish *C. pseudominor* from *C. minor*. *C. nigrocarpa* produces ascospores which are similar in size and shape to those



## PLATE XXXIII

*Ceratocystis pseudominor* WIN(M)71-30

- Figs. a-b Perithecia ( $\times 250$ )
- Figs. c-d Apices of perithecial necks ( $\times 1000$ )
- Figs. e-f Ascospores ( $\times 4000$ )
- Fig. g Conidia ( $\times 4000$ )
- Fig. h Conidiophores ( $\times 1500$ )
- Fig. i Mycelium with branching conidiophores  
( $\times 1500$ )
- Figs. j-k Conidiogenous cells ( $\times 4000$ )



of *C. pseudominor*, but the perithecia of *C. nigrocarpa* have smaller bases. Also, the perithecial necks of the latter species are longer and wider, and are funnel-shaped at the apex.

Both the conidial states and the cultural characteristics of *C. minor*, *C. nigrocarpa*, and *C. pseudominor* are very similar, which indicates that these are probably closely related species.

HOST: *Pseudotsuga menziesii*.

TYPE COLLECTION: WIN(M)71-30, Seymour Arm, British Columbia, Canada, August 26, 1971 (with *C. allantospora*, *C. davidsonii*, *C. europhioides*, *C. fasciata*, *C. olivacea*).

15. *Ceratocystis tenella* Davidson, Mycologia, 50:666.

1958. Figs. b-c, Plate XXIX; Figs. d-f, Plate XXX.

Two collections were made from jack pine in Manitoba of a species of *Ceratocystis* which closely resembles *C. tenella* in perithecial morphology, especially the structure of the neck apex. The ascospores of the Manitoba material differ slightly in that they are nearly allantoid in shape, whereas the ascospores of *C. tenella* are more lunate (compare Figs. b and c, Plate XXIX). In culture, the Manitoba species produces copious amounts of conidia, whereas *C. tenella* is reported to produce conidia sparingly. Further investigation may provide a justifiable basis for separation of these collections, however, at present, *C. tenella* appears to be the best

taxon in which these collections can be placed.

MANITOBA HOST: *Pinus banksiana*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 71-07, 71-27.

United States: BPI-FP 70809 (TYPE).

16. *Ceratocystis tremulo-aurea* Davidson, Mycologia  
56:794. 1964. Plate XXIX, Fig. h.

*C. tremulo-aurea* is readily distinguished by its  
lunate ascospores. In culture, this species is dis-  
tinctive in that it pigments malt agar yellow and  
pablum agar a buff color.

MANITOBA HOST: *Populus tremuloides*.

SPECIMENS EXAMINED: Manitoba: WIN(M) 69-64. United States:  
ATCC 15459.

The following species have not been found in Mani-  
toba but have been examined for purposes of comparison  
and are considered to belong to the Pilifera Group:

*Ceratocystis brunnea* Davidson, Mycologia 50:663.  
1958. SPECIMEN EXAMINED: BPI-FP 70806.

*Ceratocystis megalobrunnea* Davidson, Mycologia 56:  
796. 1964. SPECIMEN EXAMINED: ATCC 15493.

*Ceratocystis stenoceras* (Robak) C. Moreau, Revue de  
Mycologie, Suppl. Colonial, 17:22. 1952. SPECIMEN  
EXAMINED: TRTC Culture.

*Ceratocystis tetropii* (Mathiesen) Hunt, Lloydia  
19:45. 1956. SPECIMEN EXAMINED: AM-K 245-V-6.

*Ceratocystis ulmi* (Buism.) C. Moreau, Revue de Mycologie, Suppl. Colonial, 17:22. 1952. SPECIMEN EXAMINED: MFB 7446.

The following species have not been examined but, from the descriptions appearing in the literature, are probably referable to the Pilifera Group:

*Ceratocystis abiocarpa* Davidson, Mycopathol. Mycol. Appl. 28:273. 1966.

*Ceratocystis araucariae* Butin, Can. J. Bot. 46:62. 1968.

*Ceratocystis distorta* Davidson, Mycologia 63:10. 1971.

*Ceratocystis gossypina* Davidson, Mycologia 63:12. 1971.

*Ceratocystis perparvispora* Hunt, Lloydia 19:46. 1956.

*Ceratocystis cana* (Münch) C. Moreau, Revue de Mycologie, Suppl. Colonial, 17:22. 1952.

*Ceratocystis nigrocarpa* Davidson, Mycopathol. Mycol. Appl. 28:276. 1966.

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