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CONTENTS

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A TAXONOMIC REVISION OF THE PROTOMYCETALES[1]

M. SUGUNAKAR REDDY[2]

Department of Plant Pathology
Kansas State University, Manhattan, Kansas 66506

AND

CHARLES L. KRAMER

Division of Biology
Kansas State University, Manhattan, Kansas 66506

SUMMARY

Five genera, including the newly segregated genus *Burenia*, are recognized as members of the single family of the Protomycetales. Keys are provided to the genera and the nineteen recognized species, including one new species, of Protomycetales.

INTRODUCTION

From the time Unger (1833) described the first species of *Protomyces*, *P. macrosporus*, the taxonomic position of these fungi has remained uncertain. De Bary (1887) treated them as a group alongside the Ustilaginaceae, as did Ward

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[1] Contribution No. 582, Department of Plant Pathology and No. 1192, Division of Biology, Kansas Agricultural Experiment Station. This study was supported in part by the Kansas Agricultural Experiment Station and NSF grant GB-14972.

[2] Present address: Department of Plant Pathology, College of Agriculture, Andhra Pradesh University, Rajendranagar, Hyderabad, India.

(1887) and Plowright (1889), connecting them through the Chytridiaceae to the Phycomycetes. Van Tieghem (as given in Sappin-Trouffy, 1897) in his Traite General de Botanique was the first to relate the characteristics of the Protomycetaceae to the Taphrinaceae. Brefeld and Tavel (1891) included *Ascoidea*, *Thelobolus* and *Protomyces* into a new group: Hemiasci, which they considered as a link between the Phycomycetes and the Ascomycetes. Popta (1899) however, did not include *Protomyces* in the Hemiasci, but clearly placed it among the higher Phycomycetes.

Considering the vesicle, within which the ascospores are produced, to be a synascus (a structure containing many asci without walls) von Buren (1922) agreed with Juel (1921) in linking the Hemiasci, *Protomyces*, *Protomycopsis*, *Volkartia* and *Taphridium* with the Taphrinaceae. Gäumann and Dodge (1928) treated the Taphrinaceae and Protomycetaceae as families of the order Taphrinales, based on the assumption that the ascogenous cells of Protomycetaceae are homologous to the ascogenous cells of the Taphrinaceae. Fitzpatrick (1930) disagreed; he considered the Protomycetaceae as having phycomycetous affinities. Bessey (1950) placed the group as an order in the Phycomycetes. Martin (1950) placed the Protomycetaceae as a family in the Taphrinales while Gäuman (1964) and Kramer (1973) treated the group as an order in the Hemiascomycetes.

Much of the confusion has resulted from the differences in opinion on the nature of the vesicle that is produced from thick walled, multinucleate resting spores (herein refered to as the ascogenous cells) in most species and on the formation of the ascospores. In addition, ascogenous cells generally have been referred to in the literature as chlamydospores, indicating an asexual function. However, in some species the walls are not thick, germination may occur without a rest period in some and those that have been studied cytologically are believed to be involved in a sexual phase (von Buren, 1915; Valadon *et al.*, 1962; Pavgi and Mukhopadhyay, 1970).

The Protomycetales have received little attention as a group and a full taxonomic treatment of them is lacking. The studies of von Buren (1915, 1922) did not consider the species on a worldwide basis. We reexamined all available material in light of existing knowledge and attempted to provide a basis and stimulation for further collection and study of these fungi.

Most studies, on which our discussions are based, have been conducted on only one or a few species. More extensive studies on ascospore formation, cytology, cell composition, cultural characters, nutritional physiology, pathogenicity and probable saprophytic stages in nature are needed for a better understanding of the inter- as well as intrarelationships of these organisms.

THE ORGANISM

Cytology and Endospore Formation

The first work on the cytology and development of *Protomyces* was done by Sappin-Trouffy (1897) and Popta (1899). However, it was von Buren (1915) who proposed the first concept regarding the nature of the vesicle. He assumed that nuclear fusion occurred in the young ascogenous cells (now known to occur in some species in conjugated ascospores) and that when the ascogenous cells germinated the diploid nuclei became located in a peripheral layer within the vesicle. He proposed that the diploid nuclei divided meiotically to produce four haploid ascospores and that each tetrad resulting from a single spore mother cell was homologous to an ascus. He referred to the tetrads as naked asci and to the entire vesicle as a synascus of many naked asci. This concept of ascospore formation and the nature of the vesicle has been confirmed by Pavgi and Mukhopadhyay (1970) for *Protomyces macrosporus*.

Establishment of Diplophase

Immediately following their liberation, ascospores may conjugate in pairs. Conjugation was observed by many earlier workers, including De Bary (1887), von Buren (1915) and Tubaki (1957). In 1962, Valadon *et al.*, demonstrated bipolar heterothallism in *Protomyces inundatus*, though nuclear fusion in the conjugated cells was not demonstrated microscopically until later (Venitt *et al.*, 1968). Both the haploid and diploid cells are capable of multiplying by budding in a yeastlike manner (Valadon *et al.*, 1962) similar to that in *Taphrina*. This yeastlike phase can be maintained easily in culture (Tubaki, 1957), but nothing is known about this stage in nature.

The Parasitic Phase

Working with haploid and diploid cultures of *Protomyces inundatus* Valadon *et al.* (1962) showed that only the fused ascospores or cells derived from them were infective, producing mycelium on the host surface (the mycelium eventually penetrating the epidermis). Unfused ascospores budded heavily without producing mycelium, so were incapable of penetration and infection. Von Buren (1915) observed spores producing a germ tube that penetrated directly between the epidermal cells but not through stomata.

The multinucleate septate mycelium (Fig. 1) invades the host tissues intercellularly penetrating throughout all tissues. Although tending to avoid xylem vessels, the mycelium commonly concentrates around the vascular bundles (von Buren, 1915).

Hypertrophy and hyperplasia of the infected tissues generally results in the formation of distinct galls or swellings. Gall formation is most common in *Protomyces* and less common or absent in other genera. Leaves, stems, flowers, fruits and other aerial parts of plants may be infected, although some species of the fungus prefer certain host parts. Several species of *Protomyces* tend to localize along the veinlets, veins and midrib; occasionally they are responsible for blisterlike swellings in the interveinal areas of the leaf lamina. Species of *Protomycopsis* cause leaf spots which may be only slightly swollen. The genera *Taphridium* and *Volkartia* (except for *Taphridium cicutae*) cause lesions that may involve the entire leaf lamina.

Formation of Ascogenous Cells

Ascogenous cells may be formed intercalaraly (Figs. 2-4) or terminally (Fig. 5) by enlargement of the mycelial cell which in most species is accompanied by the formation of a thick cell wall. The exact process by which walls of

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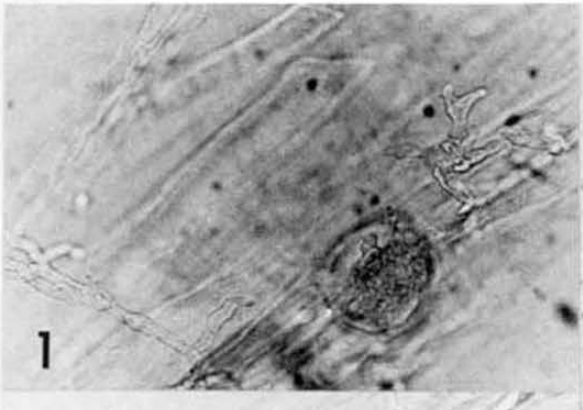
Figs. 1-7. 284X. 1, *Protomyces macrosporus*, hyphae. 2-3, *P. macrosporus* intercalary spore formation; 2, arrow indicates young spore; 3, arrows indicate hyphal fragments on either end. 4, *P. pachydermus*, intercalary spore formation. 5, *Protomycopsis belledis*, terminal spore formation. 6, *Protomyces macrosporus*: a. germinating ascogenous spore; b. vesicle. 7, *Volkartia rhaetica*, germinating ascogenous spore (a) and vesicle (b) with ascospores.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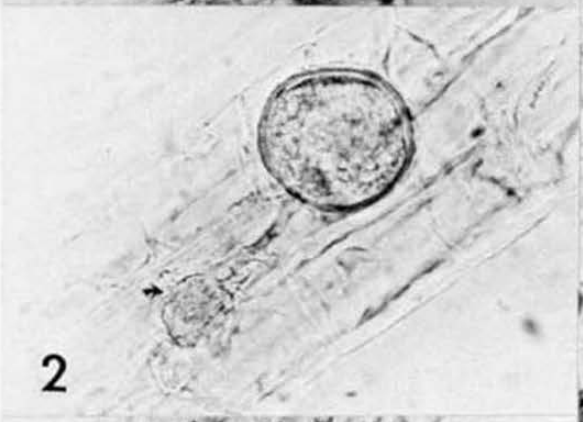
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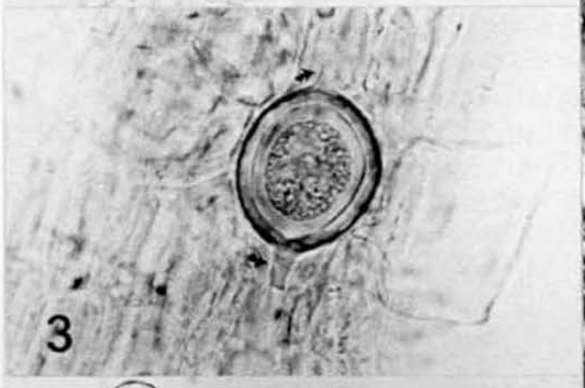
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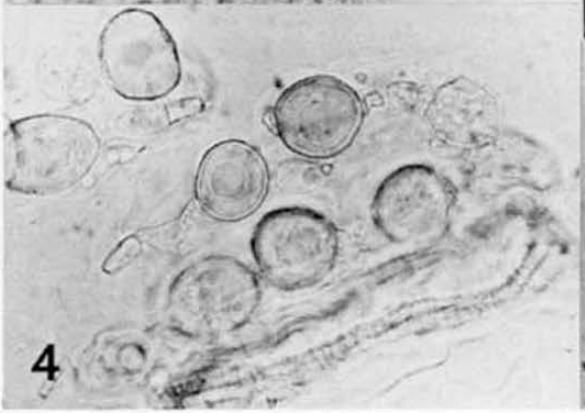
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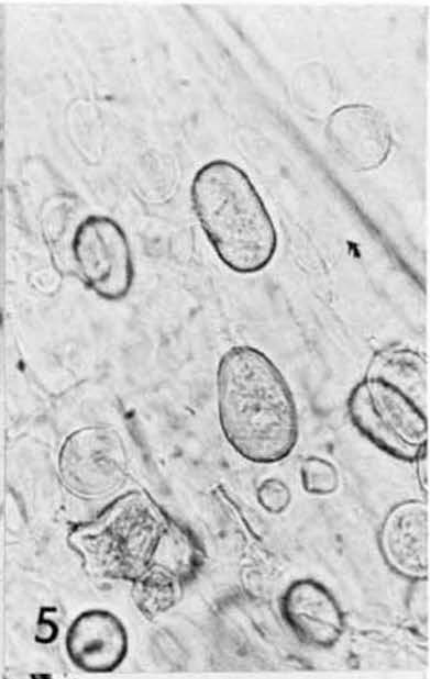
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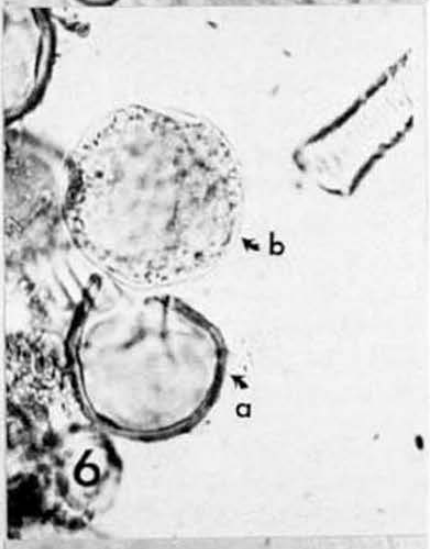
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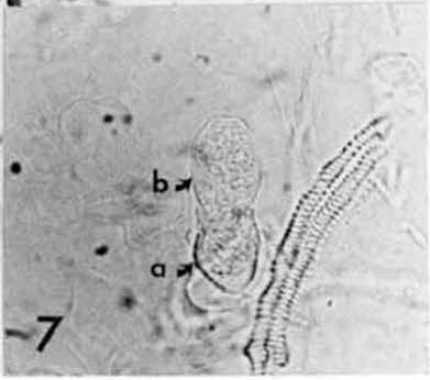
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the ascogenous cells are formed, however, has not been demonstrated.

The ascogenous cells are spherical to subspherical but may be somewhat angular due to pressures from the surrounding host tissue. Average size ranges from 17 to 73 μ in diameter, although average diameter seems to be relatively constant for a given species.

In *Protomyces* and *Protomycopsis*, ascogenous cells occur scattered throughout the host tissues; in *Taphridium* (except for *Taphridium cicutae*) and *Volkartia*, ascogenous cells are produced in a single layer, usually just below the upper (rarely inside the lower) epidermis.

Opinions on the layers and thickness of ascogenous cell walls differ considerably. For *Protomyces*, Sappin-Trouffy (1897) described the wall as three layered. Von Buren (1915) referred to the layers as exosporium (generally thick), mesosporium (generally thin), and endosporium (of variable thickness). Most other workers have described the wall as two layered (Davis, 1907; Sawada, 1928). Because the so-called inner wall often has been interpreted as including a layer of peripheral cytoplasm (Davis, 1907), various wall thicknesses have been reported. Using the electron microscope, Nozu and Yamamoto (1970) demonstrated that the wall of *Protomyces inouyei* is composed of two layers. We found that the apparent increase in the thickness of the ascogenous cell wall in *Protomyces macrosporus* was proportionate to the length of time the specimen was boiled in water. The increase was still greater when ascogenous cells were boiled in KOH.

The ascogenous cells of all genera are unicellular and multinucleate, the number of nuclei per ascogenous cell being about 50 for *Protomyces macrosporus* (Pavgi and Mukhopadhyay, 1970) and 100 to 200 for *Protomyces inundatus* (Valadon *et al.*, 1962).

Ascogenous Cell Germination

In *Protomyces* and *Protomycopsis*, a rest period is required before the ascogenous cell will germinate. Tubaki (1957) found that seven months was required for three species of *Protomyces*. *Protomyces inundatus*, an exception, will germinate immediately, as will all species of *Taphridium* and *Volkartia* that have been studied.

When the ascogenous cell begins to germinate, the homogeneous protoplasm differentiates into a central and marginal zone followed first by the appearance of vacuoles in the central portion and gradually toward the marginal zone. In those species that form vesicles, the ascogenous cell wall splits, allowing the vesicle to protrude (Fig. 6). The wall of the vesicle is the so-called endosporium. The vacuoles then begin fusing from the center, finally resulting in a large central vacuole which forces the protoplast to become concentrated in a thin peripheral layer. The vesicle is fairly constant in shape and size in some species, but in others may vary in length as much as threefold (von Buren, 1915, 1922; Gupta and Singa, 1964; Tubaki, 1957).

Once the vesicle is fully extended, the nuclei become arranged in a single peripheral layer. Pavgi and Mukhopadhyay (1970) stated that in *Protomyces macrosporus* this is followed by "radial septation" resulting in a single layer of uninucleate cells each of which undergoes meiosis to produce four haploid spores. They reported the chromosome number in *P. macrosporus* was two (n = 2).

After they form, the ascospores accumulate at the apex of the vesicle. Not all the cytoplasm is used to form ascospores. The epiplasm functions in producing excessive turgor that causes the vesicle to rupture, ejecting the contents in a single mass (von Buren, 1915). As soon as the ascospores (measuring 4.5 x 3 μ in *P. macrosporus*) are liberated, they unite in pairs by protruding small appendages. Copulation of ascospores has been observed in the genera *Protomyces*, *Taphridium* and *Volkartia* (Maire, 1907) but not in *Protomycopsis* (Fitzpatrick, 1930).

In some species, vesicles are not produced. Instead ascospores are formed within the ascogenous cell (Juel, 1902; Dangeard, 1906; Valadon *et al.*, 1962). This type of germination is characteristic of species of *Taphridium* and the new genus described below. In *Volkartia*, germination also occurs immediately but a vesicle similar to that of *Protomyces* and *Protomycopsis* forms (Fig. 7). Maire (1907), who described *Volkartia*, found that the ascospores sometimes formed within the ascogenous cell before the rupture of the external wall and at other times in the vesicle. The arrangement of germinated ascogenous cells with vesicles filled with ascospores in the genus *Volkartia* resembles in appearance the ascogenous layer of asci in species of *Taphrina*.

Mixia differs from all these in that the wall of a multinucleate cell of the mycelium extends outward in the form of a papilla. There is no rupturing of the ascogenous cell wall and while the papilla is elongating, a columella forms delimiting the sporogenous protoplast from a sterile central portion. Whether or not ascospore formation is similar to that reported for *Protomyces* is not known.

Cell Wall Composition

Von Buren (1915) considered the cell walls of *Protomyces* to be composed of cellulose on the basis of the reaction with chloride of zinc. Valadon *et al.* (1962), considering this method of testing for cellulose being unreliable, determined the wall composition by chemical analysis. Working with *Protomyces inundatus*, they showed that the cell wall is composed of neither cellulose nor chitin but glucan, a polysaccharide also found in the cell wall of yeasts. In addition they also detected the presence of an alkali-soluble polysaccharide that produced mannose on hydrolysis, another similarity with cell wall composition of yeasts.

Host Specialization

The host range of these fungi is restricted: *Protomyces* occurs on Umbelliferae and Compositae; *Protomycopsis* on Compositae; *Taphridium* on Umbelliferae; and *Volkartia* on Compositae. *Mixia*, which is doubtfully placed here, occurs on the fern *Osmunda*.

Von Buren (1922) used the results of cross inoculation studies of various isolates on different host species to differentiate species and form-species of the pathogen. Several of the species he created, based on pathogenicity, are forms that are morphologically similar and produce identical symptoms on closely related hosts. Also, there have been many species described as members of the Protomycetales based primarily on pathogenicity that have been found to belong to other groups such as the Ustilaginales.

Gupta and Sinha (1964), who studied the variation in pathogenicity of several isolates of *Protomyces macrosporus* from *Coriandrum sativum* on several cultivars, recognized three categories in their isolates based on differential reaction.

TAXONOMY

ORDER PROTOMYCETALES

PROTOMYCETALES Gäumann, Die Pilze, Birkhauser Verlag, Basel und Stuttgart 107. 1964.

Fungi causing galls and lesions on stems, leaves, and petioles of higher plants. Mycelium intercellular, septate, and multinucleate in a diploid state. Ascocarp lacking. Thick-walled multinucleate ascogenous cells produced intercalaraly or terminally on the mycelium throughout the host tissues or in a single subepidermal layer; germinating either immediately or after a period of rest, with or without the production of a vesicle. Ascospores resulting from meiotic division of the diploid nuclei; in some the entire contents forcibly discharged; usually fusing in pairs; budding in a yeastlike manner; only diploid cells capable of infection.

FAMILY PROTOMYCETACEAE

PROTOMYCETACEAE De Bary in Saccardo, Syll. Fung. 17: 317. 1905.

There is a single family with the characters of the order.

KEY TO GENERA OF PROTOMYCETACEAE

1. Ascogenous cells formed throughout the tissues of the host 2
1. Ascogenous cells formed in a single layer beneath the host epidermis 4

2. Ascogenous cells forming ascospores without a rest period; vesicle not produced . . . . . *BURENIA*
2. Ascogenous cells requiring a rest period before germinating to form a vesicle in which the ascospores are formed 3

3. Ascogenous cells produced intercalaraly, smooth walled . . . . . *PROTOMYCES*
3. Ascogenous cells produced terminally, rough walled at least when young . . . . . *PROTOMYCOPSIS*

4. Ascospores produced within the ascogenous cell; vesicle not produced . . . . . .*TAPHRIDIUM*
4. Ascospores produced within the ascogenous cell or inside the vesicle; vesicle always produced. . . . . *VOLKARTIA*

GENUS BURENIA

Burenia gen. nov.

Membra paracitica in Umbelliferis facientia pustulas tumores in caulibus v. in foliis. Cellula ascogenicae formulatae per telas; sphaericae v. ellipticae; laete flavidobrunneae; habentes parietes leves; statim germinates sine quite. Ascosporae in situ productis; non vesiculis productis.

Members parasitic on Umbelliferae causing blisters or swellings on stems and leaves. Ascogenous cells formed throughout the tissues; spherical to elliptical; light yellowish-brown; smooth-walled; germinate immediately without a rest period. Ascospores formed within the ascogenous cells; vesicle not produced.

TYPE SPECIES: *Taphridium cicutae* Lindroth

The two species for which this new genus has been created previously belonged to the genera *Protomyces* and *Taphridium*. The fungus referred to as *Protomyces inundatus* was first described as *P. macrosporus* (Sappin-Trouffy, 1897). However, in 1883, Phillips identified (without description) a specimen as *P. helosciadii*, which we examined and found to be identical to *P. inundatus*.

The drawing of the fungus in Sappin-Trouffy's paper clearly shows a different method of endospore formation than that of *P. macrosporus*. Because the ascogenous cell produces ascospores without a rest period, Dangeard (1906) proposed the name *P. inundatus*. Based on its *Taphridium*-like germination of the ascogenous cell, von Buren (1915) transferred the species to *Taphridium*. However, after finding that a few ascogenous cells also germinated in a *Protomyces*-like manner (producing ascospores within a vesicle after a period of rest), von Buren (1918) placed it back in *Protomyces*. Valadon *et al.* (1962), who studied

the fungus intensively, found that all ascogenous cells germinated in a *Taphridium*-like manner.

The species hitherto referred to as *Taphridium cicutae* was described by Lindroth in 1904. The ascogenous cells of this species also germinate immediately without producing a vesicle. Juel (1921) who studied the genus *Taphridium* in detail, thought the species probably belonged to the genus *Protomyces* because it produced ascogenous cells throughout the tissues and not in a single subepidermal layer, as do species of *Taphridium*.

Like *Protomyces*, the two species here placed in the genus *Burenia*, produce ascogenous cells throughout the host tissues and their ascogenous cells germinate in a *Taphridium*-like manner. Because they have characteristics clearly different from those of both *Protomyces* and *Taphridium*, we placed them in a new genus *Burenia* named after G. von Buren, who for more than half a century has contributed greatly to our knowledge of this group.

KEY TO THE SPECIES OF BURENIA

1. Ascogenous cells 55(37-73) x 63(37-100) µ; parasitic on species of *Cicuta* . . . . . *B. cicuta*
1. Ascogenous cells 47(30-56) µ; parasitic on species of *Apium*, *Daucus* and *Sium*. . . . . *B. inundata*

1. *Burenia cicuta* (Lindroth) Reddy & Kramer, comb. nov.

BASIONYM: *Taphridium cicutae* Lindroth, Acta Societatis pro Fauna et Flora Fennia 26(5): 9. 1904.

ILLUSTRATIONS: Figs. 8-11.

Pustules at the base or tip of the petiole; round, elliptical to elongate. Ascogenous spores spherical to elliptical; 55(37-74) x 63 (37-100) µ. Ascospores 4-7 x 1-2 µ; fusion of ascospores not observed.

HOST GENUS: *Cicuta*

DISTRIBUTION: Europe: Finland, U.S.S.R.

2. *Burenia inundata* (Dangeard) Reddy & Kramer, comb. nov.

SYNONYM: *Protomyces helosciadii* Phillips, 1883, nom. nudum
BASIONYM: *Protomyces inundatus* Dangeard, Le Botaniste 9: 274. 1906.
SYNONYM: *Taphridium inundatus* (Dangeard) von Buren, Beitr. Kryptfl. Schweiz 5(1): 29. 1915.

ILLUSTRATIONS: Figs. 12-16.

Small blister-like warts on leaves. Ascogenous cells spherical to roughly spherical, 47(30-56) μ; light brown. Ascospores usually produced within the ascogenous cells which do not undergo a rest period; following release, fusing in pairs.

HOST GENERA: *Apium, Daucus, Sium*

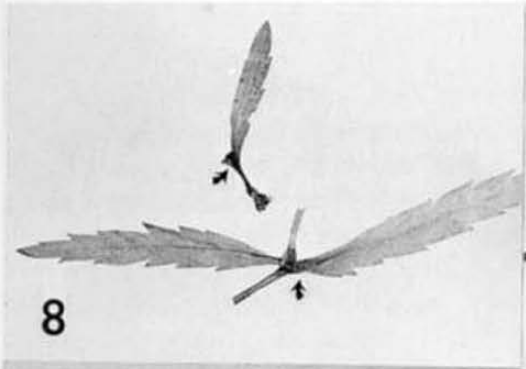
DISTRIBUTION: Europe: England, France, W. Germany, Switzerland

OBSERVATIONS: A collection on *Sium latifolium* L. (France, May 1884, J. Therry, 3025 (N.Y.) originally reported as a host for *Protomyces macrosporus*, was found instead to host *Burenia inundata*. From this it seems likely that *Sium erectum* Huds., also a reported host for *P. macrosporus* of which specimens have been unavailable, is similarly a host of *B. inundata*.

GENUS PROTOMYCES

Protomyces Unger, Die Exantheme der Pflanzen Wien 341. 1833.

Figs. 8-11. *Burenia cicuta*: 8, pustules on petioles of *Cicuta virosa* (arrows); 9-10, cross section of pustule (9. 73X, 10. 284X); 11, ascospores formed within ascogenous cells, slide prepared from teased material. Figs. 12-16. *Burenia inundata*: 12, blisters on leaves of *Apium nodiflorum*; 13-14, cross section of blister showing germination of ascogenous cells (13. 73X, 14. part shown by arrow in 13, 284X); 15, ascogenous cell from teased material, 284X; 16, ascospores formed within ascogenous cells, from teased material, 284X.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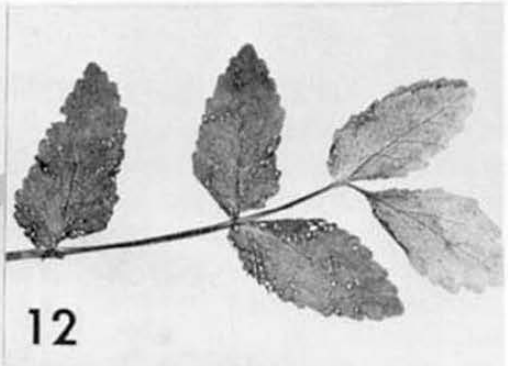
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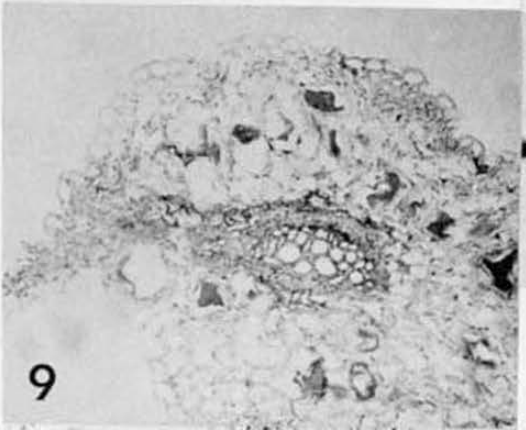
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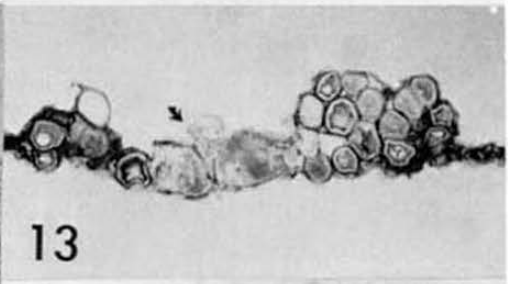
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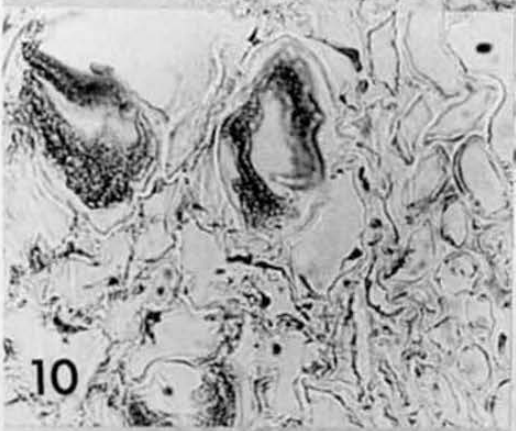
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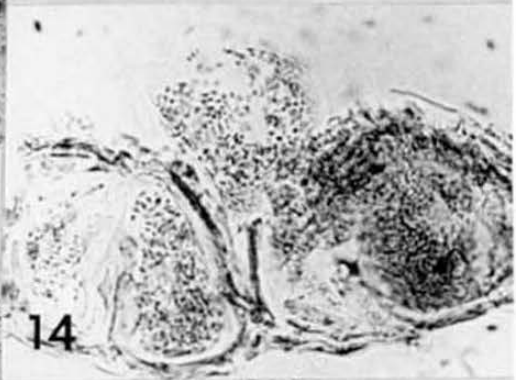
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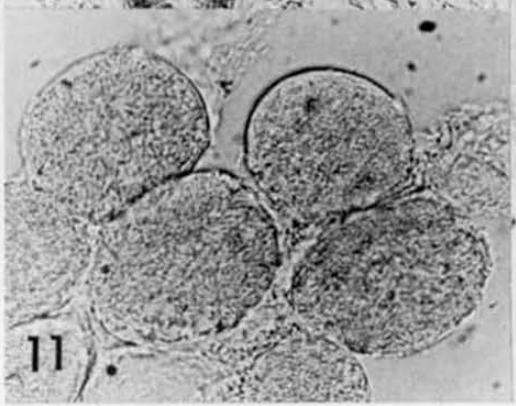
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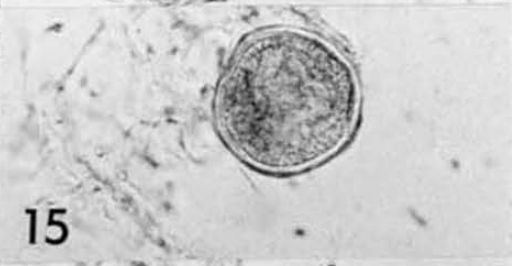
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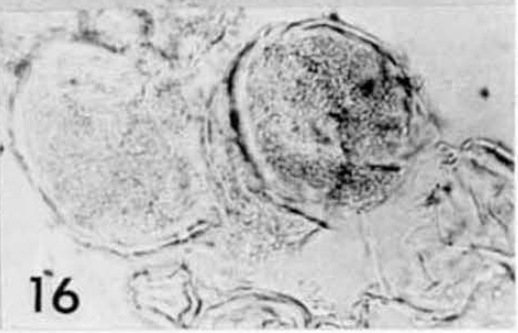
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Parasitic on species of Compositae and Umbelliferae; galls on stems, leaves, flowers, and fruits; on leaves galls usually restricted to petiole, midrib, veins, and veinlets; hypertrophy and hyperplasia occurring in various degrees. Ascogenous cells occurring intercalaraly in the intercellular mycelium throughout the infected tissues; spherical to subspherical, rarely broadly ellipsoidal; walls pale to light yellowish-brown, thick and smooth (rough in *P. inouyei*); germinating on overwintered remains of host by forming vesicles. Numerous haploid ascospores produced in the vesicle; following release, ascospores fusing in pairs.

TYPE SPECIES: *Protomyces macrosporus* Unger

KEY TO SPECIES OF PROTOMYCES BASED ON HOST GENERA

UMBELLIFERAE:

Host genera include: *Aegopodium, Ammi, Angelica, Anthriscus, Archangelica, Athamanta, Canopodium, Carum, Caucalis, Chaerophyllum, Coriandrum, Ferula, Heracleum, Hydrocotyle, Laserpitium, Ligusticum, Meum, Onanthe, Pancicia, Parum, Peucedanum, Pimpinella, Seseli, Silaus, Thapsia,* and *Trinia.*

Ascogenous cells 51(37-74) µ; small to medium galls on stems, leaves, flowers, and fruits; Europe, S. Asia and N. Africa . . . . . *P. macrosporus*

COMPOSITAE:

Ambrosia

Ascogenous cells 65(48-83) x 73(52-85) µ; large galls on stem; N. America . . . . . *P. grandisporus*
Ascogenous cells 37(30-52) µ; large galls usually on stems; N. America. . . . . *P. gravidus*

Aposeris

Ascogenous cells 36(26-52) µ; swellings on midrib, veins, and veinlets; Europe, Israel and Japan . . . . . *P. pachydermus*

Bidens

Ascogenous cells 59(48-74) x 63(48-74) µ; large galls on stems; S. America. . . . . *P. andinus*
Ascogenous cells 37(30-52) µ; large galls usually on stems; N. America and Europe. . . . . *P. gravidus*

Centaurea

Ascogenous cells 36(26-52) µ; swellings on midrib, veins, and veinlets; Europe . . . . . *P. pachydermus*

Crepis

Ascogenous cells 36(26-52) µ, walls smooth; swellings on midrib and veins; Europe . . . . . *P. pachydermus*
Ascogenous cells 38(33-48) µ, walls rough; swellings on leaves and large galls on stems and petioles; Japan . . . . . *P. inouyei*

Galinsoga

Ascogenous cells 54(33-67) x 58(44-78) µ; large linear galls on stems and leaves; Europe . . . . . *P. burenianus*

Hyoseris

Ascogenous cells 36(26-52) µ; swellings on midrib, veins, and veinlets; Europe . . . . . *P. pachydermus*

Hypochoeris

Ascogenous cells 59(48-74) x 63(48-74) µ; large galls on stems and small galls on leaves; S. America . . . . . *P. andinus*
Ascogenous cells 36(26-52) µ; swellings on midrib, veins and veinlets; Europe. . . . . *P. pachydermus*

Lactuca

Ascogenous cells 44(37-63) µ; twisting and large gall formation on stems, leaves, and petioles; Japan and Taiwan. . . . . *P. lactucae-debilis*

Leontodon

Ascogenous cells 36(26-52) µ; swellings on midrib, veins, and veinlets; Europe . . . . *P. pachydermus*

Matricaria

Ascogenous cells 41(30-52) μ; galls on stems and leaves; Europe. . . . . *P. matricariae*

Picris

Ascogenous cells 36(26-52) μ; swellings on midrib, veins, and veinlets; Europe . . . . *P. pachydermus*

Sonchus

Ascogenous cells 37(26-48) μ; large galls on stems; Europe including U.S.S.R. . . . . *P. sonchi*

Taraxacum

Ascogenous cells 36(26-52) μ; swellings on midrib, veins, and veinlets; Europe, Asia and N. America . . . . . *P. pachydermus*

1. *Protomyces andinus* Patouillard in Patouillard, N. & G. Lagerheim, Bull. Soc. Mycol. France 8:124. 1892.

SYNONYM: *Protomyces giganteus* Schroter in P. Hennings, Hedwigia 35:212. 1896.

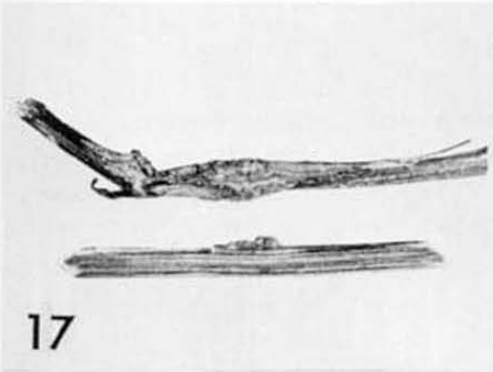
ILLUSTRATIONS: Figs. 17-20.

Large galls on stems and small galls on petioles and midrib. Ascogenous cells numerous, spherical to elliptical, 59(48-74) x 63(48-74) μ, light yellowish-brown, germination not observed.

HOST GENERA: *Bidens, Hypochoeris*

DISTRIBUTION: S. America: Ecuador, Brazil.

Figs. 17-20. *Protomyces andinus*: 17, galls on stems of *Bidens andicola*; 18-19, cross section of the gall (18. 73X; 19. 284X); 20, teased ascogenous cells, 284X. Figs. 21-24. *Protomyces burenianus*: 21, galls on stems of *Galinsoga parviflora*; 22-23, cross section of the gall (22, 73X; 23, 284X); 24, teased ascogenous cells, 284X.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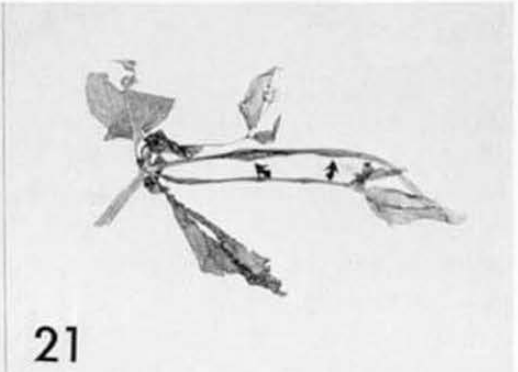
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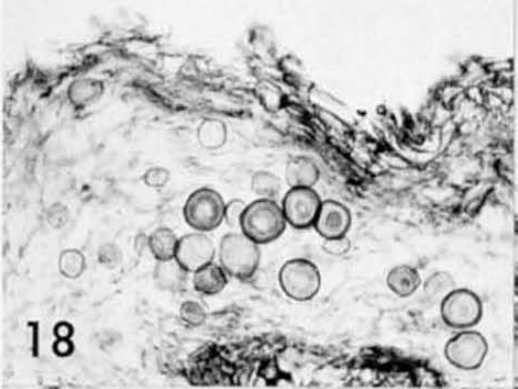
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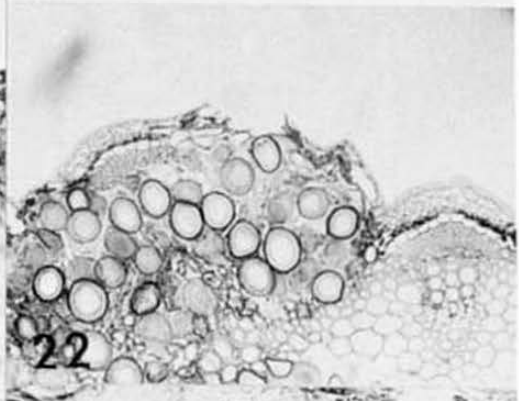
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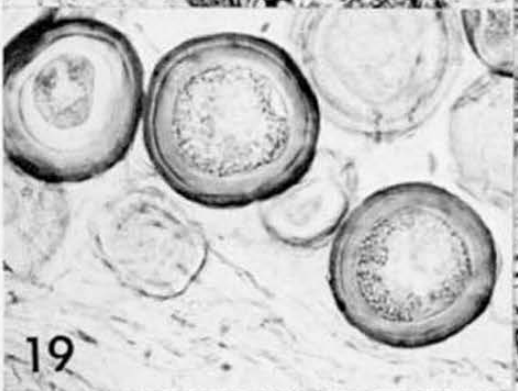
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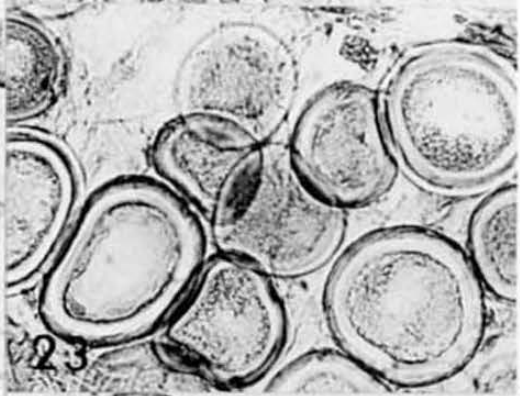
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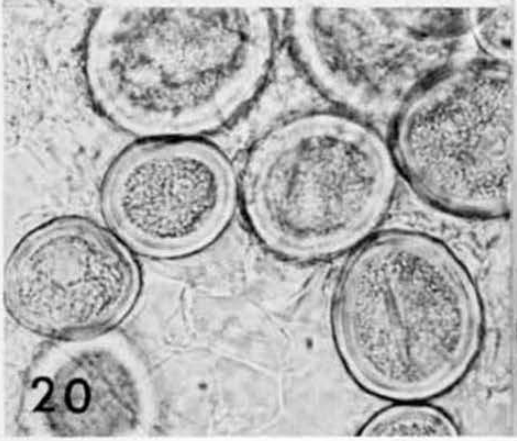
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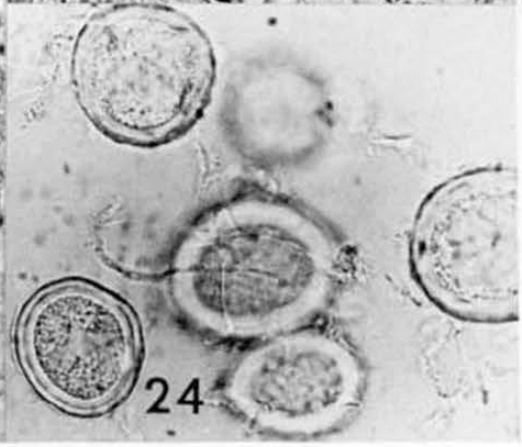
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OBSERVATIONS: Based on ascogenous cell measurements and distribution, *P. giganteus* is considered synonymous to *P. andinus*. K. Sawada (1922) described the species *P. bidentis* on *Bidens pilosa* L. but neither description nor specimens could be obtained.

2. *Protomyces burenianus* Buhr, Phytopath. Zeit. 15:405. 1949.

ILLUSTRATIONS: Figs. 21-24.

Galls on stems, leaves (? and occasionally roots). Ascogenous cells spherical to broadly elliptical, 54(33-67) x 58(44-78) µ, light yellowish-brown, germination not observed.

HOST GENUS: *Galinsoga*

DISTRIBUTION: Europe: E. Germany, W. Germany, Poland, Switzerland.

OBSERVATIONS: Based on host, ascogenous cell measurements and distribution, *Protomyces wodziczkoi* Szul. (whose speciments were not available for examination) could be synonymous with *P. burenianus*.

3. *Protomyces grandisporus*, sp. nov.

ILLUSTRATIONS: Figs. 25-28.

Gallae magnae in caulibus. Cellula ascogenicae multae, sphaericae v. ellipticae, magnae 68(48-83) x 78(52-85) µ, laete flavido-brunneae.

Galls large on stems. Ascogenous cells numerous, spherical to elliptical, large, 65(48-83) x 78(52-85) µ, light yellowish-brown; germination not observed.

HOLOTYPE: Wisconsin (U.S.A.), 13.9. 1907, J. J. Davis (WIS).

HOST GENUS: *Ambrosia*

DISTRIBUTION: N. America: Oregon, Wisconsin, Pennsylvania

OBSERVATIONS: All collections on *Ambrosia* and *Bidens* have been identified either as *Protomyces andinus* or *Protomyces gravidus*, irrespective of vast differences in spore sizes. We studied a number of specimens carefully, and a pattern evolved indicating three distinct species exist: (1) *Protomyces andinus* parasitizing *Bidens andicola* in Ecuador, S. America, with ascogenous cells measuring 59(48-74) x 63 (48-74) μ; (2) *Protomyces gravidus* parasitizing *Ambrosia artemisaefolia, A. trifida, Bidens cernua, B. cannata* and *B. frondosa* in N. America and Europe (only one specimen), with ascogenous cells measuring 37(30-52) μ; and, (3) *Protomyces grandisporus* parasitizing only *Ambrosia artemisaefolia* in N. America, with the largest ascogenous cells within the genus *Protomyces* measuring 65(48-83) x 73(52-85) μ.

4. *Protomyces gravidus* Davis, Jour. Mycol. 13:188. 1907.

ILLUSTRATIONS: Figs. 29-32.

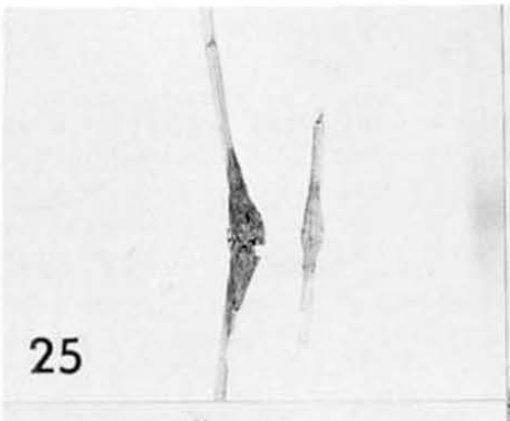
Large hypertrophic galls mostly on stems, occasionally on petioles and midrib. Ascogenous cells spherical to subspherical, 37(30-52) μ, germination not observed.

HOST GENERA: *Ambrosia* and *Bidens*

DISTRIBUTION: N. America: New York, Wisconsin; Europe: Finland.

5. *Protomyces inouyei* Hennings, Engler's Botan. Jahrb. 32: 34. 1902.

Figs. 25-28. *Protomyces grandisporus*: 25, galls on stems of *Ambrosia artemisaefolia*; 26-27, cross section of the gall (26. 73X; 27. 284X); 28, teased ascogenous cells, 284X. Figs. 29-32. *Protomyces gravidus*: 29, galls on stems of *Ambrosia trifida*; 30-31, cross section of the gall (30, 73X; 31, 284X); 32, teased ascogenous cells, 284X.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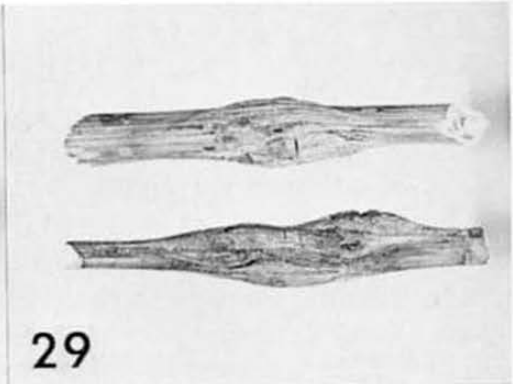
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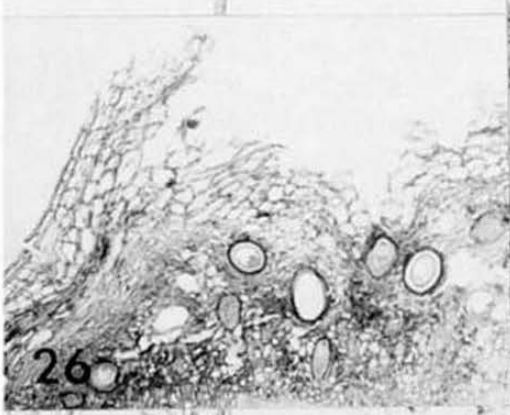
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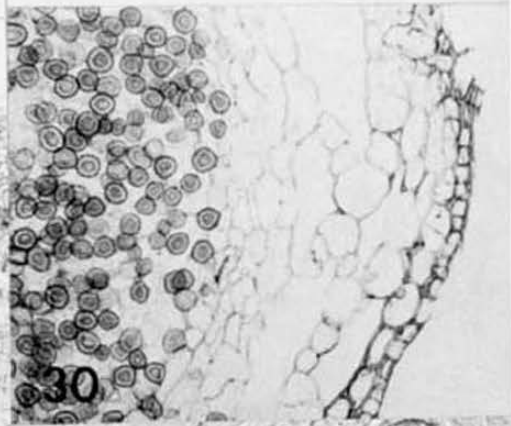
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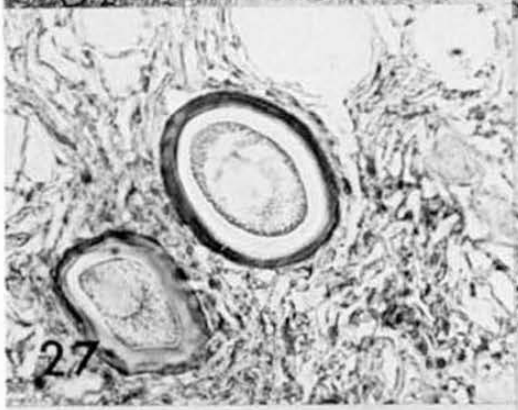
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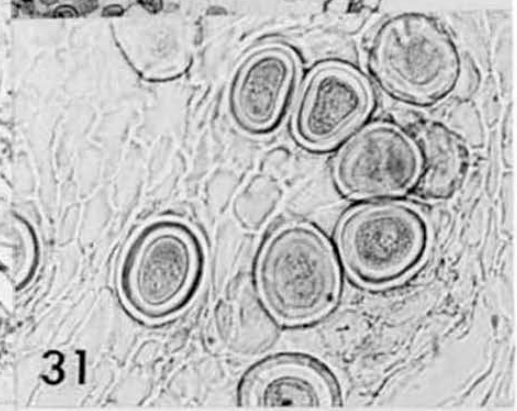
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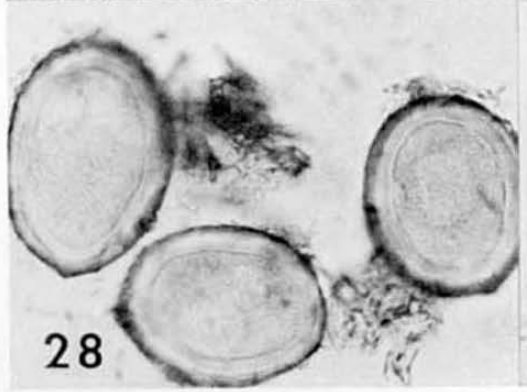
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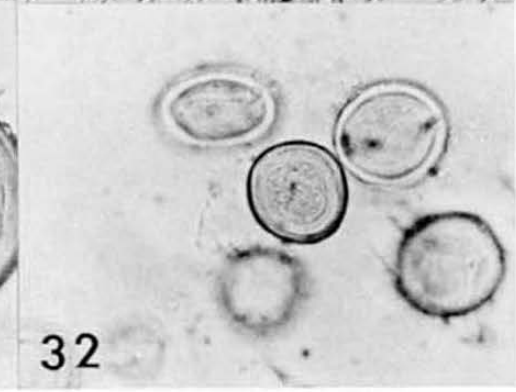
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ILLUSTRATIONS: Figs. 33-36.

Extensive galls on stems and petioles; leaves when attacked become crinkled. Ascogenous cells spherical with rugulose walls, 38(33-48) μ, light brown. Vesicles 25-45 x 55-145 μ.

HOST GENUS: *Crepis*

DISTRIBUTION: Asia: Japan

OBSERVATIONS: The rough walled ascogenous spores indicate a relationship with *Protomycopsis*, yet because of their intercalary production, this species is retained in *Protomyces*.

6. *Protomyces lactucae-debilis* Sawada, Descriptive Catalogue of the Formosan Fungi 4:19. 1922.

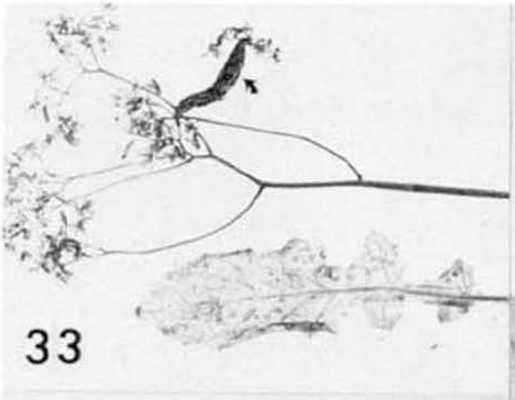
Swellings and galls on stems, buds, and leaves; leaves when infected curl and other parts may be twisted. Ascogenous cells roughly spherical, 44(37-63) μ, light yellow. Vesicles 20-40 x 100-280 μ.

HOST: *Lactuca debilis* Benth. & Hook.

DISTRIBUTION: Asia: Japan, Taiwan

Material of this species was unavailable for study. Description and records are taken from the literature. *Protomyces lactucae* Sawada and *P. ixeridis-oldhami* Sawada may be synonymous to *P. lactucae-debilis* because of the apparent similarities in spore measurements, hosts, and distribution. However, because specimens could not be obtained, the question remains open.

Figs. 33-36. *Protomyces inouyei*: 33, gall on stem of *Crepis japonica* (arrow); 34, cross section of gall, 73X; 35, cross section of gall showing rugulose wall of the ascogenous cells, 284X; 36, teased ascogenous cells with rugulose walls, 284X. Figs. 37-40. *Protomyces macrosporus*: 37, galls on leaf veins (a) and stem (b) of *Aegopodium podagravia*; 38-39, cross section of the gall (38. 73X; 39. 284X); 40, teased ascogenous cells, 284X.



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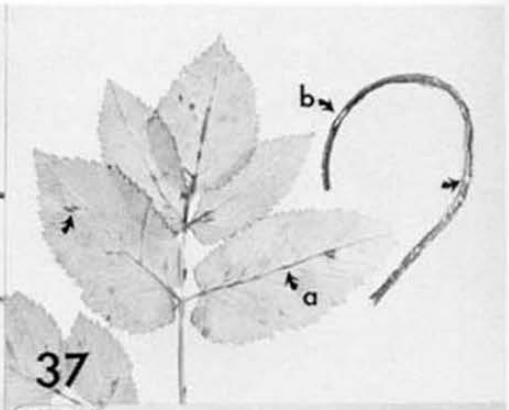

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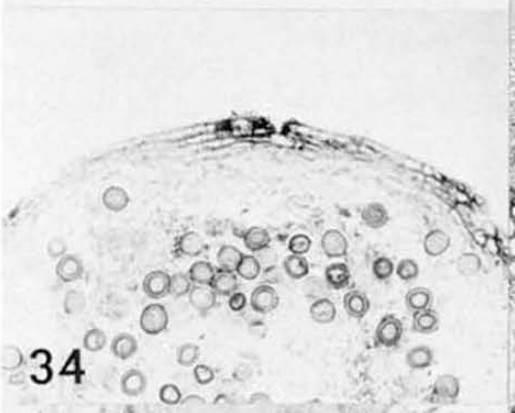

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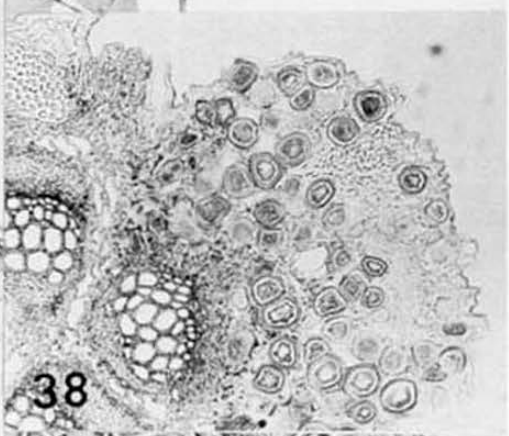

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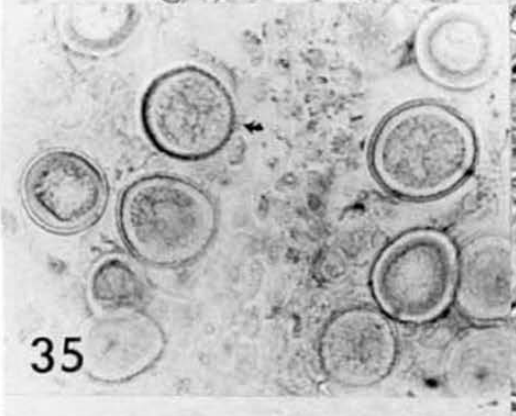

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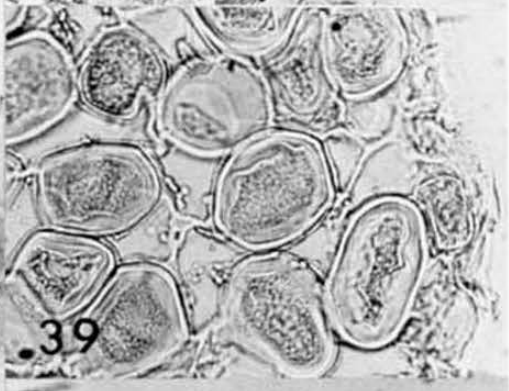

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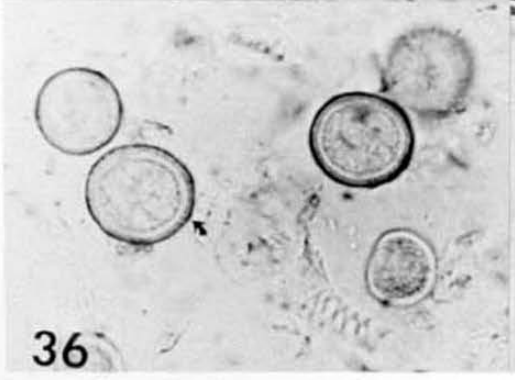

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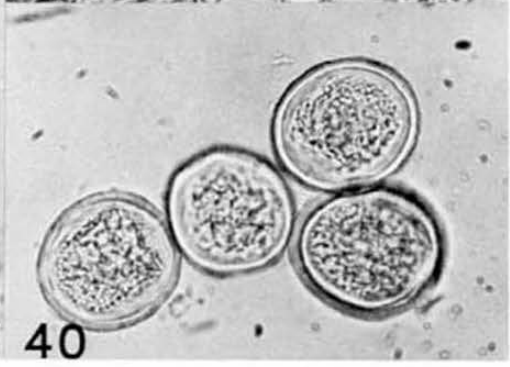

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7. *Protomyces macrosporus* Unger, Die Exanth. der Pflanzen 344: 1833.

SYNONYMS: *Physoderma gibbosum* Wallroth, Flora Cryptog. Germaniae 192. 1833.
Protomyces cari Blytt, Forh Vidensk-Selsk. Christ 6: 77. 1896.

ILLUSTRATIONS: Figs. 37-40

Galls on stems, petioles, leaves, pedicels, and fruits of Umbelliferae; when on leaves galls mostly in veins, rarely in interveinal areas. Ascogenous cells spherical to roughly spherical, 51(37-74) μ, light yellowish brown. Ascospores cylindrical to oblong, 4.5 x 3 μ.

HOST GENERA: *Aegopodium, Ammi, Angelica, Anthriscus, Archangelia, Athamanta, Canopodium, Carum, Caucalis, Chaerophyllum, Coriandrum, Ferula, Heracleum, Hydrocotyle, Laserpitium, Ligusticum, Meum, Onanthe, Pancicia, Parum, Peucedanum, Pimpinella, Seseli, Silaus, Thapsia,* and *Trinia.*

DISTRIBUTION: Asia: India, Nepal, Pakistan; Europe: Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, England, Finland, France, East and West Germany, Hungary, Ireland, Malta, Netherlands, Italy, Norway, Poland, Scotland, Sweden, Switzerland, Wales, Yugoslavia; N. Africa: Algeria

Specimens of the following genera reported as hosts of *Protomyces macrosporus* were not available for study: *Conopodium, Ovanthe* and *Pimpinella.*

8. *Protomyces matricariae* Sydow, Ann. Mycol. 30:96. 1932.

ILLUSTRATIONS: Figs. 41-44

Galls on stems and leaves. Ascogenous cells spherical to subspherical, 41(30-52) μ, light yellowish-brown, germination not observed.

HOST GENUS: *Matricaria*

DISTRIBUTION: Europe: W. Germany

9. *Protomyces pachydermus* Thumen, Hedwigia 13:97. 1874.

SYNONYMS: *Protomyces kreuthensis* Kuhn, Hedwigia 124. 1877.
Protomyces centaurea Lagerheim. Publication not known (specimen examined collected by G. Lagerheim, July 1896, Sweden (K), marked TYPE).
Protomycopsis crepidis Jaap. Ann. Mycol. 6: 204. 1908.
Protomyces crepidis von Buren, Beitr. Kryptfl. Schweiz 5(1):83. 1915.
Protomyces crepidicola von Buren, Beitr. Kryptfl. Schweiz 5(3):57. 1922.
Protomyces crepidis-paludosae von Buren, Beitr. Kryptfl. Schweiz 5(3):58. 1922.
Protomyces picridis von Buren, Beitr. Kryptfl. Schweiz 5(3):57. 1922.
Protomyces kriegarianus von Buren, Beitr. Kryptfl. Schweiz 5(3):57. 1922.
Protomyces crisii-oleracei Buhr, Archiv Des Vereins Der Freunde Der Naturgeschichte in Mecklunburg 40. 1936.

ILLUSTRATIONS: Figs. 45-48.

Swellings on petiole, midrib, veins, and veinlets, often forming a network of swollen veins and veinlets; sometimes the infected parts turning brown to reddish. Ascogenous cells spherical to roughly spherical, 36(26-52) µ, light yellowish-brown. Vesicles 30-60 x 45-150 µ.

HOST GENERA: *Aposeris, Centaurea, Crepis, Criseum, Hyoseris, Hypochoeris, Leontodon, Picris* and *Taraxacum*

DISTRIBUTION: Asia: Israel, Japan; Europe: Austria, Czechoslovakia, Denmark, England, E. and W. Germany, Iceland, Italy, Scotland, Sweden, Switzerland, Yugoslavia; N. America: Canada, Utah.

A species of *Protomyces* with a description resembling *Protomyces pachydermus* has been reported on *Cephalorynchus hispidus* (Magnus, 1896). Although this collection was not seen, *Cephalorynchus* is probably another host for *Protomyces pachydermus*.

OBSERVATIONS: G. von Buren (1915, 1922) created *Protomyces crepidis, P. crepidicola, P. crepidis-paludosa, P. picridis,* and *P. kriegerianus*, all of which resemble *P. pachydermus*, on the basis of differences seen in pathogenicity

studies and vesicle sizes. However, it is now believed that these and other synonyms of *P. pachydermus* mentioned herein resemble each other so closely in ascogenous cell measurements, host range, symptoms, and distribution that they are considered one and the same. Although von Buren (1915, 1922) has shown vesicle size to be a constant factor for some species, for others he has recorded a wide variation. Considerable variation in vesicle size is reported for *P. pachydermus* (von Buren, 1922) and *P. crepidis* (von Buren, 1915). Similarly, variations in size are reported by Tubaki (1957) for *P. pachydermus* and two other species. Therefore, it is assumed that vesicle size is variable, not suitable as a taxonomic character. The various shapes and sizes of vesicle in the species that are now considered synonymous to *P. pachydermus* fall mostly within the range found in *P. pachydermus*.

Protomyces helminthae Maire could be synonymous with *Protomyces pachydermus* based on symptoms, host genus, and ascogenous cell measurements. As the specimens were not available for study, the question remains open.

10. *Protomyces sonchi* Lindfors, Svensk Botanisk Tidskrift. 12(2):224. 1918.

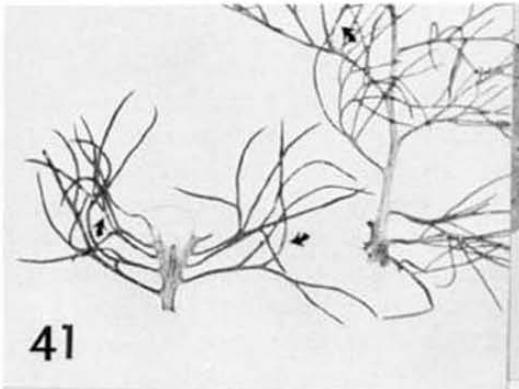
ILLUSTRATIONS: Figs. 49-52.

Galls large on stems. Ascogenous cells spherical to subspherical, 37(26-48) µ, light yellowish-brown; vesicle 50 µ long.

HOST GENUS: *Sonchus*

DISTRIBUTION: Europe including U.S.S.R.

Figs. 41-44. *Protomyces matricariae*: 41, small galls on leaves of *Matricaria inodora* (arrows); 42-43, cross section of gall (42, 73X; 43, 284X); 44, teased ascogenous cells, 284X. Figs. 45-48. *Protomyces pachydermus*: 45, swollen veins of *Aposeris foetida*; 46-47, cross section of swollen vein (46, 73X; 47, 284X); 48, teased ascogenous cells, 284X.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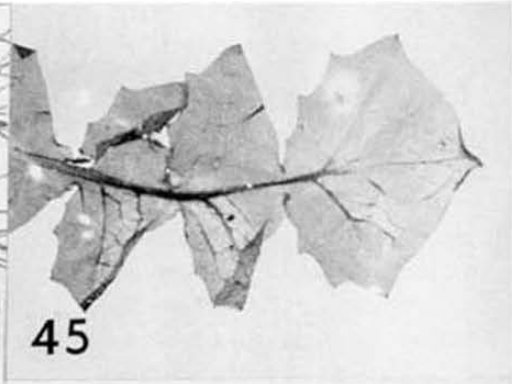
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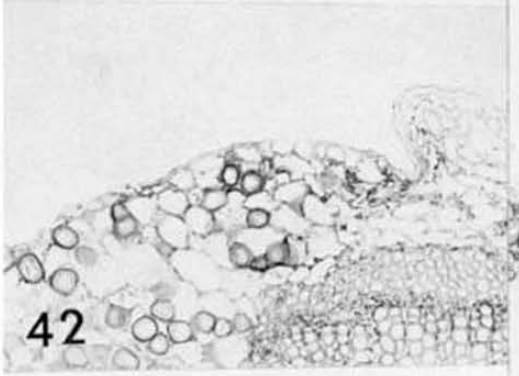
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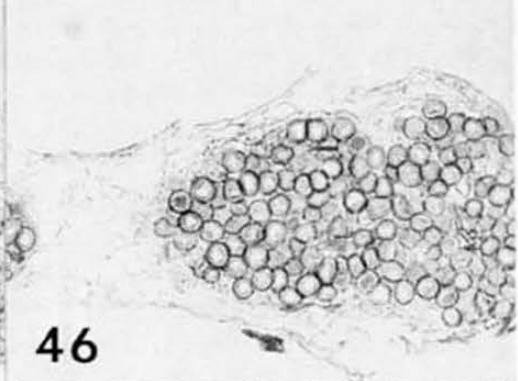
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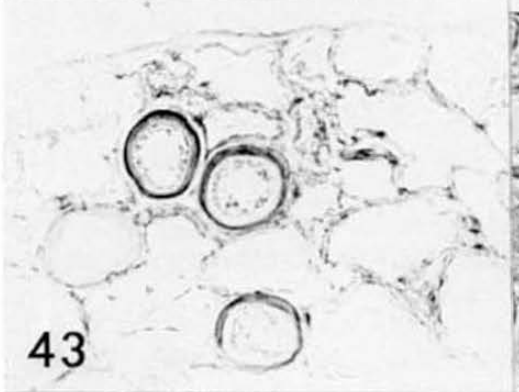
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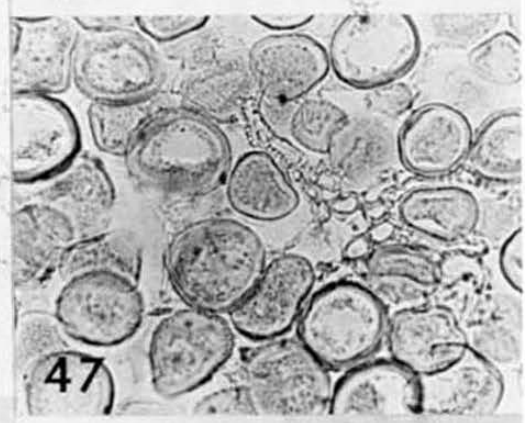
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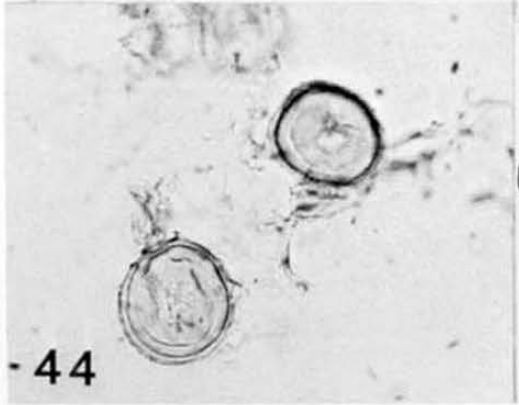
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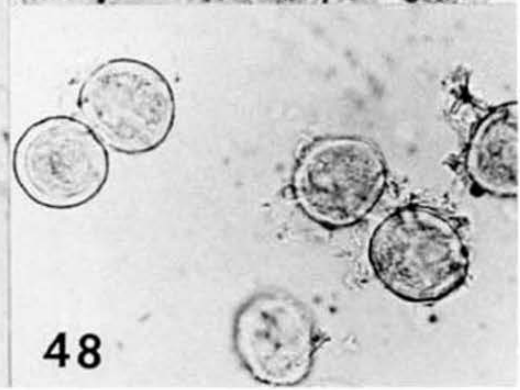

48

SPECIES UNAVAILABLE FOR STUDY

The following species listed here were not available for study and germination of ascogenous cells has not been reported in the literature. It is believed that most, if not all, of these species will be assigned as synonyms of existing species when material becomes available for study.

Protomyces bidentis Sawada, Descriptive Catalogue of the Formosan Fungi 3:53. 1922.

HOST: *Bidens pilosa* L.

DISTRIBUTION: Taiwan

No description available; Sawada's (1922) publication could not be obtained. However, two other species of *Protomyces*, *P. andinus* and *P. graviduş*, are parasitic on species of *Bidens*.

Protomyces helminthae Maire, Bull. de la Soc. d'Hist. Nat. de l'Afrique du Nord 6:255. 1914.

HOST: *Helminthae echioides* (=*Picris echioides* L.)

DISTRIBUTION: N. Africa: Tunisia

Based on the symptoms, host, and ascogenous cell measurements, this species seems to be synonymous with *Protomyces pachydermus*.

Protomyces ixeridis-oldhami Sawada, Trans. Nat. Hist. Soc. Formosa 32:130. 1942.

HOST: *Ixeris oldhami* Kitamura (=*Lactuca thumbergii* Maxim.)

DISTRIBUTION: Taiwan

This species seems to be synonymous with *Protomyces lactucae-debilis*, based on the host, distribution, and ascogenous cell measurements.

Protomyces lactucae Sawada, Descriptive Catalogue of the Formosan Fungi 4:18. 1928.

HOST: *Lactuca* sp.

DISTRIBUTION: Taiwan

It is likely that this species is synonymous with *Protomyces lactucae-debilis* because of the similarities in

host group, distribution, and ascogenous cell measurements.

Protomyces wodziczkoi Szulczewski, Octa Soc. Bot. Polon 21:191. 1951.

HOST: *Galinsoga parviflora* Cavada

DISTRIBUTION: Poland

Because of the same host species, ascogenous cell measurements, and distribution, this species seems to be synonymous with *Protomyces burenianus*.

EXCLUDED OR DOUBTFUL SPECIES OF PROTOMYCES

Protomyces ari Cooke, Grevillea 1:7. 1872. = *Melanotaenium ari* (Cooke) Lagerheim.

Protomyces bizzozerianus Saccardo, Michelia 1:14. 1879. = *Doassansia sagittariae* (West) Fischer.

Protomyces calendulae Oudeman, Oud. Arch. Neerl. 8: 384. 1877. = *Entyloma calendulae* (Oud.) De Bary.

Protomyces calthae, name taken from specimen: Fungi ross. Coll. F. Bucholtz, 7.5. 1908, 1589 (FH). Spores are small (29 μ), not typical of *Protomyces*; publication and host name not known.

Protomyces carpogenus Saccardo, Michelia 1:118. 1879. Although specimens have not been seen, the reported size of the spores (18-20 μ) is probably too small for *Protomyces* and the host, which belongs to the Curcurbitae, seems unlikely for a member of this group.

Protomyces centelli Ciferri, Arkiv fur Botanik 23(14): 26. 1931. Parasitizes *Centella (Hydrocotyle) asiatica*, which is a host for *Protomyces macrosporus*. In this case symptoms (yellowish, dry spots resulting in shot holes) do not resemble those of *Protomyces*, and the spore size is small (20-40 μ). Specimens not seen.

Protomyces chrysoplenii Berkeley & Broome, Annals of Natural History 15:36. 1875. = *Entyloma chrysoplenii* Schroter

Protomyces? cocae Spegazzini, Annals Sociedad Cientifica Argentina 90:29. 1920. The description of

this species does not indicate a species of Protomycetaceae. In addition its reported host, a species of Erythroxilaceae, is not known to be a host of this group. Specimens not seen.

Protomyces comari Berkeley & White, Ann. Nat. Hist. Ser. V 1:27 1878. = *Doassansia comari* De Toni

Protomyces concomitans Berkeley, The Gardeners Chro icle 392. Sep. 23. 1882. The orchid, reported as host of this species, is an unlikely host for a member of the Protomycetaceae. Specimens not seen.

Protomyces conglomeratus Peck, Annual Report of the State Botanist of the State Museum of New York. 32: 39. 1879. This species is parasitic on Chenopodiaceae, which is an unlikely host for species of Protomycetaceae. Specimens not seen.

Protomyces corticola Karsten, Meddel of Societas pro Fauna et Flora Fennica 11:146. 1884. The spores of this species appear to be too small (15-30 μ) for *Protomyces* and the host, *Betula alba*, has not been reported for Protomycetaceae. Specimens not seen.

Protomyces cyrenaicus Parisi, Naples, Universita Orto Botanico Bulletino 9:56. 1929. Spores are too small (12-14 μ) for *Protomyces* and the host, a species of Thelogonaceae, appears unlikely for Protomycetaceae. Specimens not seen.

Protomyces endogenus Unger, Die Exanth. der Pflanzen 342. 1833. = *Melanotaenium endogenum* (Unger) De Bary.

Protomyces eryngii Fuckel, Symb. Mycol. 75. 1869. = *Entyloma eryngii* (Corda) De Bary.

Protomyces erythronii Peck, Twenty-fifth Annual Report of State Botanist of State Museum, of the State of New York 90. 1872. Differs from members of Protomycetaceae in many ways. The host is a species of Liliaceae.

Protomyces fallax Saccardo, Michelia 1:118. 1879. Spores appear to be too small (16-20 μ) for *Protomyces*, and the host, a species of Pinaceae, appears unlikely for *Protomyces*. Specimens not seen.

Protomyces? fallax Saccardo, Syll. Fung. 7:320 -- var. *albellinensis* Saccardo in Saccardo (E. Trotter) I Funghi dell' Avellinese, Avellino 108. 1920. Spores too small (15-19 μ) for *Protomyces*, and the host, a species of Pinaceae seems unlikely for *Protomyces*. Specimens not seen.

Protomyces fergussoni Berkeley & Broome, Annals of Natural History 15(1): 36. 1875. = *Entyloma fergussoni* (Berkeley & Broome) Plowright.

Protomyces ficariae Cornu & Roze, Bull. Soc. Bot. De France 22:161. 1874. = *Entyloma ranunculi* Schroter.

Protomyces? filicinus Niessl. in P. Magnus, Estratto dagli Atti del Congresso Botanico Internationale 1892. 1. 1893. = *Hyalospora polypodii* Magnus.

Protomyces fuscus Peck, Thirty-first Annual Report of the New York State Museum of Natural History 27, 1879. Differs from members of Protomycetaceae in many respects. The host is a species of Ranunculaceae.

Protomyces? gaillardiae Spegazzini, Museo Nacional de Buenos Aires 19:284. 1909. Although specimens have not been seen, Spegazzini suspected that the "spores" of this species could be oospores of *Albugo* or Peronosporaceae.

Protomyces gallii Nees., Das Syst. d. Pilze 10. 1837. = *Melanotaenium endogenum* (Unger) De Bary.

Protomyces graminicola Saccardo, Nuovo Giornale Botanico Italiano 8:172. 1876. = *Sclerospora graminicola* (Sacc.) Schroter.

Protomyces helocharidis Fuckel, Symb. Myc. 75. 1869. = *Cladochytrium helocharidis* Busgen.

Protomyces hispanicus Ciferri, Atti dell institutio botanico della R. Universita di Paris. Milan Ser 2 and 3:12. 1925. Symptoms unlike those of Protomycetaceae; the host is a species of Ranunculaceae. Specimens not seen.

Protomyces kemneri Lindfors, Svensk Botanisk Tidskrift 12(2):226. 1918. Although the description might indicate *Burenia*, symptoms differ and spores are

brown. The host, a species of Leguminosae, appears unlikely for Protomycetaceae. Specimens not seen.

Protomyces leniaris Peck. Name taken from specimen and apparently not published: Herbarium New York State Museum, Aug. 1925, C. H. Peck (WIS). Symptoms differ from those of *Protomyces* species, and host is a member of Cyperaceae. No spores were found in the specimen.

Protomyces limnanthemii Ciferri, Arkiv for Botanik 23(14):25. 1931. This species differs in symptoms from *Protomyces*, and the host, a species of *Limnanthemum* appears unlikely for Protomycetaceae. Specimen seen had no spores.

Protomyces limosellae Kunze, Rabenh., Fungi Europe 1694. 1873. = *Doassansia limosellae* Schroter.

Protomyces macularis (Wallr.) Fuckel, Symb. Myc. 75. 1869. = *Doassansia alismatis* (Nees.) Cornu.

Protomyces martianoffianus Thumen, Bulletin de la Society imperiales des Naturalists de Moscou, Moscow 53:207. 1878. = *Doassansia martianoffiana* (Thum.) Schroter.

Protomyces martindalei Peck, Bull. Torrey Bot. Club 5: 2. 1874. Spores are too small (18 μ) for *Protomyces*, and the host, *Cuscuta gronovii* Willd. appears unlikely for Protomycetaceae.

Protomyces melanodes Berkeley & Broome, Annals of Natural History Ser. 5, 7:129. 1881. Spores too small (15 μ long) for *Protomyces*. Specimens not seen.

Protomyces menyanthis De Bary, Brandpilze 19. 1891. = *Cladochytrium menyanthis* De Bary on host *Menyanthis trifoliata* L. = *Doassansia comari* De Toni on host *Comarium palustre* L.

Protomyces microsporus Unger, Die Exantheme der Pflanzen Wein 343. 1833. = *Entyloma microsporus* (Unger) Schroter on host *Ranunculus repens* L. = *Entyloma ranunculi* (Bonorden) Schroter on host *Ficaria verna*. Specimens on *Ficaria* sp. examined.

Protomyces muscorum Karsten, Fragmenta Mycologia 11:4. 1884. The gelatinous nature of the spores and its association with mosses indicates that it might be a species of *Endogone*.

Protomyces najadis Chwodhury, Sydowia 23:46. 1869. Spores are large (100-192 x 79-144 µ), not resembling those of Protomycetaceae; the host belongs to the family Najadaceae. Specimens not seen.

Protomyces paridis Unger, Die Exantheme der Pflanzen 344. 1833. = *Sorosporium paridis* Unger. = *Tubercinia paridis* (Ung.) Vestergren on host *Paris quadrifolia* L.

Protomyces? persicifilus Spegazzini, Rev. Ministerio Agric. Buenos Aires 2(2):39. 1908. Symptoms do not resemble those of Protomycetaceae, and the host is a species of Rosaceae. Specimens not seen.

Protomyces physalidis Kalchenbrenner & Cooke, Grevillea 10:22. 1880. = *Entyloma australe* Spegazzini.

Protomyces? pithiophilus Karsten, Fragmenta Mycologica 11:4. 1884. Symptoms do not resemble those of Protomycetaceae, spores are of two different sizes, and the host is a species of Pinaceae. Specimens not seen.

Protomyces polysporus Peck. Name apparently not published. Source--Exsiccati de Thumen, Mycotheca Universalis 1813. *Protomyces polysporus* Nov. Spe. Leg. H. C. Peck. 1880. Spores are too small (9 µ) for *Protomyces*.

Protomyces punctiformis Niessl, Verhandlunger Naturf. Ver Brunn 10:166. 1872. = *Setchellia (Doassansia) punctiformis* Magnus.

Protomyces purpureo-tinges Massee, British Fungi 164. 1891. Symptoms do not resemble those of Protomycetaceae and the host is a species of Liliaceae.

Protomyces radicicola Zopf, Handbuch der Botanik von Professor Dr. A. Schenk 4:280. 1890. Infection occurs in the roots of a species of Scrophulariaceae. Both the location of infection site and the host family are not characteristic of Protomycetaceae. Specimens not seen.

Protomyces reticulatus Saccardo, Michelia I:13. 1879. Formation of "endospores" (one per sporangium) and symptoms differ from those of Protomycetaceae. Specimens not seen.

Protomyces rhizobius Trail, Scottish Naturalist and Journal of Perthshire Society of Natural Sciences 125. 1884. Infection occurs in the roots of *Poa*. Both the location of infection site and the host are not characteristic of Protomycetaceae. Specimens not seen.

Protomyces sagittariae Fuckel, Symb. Mycol. 75. 1869. = *Doassansia sagittariae* (West.) Fischer.

Protomyces stellariae Fuckel, Enumeration Fungorum Nassoviae series 1:1. 1860. = *Peronospora alsineriarum* Casp.

Protomyces theae Zimmerman, Centrablatt f. Bakteriologie 2(4):140. 1901. Infection occurs on the roots of a species of Theaceae. Both the location of infection site and the host family are not characteristic of Protomycetaceae. Specimens not seen.

Protomyces tuberum-solani Martinus, Die Kartoffel Epidemie der letzen Jahre oder die Stocksaule und Raude der Kartoffeln. Muchen 28. 1842. = *Spongospora scabies* (Berkeley) Massee.

Protomyces vagabundus Spegazzini, Revista Argentina de Historia Natural 37. 1891. = *Urophlyctis hemisphaerica* (Speg.) Sydow.

Protomyces violaceus Cesati. Atti della 6. Ruionne degli Scienziati Italinao 511. Milano. 1884. = *Ustilago haesendonckii* West.

Protomyces xylogenus Saccardo, Michelia I:14. 1879. = *Sphaerosporium lignatile* Schweinitz. = *Coccospora aurantiaca* Wallr. on host "*Populus anonymae*".

GENUS PROTOMYCOPSIS

Protomycopsis Magnus, Die Pilze (Fungi) von Tirol, Vorarlberg und Liechtenstein 322. 1905.

Members parasitic on species of Compositae, producing swellings and slightly raised spots on the leaves. Ascogenous cells, formed terminally on the mycelium, occurring throughout the infected tissues of the host; spherical to subspherical, light yellowish-brown; rough-walled at least when young; germinating after a period of rest, producing a vesicle within which numerous ascospores are formed.

Fusion of ascospores reported.

TYPE: *Protomycopsis leucanthemi* Magnus

KEY TO SPECIES OF PROTOMYCOPSIS BASED ON HOST GENERA

Bellis

Ascogenous cells 32(26-41) µ, wall rugulose; leaf spots barely raised . . . . . .*P. bellidis*

Chrysanthemum

Ascogenous cells 35(22-48) µ, wall rugulose; leaf spots barely raised . . . . . *P. leucanthemi*

Hyoseris

Ascogenous cells 30(22-48) µ, smooth walled when mature; blisters on leaves, small and round . . . . . *P. hyoseridis*

Leontodon

Ascogenous cells 34(30-41) µ, smooth walled when mature. Small galls on midrib and veins . . . . . *P. leontodontis*

1. *Protomycopsis arnoldii* Magnus, Pilzflora von Tirol 322. 1915.

HOST: *Leontodon montani* Lam.

DISTRIBUTION: Europe

OBSERVATIONS: By its host genus, symptoms, and ascogenous spore measurements (as reported by von Buren, 1922), this species appears to be very similar to *Protomycopsis leontodontis*. It is possible they are synonymous. However, specimens of *P. arnoldii* were not available for study.

2. *Protomycopsis belledis* (Krieger) Magnus in G. von Buren, Beitr. Kryptfl. Schweiz 5(1):85. 1915.

SYNONYM: *Protomyces belledis* Krieger, Hedwigia 35:144.

1896.

ILLUSTRATIONS: Figs. 53-56.

Round, yellowish to yellow-brown, barely raised leaf spots. Ascogenous cells 32(26-41) μ, spherical to subspherical, immature cells often elliptical.

HOST GENUS: *Bellis*

DISTRIBUTION: Europe: E. and W. Germany, Switzerland.

3. *Protomycopsis hyoseridis* Sydow, Ann. Mycol. 12:197. 1914.

ILLUSTRATIONS: Figs. 57-60.

Small, round, pale yellow blisters on leaves. Ascogenous cells 30(22-37) μ spherical to subspherical; light yellowish-brown to light brown. Spore germination not observed.

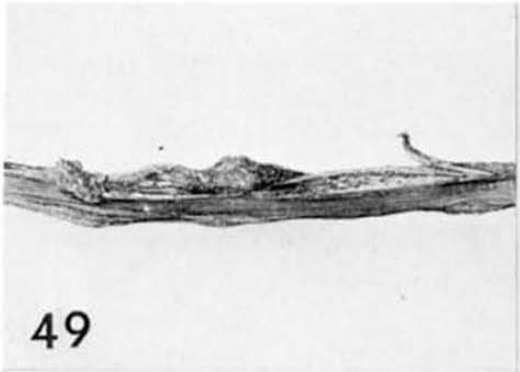
HOST GENUS: *Hyoseris*

DISTRIBUTION: Europe: Italy, France.

4. *Protomycopsis leontodontis* von Buren, Beitr. Kryptfl. Schweiz 5(3):71. 1922.

Figs. 49-52. *Protomyces sonchi*: 49, galls on stems of *Sonchus arvensis*; 50-51, cross section of gall (50, 73X; 51, 284X); 52, teased ascogenous cells, 284X. Figs. 53-56. *Protomycopsis belledis*: 53, spots on leaves of *Bellis perennis* (arrows); 54-55, cross section through leaf spot (54, 73X; 55, 284X); 56, teased ascogenous cells showing rugulose wall (arrow), 284X.

Figs. 57-60. *Protomycopsis hyoseridis:* 57, blisters on leaves of *Hyoseris baetica* (arrow); 58-59, cross section through the blister (58, 73X; 59, 284X); 60, teased ascogenous cells, 359X. Figs. 61-64. *Protomycopsis leontodontis*: 61, galls on the mid-ribs of *Leontodon autumnale* (arrows); 62-63, cross section through the gall (62, 73X; 63, 284X); 64, teased ascogenous cells, 284X.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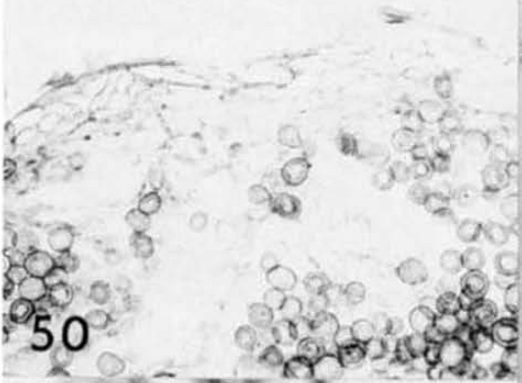
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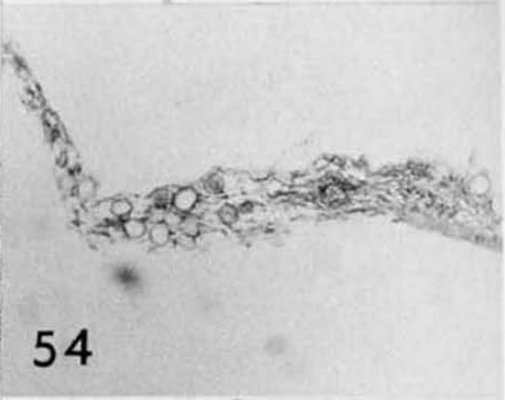
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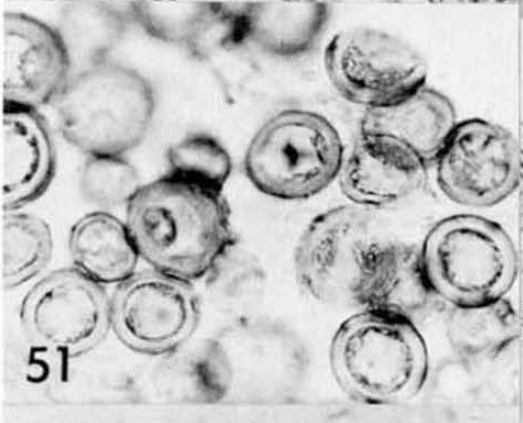
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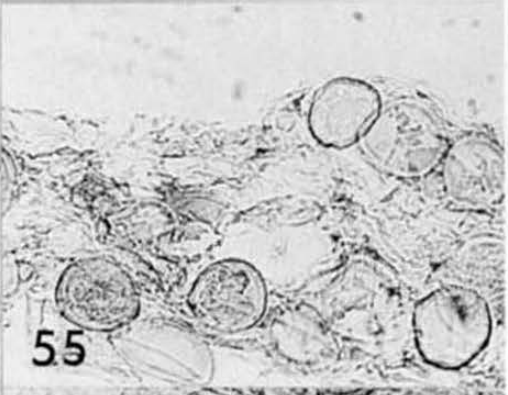
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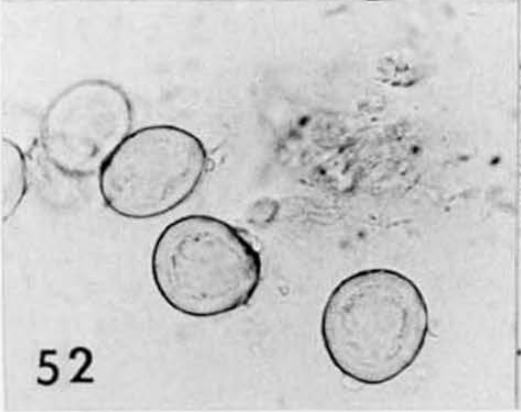
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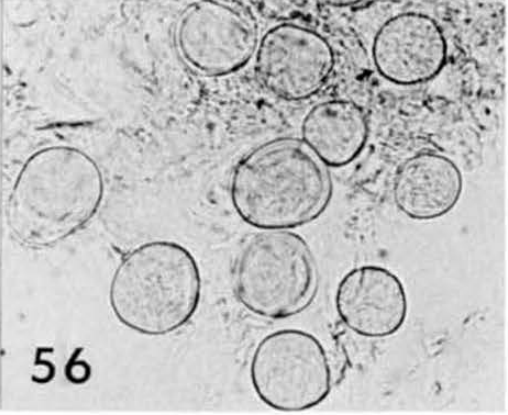
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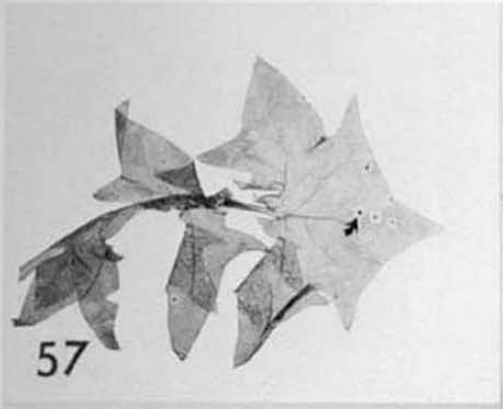
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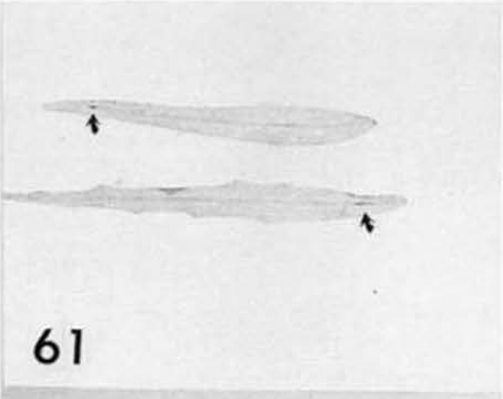
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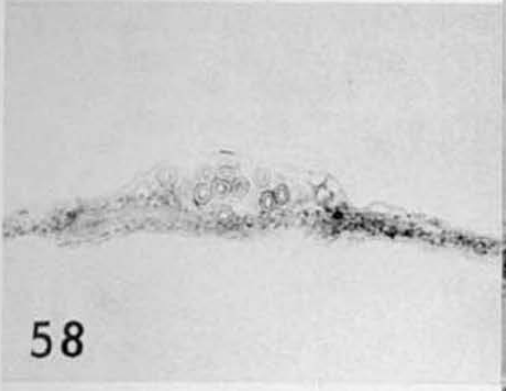
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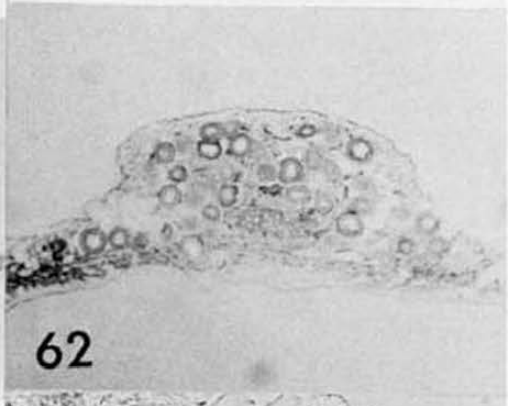
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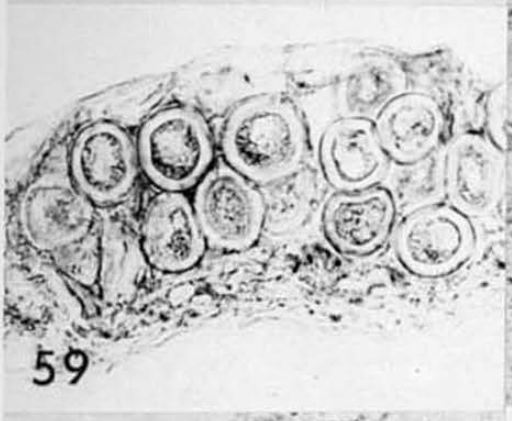
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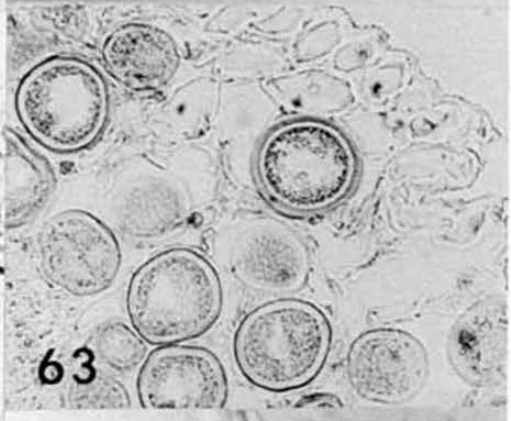
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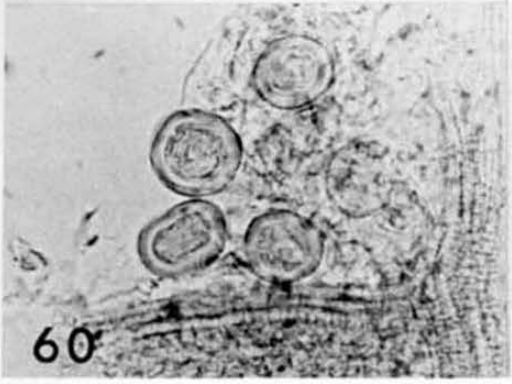
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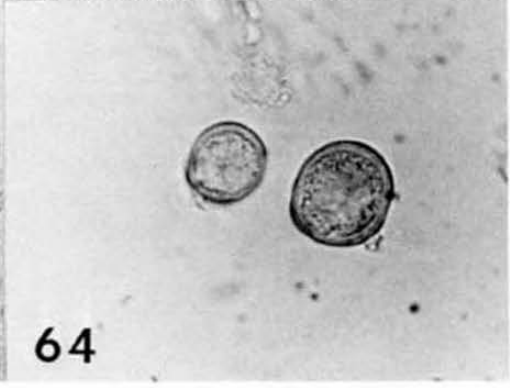
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ILLUSTRATIONS: Figs. 61-64.

Small galls on midrib and veins. Ascogenous cells 34 (30-41) μ, spherical, rugulose when young and smooth walled when mature; vesicle 105 x 45 μ.

HOST GENUS: *Leontodon*

DISTRIBUTION: Europe: Finland, Sweden.

OBSERVATIONS: Based on the host genus, symptoms, and ascogenous cell measurements (as reported by von Buren, 1922), this species appears to be very similar to *Protomycopsis arnoldii*. It is possible they are synonymous. However, specimens of *P. arnoldii* were not available for study.

5. *Protomycopsis leucanthemi* Magnus, Die Pilze von Tirol, Vorarlberg und Liechtenstein 323. 1905.

ILLUSTRATIONS: Figs. 65-69.

Greyish-yellow, slightly raised leaf spots. Ascogenous cells 35(22-48) μ, spherical to subspherical, rugulose; vesicle 52-66 μ long and 37-48 μ broad. Ascospores 4 x 2.5 μ.

HOST GENERA: *Chrysanthemum* and *Achillea*

DISTRIBUTION: Europe: Austria, E. and W. Germany, Switzerland.

OBSERVATIONS: *Protomycopsis chrysanthemi* von Buren (Beitr. Kryptfl. Schweiz 5(3):76. 1922; *Chrysanthemum atratum* L. and *C. alpinum* L.) seems to be very close to *Protomycopsis leucanthemi* because of the similarities in host genus, symptoms, and ascogenous cell measurements. Possibly the species are synonymous. However, this cannot be said with certainty as no specimens of *Protomycopsis chrysanthemi* were available for comparative study.

SPECIES UNAVAILABLE FOR STUDY

Species listed here have been reported as belonging to the genus *Protomycopsis*. Although apparently their ascogenous cells have never been germinated and specimens have

not been available for study, they quite likely should be included as recognized species.

Protomycopsis pharenris Jaap, Ann. Mycol. 19:4. 1916.

HOST: *Pallenis spinosa* (L.) Cass.

DISTRIBUTION: Asia Minor: Turkey

Protomycopsis pullicariae Maire, Bulletin de la Societe Historie Naturelle Afrique de Nord 22. 1931.

HOST: *Pulicaria inuloides* DC.

DISTRIBUTION: N. Africa: Algeria

DOUBTFUL SPECIES OF PROTOMYCOPSIS

Protomycopsis ajmeriensis Gupta, Indian Phytopathology 9:72. 1956. (See comments at end of this section)

Protomycopsis crotolariae Joshi, Current Science 24: 168. 1955. (See comments below.)

Protomycopsis phaseoli (Patel, Kulkarni & Dhande) Ramakrishan & Subramanian, The Madras University Journal B. 26(2):367. 1956. (See comments below.)

SYNONYMS: *Synchytrium phaseoli* Patel, Kulkarni & Dhande RS46. This name has probably never been published.
Protomycopsis patelli Pavgi & Thirumalachar, Nature 172:315. 1953.

Protomycopsis thirumalacharii Pavgi, Experientia 25 (5):282. 1965.

The above four species are parasitic on Leguminosae, a family that is not host to any other recognized species of Protomycetaceae. We examined specimens of the species and observed that their spores were much smaller, darker, and more heavily ornamented than those of Protomycetaceae, and they appeared to be produced both terminally and intercalaraly on the mycelium. Haware and Pavgi (1971), who germinated the spores of *P. patelii* and *P. thirumalacharii*, did not observe ascospore production within a vesicle, indicating a different mode of germination than that seen in

Protomycetaceae. Moreover, both species produced mycelium in culture, in contrast to the yeastlike growth produced by species of Protomycetaceae. In addition, one of them, *P. thirumalacharii*, was reported to have a conidial stage (Pavgi and Haware, 1970). These characters do not indicate a relationship to the Protomycetaceae.

GENUS TAPHRIDIUM

Taphridium Lagerheim & Juel, Bihang Till K. Svenska Vet-Acad. Hardlinger 27(3):7. 1902.

Members parasitic on species of Umbelliferae, causing effused blotches on leaves. Ascogenous cells occurring in a single, compact, continuous layer beneath the epidermis; spherical, elliptical to polyhedral, because of mutual pressures; almost hyaline, smooth walled; germinating immediately without a rest period; vesicles not produced. Ascospores produced within the ascogenous cell (without the formation of a vesicle), released by the rupture of the ascogenous cell wall; following their release, ascospores fusing in pairs.

TYPE SPECIES: *Taphridium umbelliferarum* (Rostrup) Lagerheim & Juel.

KEY TO THE SPECIES OF TAPHRIDIUM

1. Ascogenous cells 55(30-78) µ, parasitic on *Carum* and *Furula*. . . . . *T. algeriense*
1. Ascogenous cells 35(19-48) µ, parasitic on species of *Angelica, Heracleum* and *Peucedanum*. . *T. umbelliferarum*

1. *Taphridium algeriense* Juel, Bihang Till K. Svenska Vet-Acad. Hardlinger 27(3):7. 1902.

ILLUSTRATIONS: Figs. 70-72.

Effused blotches on upper surface of leaves. Ascogenous cells 55(30-78) µ, smooth walled, spherical, elliptical to polyhedral because of mutual pressure; hyaline. Ascospores 4 x 2 µ.

HOST GENERA: *Carum* and *Ferula*

DISTRIBUTION: N. Africa; Algeria; Europe: Finland, U.S.S.R.

2. *Taphridium umbelliferarum* (Rostrup) Lagerheim & Juel, Bihang Till K. Svenska Vet-Acad. Hardlinger 27(3):7. 1902.

SYNONYMS: *Taphrina umbelliferarum* Rostrup, Botan. Tidsskrift, Kjobenhavn 14:239. 1883.
Taphrina oreoselini Massalongo, Nuovo Giornale Botanico Italiano 21:141. 1889.
Magnusiella umbelliferarum Sadebeck, Jahrb. Hamburg, wiss, Anstalt 10(2):88. 1893.
Volkartia umbelliferarum (Rost.) von Buren, Beitr. Kryptfl. Schweiz 5(1):69. 1915.

ILLUSTRATIONS: Figs. 73-75.

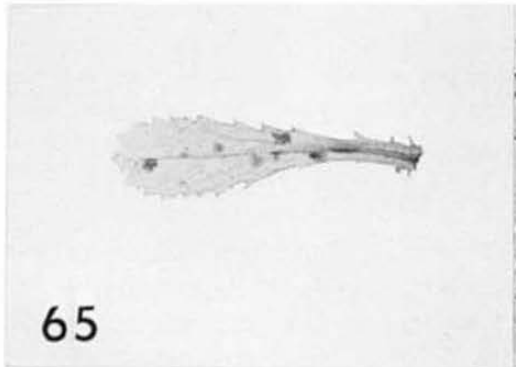
Effused blotches, often extensive, on the upper surface of the leaves. Ascogenous cells 35(19-48) μ, spherical, elliptical to polyhedral because of mutual pressure; hyaline, smooth walled. Ascospores 2-7 x 1-4 μ.

HOST GENERA: *Angelica, Heracleum, Peucadanum*

DISTRIBUTION: Asia: Japan; N. America: California; Europe: Austria, Czechoslovakia, Denmark, England, Finland, E. and W. Germany, Ireland, Italy, Norway, Scotland, Sweden, Switzerland, U.S.S.R.

Taphridium umbelliferarum has been reported to occur on *Heracleum aspercum* Bieb. but specimens were unavailable for study.

Figs. 65-69. *Protomycopsis leuconthemi*: 65, spots on leaves of *Chrysanthemum leucanthemi*; 66-67, cross section through the leaf spot (66, 73X; 67, 284X); 68, teased ascogenous cells showing rugulose wall (arrow), 284X; 69, young ascogenous cells, 284X. Figs. 70-72. *Taphridium algeriense*: 70, effused leaf blotches on leaves of *Ferula communis* (arrows); 71, cross section of leaf blotch, ascospores (arrow) produced within ascogenous cells, 284X; 72, teased ascogenous cells, 284X.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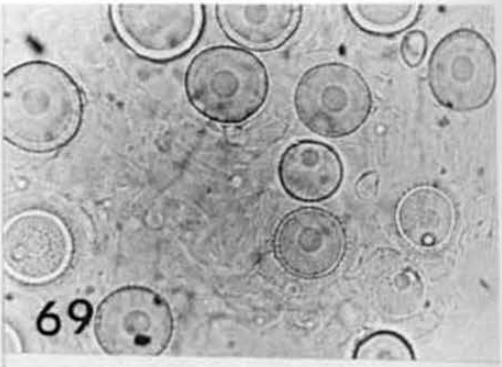
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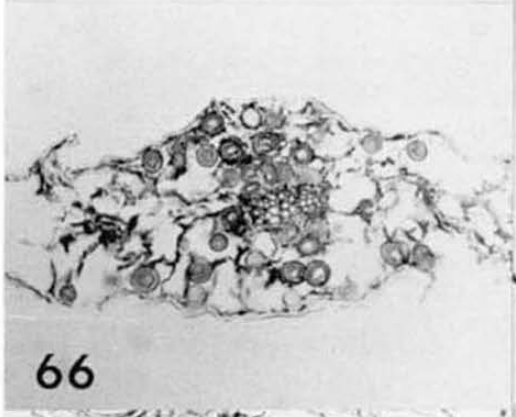
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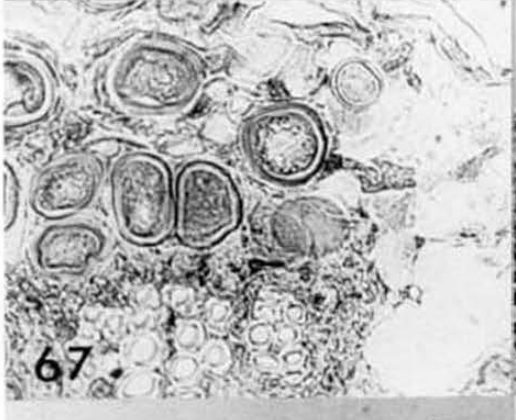
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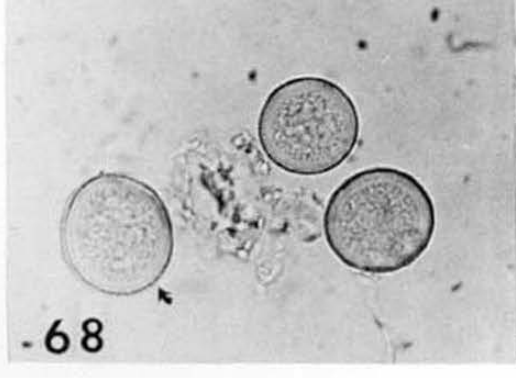
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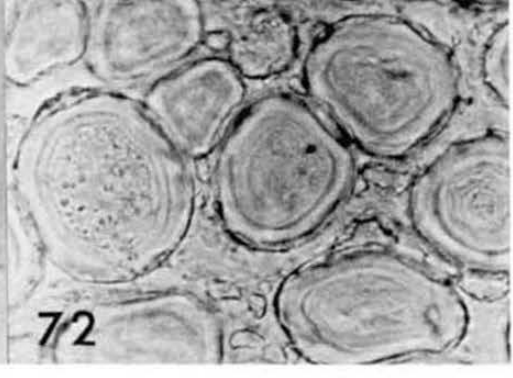
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GENUS VOLKARTIA

Volkartia Maire, Bull. de la Societe Botanique de France 54:145. 1907.

Parasitic on species of Compositae. Ascogenous cells in a single compact continuous layer, usually beneath the upper epidermis; spherical, smooth walled; germinating immediately by producing a vesicle. Ascospores produced either in the ascogenous cell, then moving into the vesicle, or produced in the vesicle; ascospores fusing in pairs following their release.

The single species *Volkartia rhaetica* is recognized.

TYPE SPECIES: *Volkartia rhaetica* (Volkart) Maire

The fungus originally described as *Taphrina rhaetica* by Volkart (1903) also has been referred to as *Taphridium crepidis* (Lagerheim, 1903). Maire (1907) erected the genus *Volkartia* to accommodate this organism, distinguished from *Taphrina* and from *Taphridium* by its thick-walled ascogenous cells that germinate by producing a vesicle. Von Buren (1915, 1922) considered *Taphridium* and *Volkartia* to be synonymous, based on the ascogenous cells that occurred in a single subepidermal layer. We have chosen to retain *Volkartia* separate from *Taphridium*.

1. *Volkartia rhaetica* (Volkart) Maire, Bull. de la Societe Botanique de France 45:146. 1907.

SYNONYMS: *Taphrina rhaetica* Volkart, Berichte der Duetschen Botan. Gesellschaft. 21:477. 1903. *Taphridium crepidis* Lagerheim in Vestergren, Micromycetes rariores selecti 719--Exsiccati (15.6. 1903).

ILLUSTRATIONS: Figs. 76-79.

Produces blotches, occasionally puckering the leaves. Ascogenous cells spherical, 17(11-22) µ, hyaline; vesicle oval, oblong to cylindrical, 60-120 x 15-25 µ. Ascospores 4-7 x 1-2 µ.

HOST GENUS: *Crepis*

DISTRIBUTION: Europe: France, E. and W. Germany, Switzerland.

PHYLOGENETIC RELATIONSHIPS

Recent workers, including Tubaki (1957), Valadon *et al.* (1962), Pavgi and Mukhopadhyay (1970), and Kramer (1973), place the Protomycetales in the Hemiascomycetes. In the past Protomycetales were included in the Ascomycetes, based primarily on the assumption that the vesicle within which the ascospores are produced was a synascus containing numerous naked asci. Now that meiotic division of the diploid nuclei within the vesicle, resulting in tetrads of haploid spores (Pavgi and Mukhopadhyay, 1970), has been demonstrated, there remains little doubt that these fungi should be placed among the Ascomycetes.

Based on their cell-wall composition and their predominantly diploid life cycle Valadon *et al.* (1962) considered the Protomycetaceae as a family in the Endomycetales. They considered *Protomyces* as derived from *Spermophthora* (Spermophthoraceae) or its ancestral forms. Tubaki (1957) considered *Protomyces* to be related to *Taphrina*, because the two species are similar in nutritional physiology, cultural characters, and parasitic mycelial stage (in contrast to the yeastlike growth in culture). However, he added that *Protomyces*, also related to yeasts in cultural characters, must have evolved from the yeasts, possibly the Endomycetaceae or Cryptococcaceae. On the basis of GC (gaunine-cytocine) content of 52-52.4% in three species of *Protomyces*, Nakase and Komagata (1971) indicated a close relationship between *Protomyces* and *Taphrina*. Apparently, also a strong relationship exists between yeasts and the Protomycetales, and Protomycetales and Taphrinales.

Protomyces probably evolved from yeasts through members of the Spermophthoraceae, Endomycetaceae, or Cryptococcaceae. However, Pavgi and Mukhopadhyay (1970) have indicated the possibility of a monophyletic origin of

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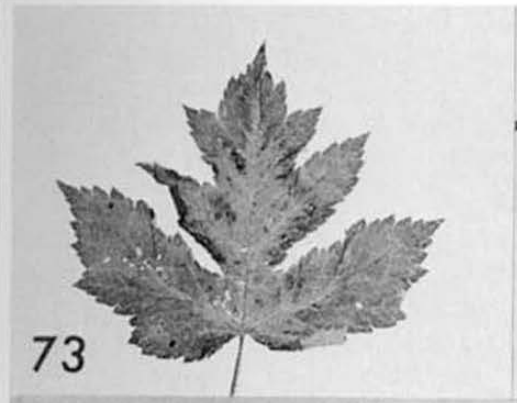
Figs. 73-75. *Taphridium umbelliferarum*: 73, effused blotch on leaf of *Heraclum sibiricum*; 74, cross section of leaf blotch, ascospores (arrow) produced within ascogenous cells, 284X; 75, teased ascogenous cells, 284X. Figs. 76-79. *Volkartia rhaetica*: 76, blotches on leaves of *Crepis succisaefolia* (arrows); 77, cross section of leaf blotch, ascogenous cells and vesicles with ascospores, on both upper and lower surfaces, 284X; 78, teased ascogenous cell (a), germinating ascogenous cell (b) and vesicle (c) with endospores, 284X; 79, germinating ascogenous cells.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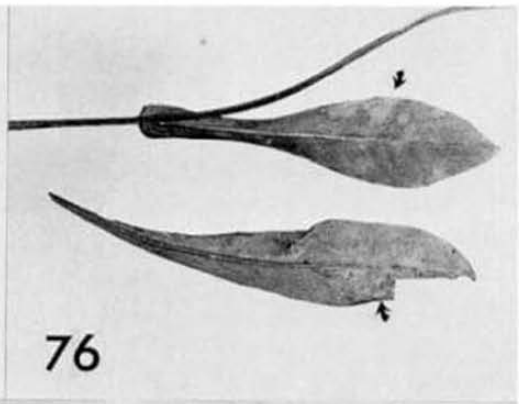
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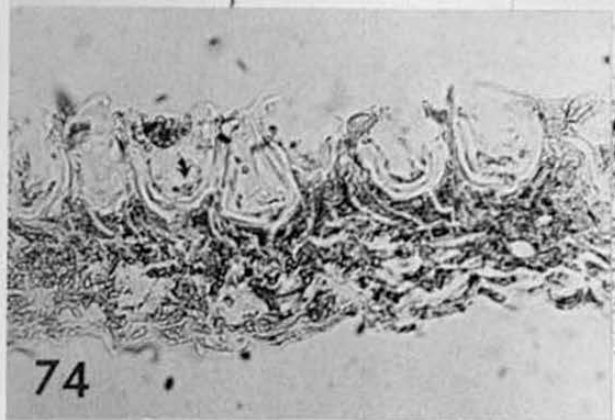
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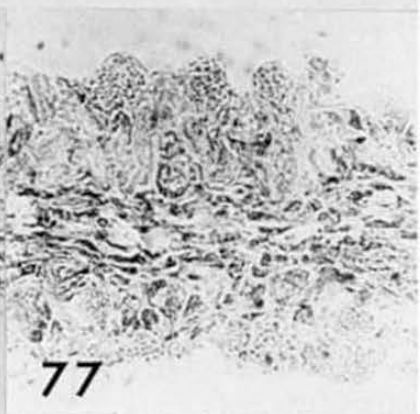
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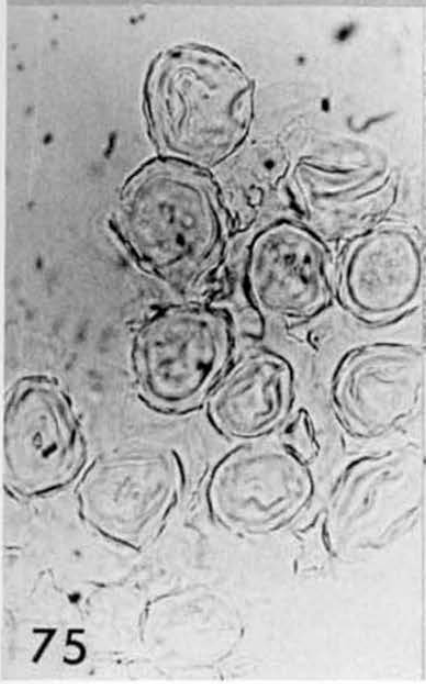
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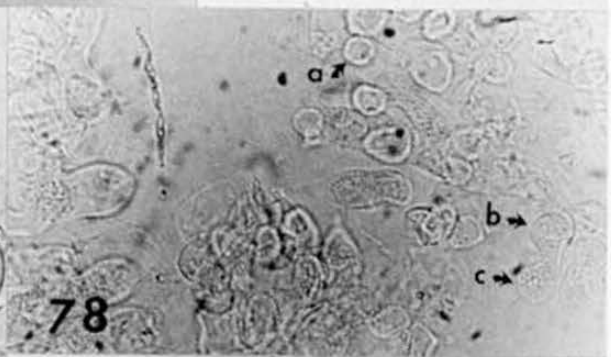
a
b
c
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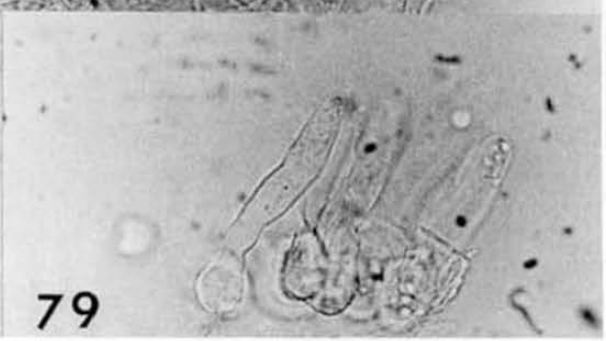
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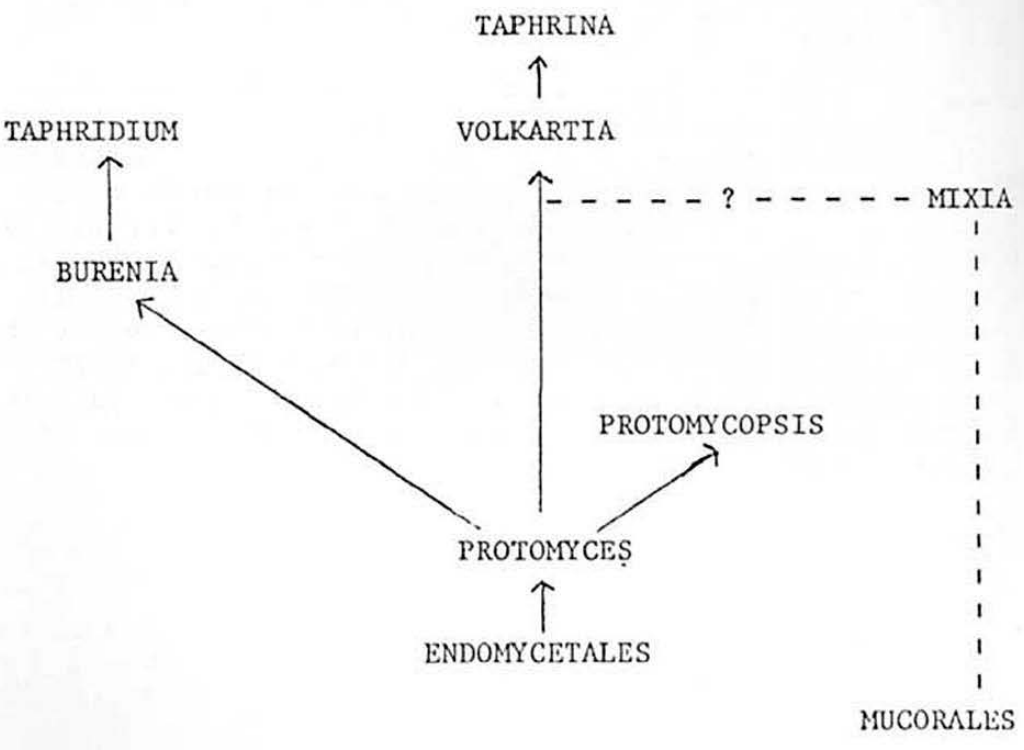
Ascomycetes (*Protomyces*) from Phycomycetes through members of the Entomophthorales, such as species of *Basidiobolus* that produce endospores in tetrads.

The genus *Mixia* tentatively was placed in the Protomycetales (Kramer, 1958, 1973), because of enlarged multinucleate cells that develop from the mycelium and give rise to vesicles within which "endospores" are produced. The single species of the genus, *Mixia osmundae* (Nishida) Kramer, has not been studied cytologically, and thus it is not known if meiosis occurs in the vesicle prior to "endospore" formation. If it does, it may be proper to treat the genus as a separate family within the Protomycetales. However, the formation of a columella within the vesicle from the basal cells and the fern hosts do not indicate a close relationship with the genera treated in this study.

The possible phylogenetic relationships of the genera of this group and of other related groups is shown in this diagram:



The genera *Protomyces* and *Protomycopsis* have much in common; they differ mainly in the position of their ascogenous cells on the mycelium. Quite likely, species of *Protomycopsis* have arisen from members of *Protomyces*. *Protomyces inouyei* produces ascogenous cells intercalaraly on the mycelium (as does any other species of *Protomyces*), but the ascogenous cell walls are rough like those of *Protomycopsis*.

The genus *Burenia* has been created to accommodate two species that resemble both *Protomyces* and *Taphridium*. The ascogenous cells in *Burenia* germinate immediately without producing a vesicle. Von Buren's (1918) observation that occasionally a few of the ascogenous cells of *Burenia inundata* germinate to produce a vesicle after a rest period indicates its relationship to *Protomyces*. In *Burenia cicuta*, all the ascogenous cells germinate immediately, as in the genus *Taphridium*, without forming a vesicle. *Taphridium* differs from *Burenia cicuta* in the location of its ascogenous cells--in a single subepidermal layer. The ascogenous cell walls of *Taphridium* and *Burenia* (best seen in germinated cells) are comparatively thinner than those of *Protomyces*.

Although von Buren (1915) and Juel (1921) have considered them synonymous, *Volkartia* and *Taphridium* have been retained here as separate genera, based on the production of a vesicle by the former and its absence in the latter. *Volkartia* differs from *Protomyces* in that it produces ascogenous cells in a single subepidermal layer and in that they germinate immediately. The single layer of germinated ascogenous cells (the smallest of any member of the Protomycetales) plus vesicles filled with ascospores superficially resembly species of *Taphrina*. Also, the symptoms, leaf spots, and blisters, are similar to those of many species of *Taphrina*.

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MYCOTAXON

Vol. III, No. 1, pp. 51-54 October-December 1975

A NEW SPECIES OF SYNCEPHALASTRUM

P. C. MISRA

Department of Botany, University of Gorakhpur
Gorakhpur 273001, U.P., India

SUMMARY

Syncephalastrum verruculosum Misra, a new species isolated from air of Gorakhpur, India, is described and illustrated.

The genus *Syncephalastrum* Schroeter is characterized by cylindrical, multispored merosporangia borne in large numbers on the surface of vesicular enlargements produced terminally on simple or branched sporangiophores; the zygospores are *Mucor*-like in formation and appearance. Benjamin (1959, 1966), and Hesseltine and Ellis (1973) recognize a single species, *S. racemosum* Cohn ex Schroeter, in this genus.

An interesting species of *Syncephalastrum* was isolated by the author in February 1973. It appeared in a petri dish containing Martin's peptone-dextrose agar medium (Martin, 1950) and exposed to air in a first-floor verandah of the Department of Botany, University of Gorakhpur. The fungus grew readily in pure culture and is believed to be sufficiently different from *S. racemosum* to be regarded as a new species on morphological grounds. The isolate is described here as a new species. The description is based on monospore cultures grown on synthetic *Mucor* agar (SMA; Hesseltine, 1954) and potato dextrose agar (PDA) media. The color plate numbers in parentheses are cited from Maerz and Paul (1950). The specific epithet of the new taxon is based on the verruculose nature of its sporangiospores.

SYNCEPHALASTRUM VERRUCULOSUM sp. nov. (Fig. 1)

Coloniae in SMA (agaro composito ad Mucoraceas colendas idoneo) vel PDA (agaro e Solani tuberis cum dextroso composito) septem dies ad 25 C caloris vigentes 9 cm diametro, viridi-griseae, denique pallide brunneae, c. 1 mm altae, vel-

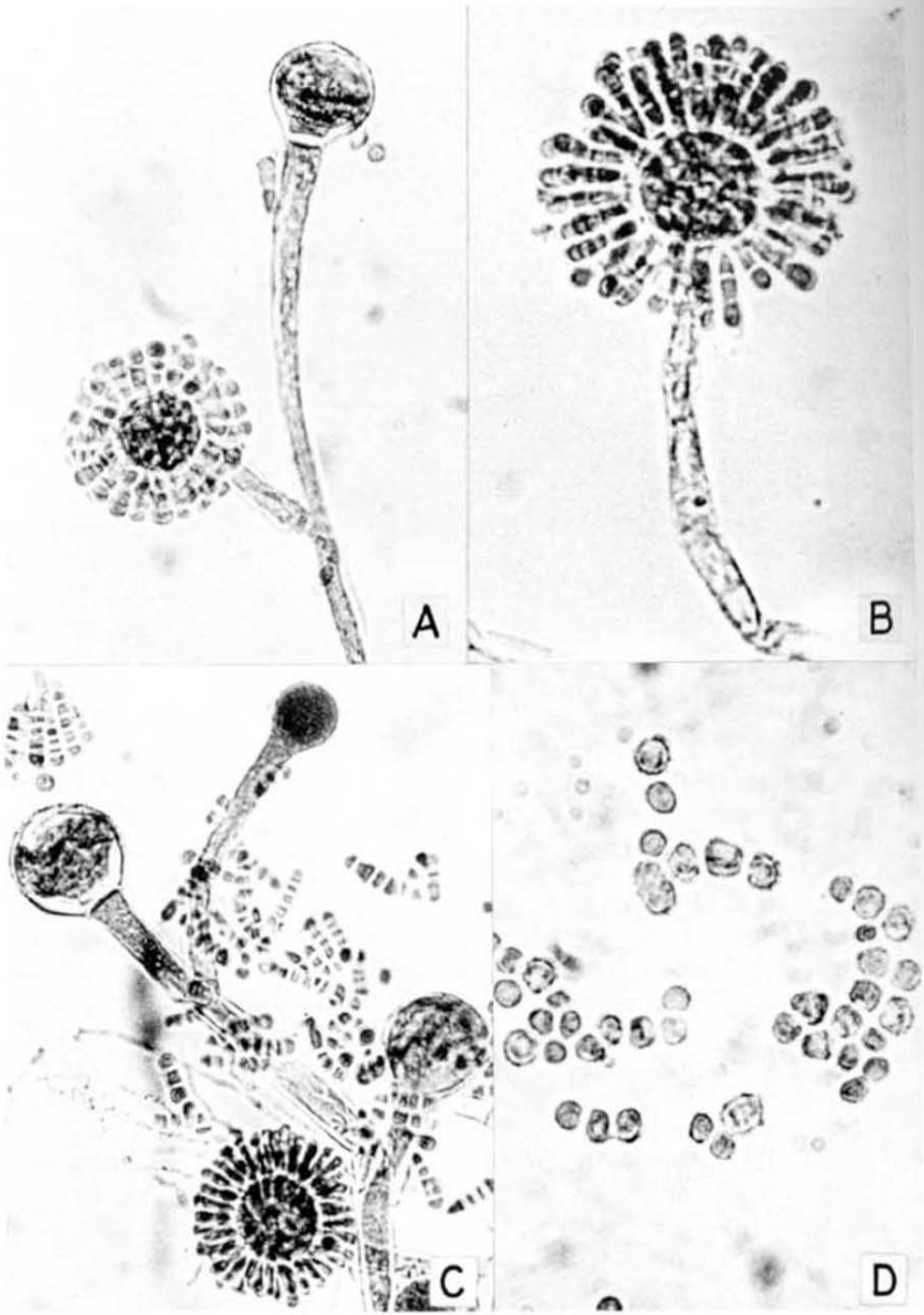

Fig. 1. *Syncephalastrum verruculosum*. A-C, sporangiophores and merosporangia (A x450; B x700; C x400). D, sporangiospores (x750). All stained with cotton blue.

Syncephalastrum verruculosum also grows well on yeast extract - soluble starch agar (YpSs; Benjamin, 1959) and malt extract agar (Blakeslee, 1915) media. The morphological features of the fungus do not vary to any significant extent on these media. Growth is very slow on Czapek's agar medium.

Syncephalastrum verruculosum differs sharply from *S. racemosum* in having very low, velvety colonies, narrower sporangiophores, smaller and consistently globose vesicles, shorter but wider merosporangia, fewer sporangiospores in the merosporangia, and larger sporangiospores which are verruculose.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. R. K. Benjamin for examining the fungus and giving many helpful suggestions, Prof. K. S. Bhargava for encouragement and facilities, and Dr. Donald P. Rogers for the Latin translation of the diagnosis.

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MYCOTAXON

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SOIL MICROFUNGI OF CENTRAL AND SOUTHERN OHIO[1]

L. H. HUANG[2] AND J. A. SCHMITT

Department of Botany, The Ohio State University, Columbus, Ohio 43210

SUMMARY

A survey was made of soil microfungi in subsurface soil samples collected in 22 localities from the non-agricultural, relatively undisturbed areas of central and southern Ohio. Fungi were isolated by the dilution plate method and from soil subjected to alcohol treatment, heat incubation, and hair-baiting. A total of 180 species and one variety in 84 genera were obtained, including 26 phycomycetes, 43 ascomycetes, and 112 deuteromycetes. Forty genera are reported from Ohio soils for the first time. The most prevalent genera in a decreasing order of frequency were Penicillium, Trichoderma, Mortierella, and Talaromyces. The dominant species were Aspergillus fumigatus, Fusarium oxysporum, Geniculisporium serpens, Mortierella nana, Mucor hiemalis, Nodulisporium sp., Talaromyces luteus, T. trachyspermus, Trichoderma hamatum, T. koningii, and T. polysporum. Six thermophilic fungi and 3 keratinophilic fungi were isolated. The alcohol treatment method appeared to be highly selective for the Ascomycetes, especially members of the Eurotiaceae, the Melanosporaceae, the Sordariaceae, and small discomycetes such as those of the Ascobolaceae and the Pyronemataceae. This method not only selected 36 ascomycetes, which accounted for about 84% of the ascomycete species, but

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[1] Paper No. 891, Department of Botany, The Ohio State University, Columbus.

[2] Present address: Department of Plant Pathology, The University of Georgia, Athens, Ga. 30602

yielded many soil fungi which are infrequently recorded in the literature.

INTRODUCTION

Since Adametz (2) first isolated 11 filamentous fungi and four yeasts from the soil of some experimental plots in Germany, soil fungi have been studied for nearly 90 years. Some soil fungi are known to be potential allergens, zoopathogens, or phytopathogens, and others are capable of producing antibiotics, mycotoxins, and other metabolites. Moreover, soils provide a rich source of materials for taxonomic and morphological studies of fungi that sporulate in culture. Such practical and theoretical considerations have made the study of soil fungi a major area of mycological research.

In the United States, Abbott (1), Jensen (30), and Waksman (48) were pioneer soil mycologists. Among these, Waksman's studies were particularly notable and had a world-wide impact. In the United States, studies on soil fungi have been carried out in Colorado (35), Georgia (21, 39), Hawaii (31), Iowa (42), Louisiana (1), Mississippi (6), New Jersey (48), New York (30), Ohio (12, 52), the Sonoran Desert (43), the southern states (22, 24), Texas (51), and Wisconsin (10, 47).

Previous studies on soil fungi in Ohio have been concerned with the microfungi of cultivated or disturbed soils (12, 52). The present study was undertaken to chart the soil fungus population of non-agricultural, relatively undisturbed soils in central and southern Ohio. The emphasis here has been chiefly qualitative rather than quantitative. Two new fungi and several interesting fungi have been reported elsewhere (26, 27, 28, 29).

MATERIALS AND METHODS

Twenty-two soil samples were collected from non-agricultural, relatively undisturbed, forested or grassy sites in central and southern Ohio (Table I). The locations of soil samples were as follows: Sample 1, "Cedar Swamp," 3 miles north of Springfield on Route 68; Sample 2, Cincinnati; Sample 3, half mile east of Hillsboro on

Table I.

Predominant vegetation, pH, and number of fungi of Ohio soils

Soil number and locality	Date sampled	Predominant vegetation	pH	Number of fungi, in thousands, per gram of dry soil
1. Clark Co.	6/28/72	evergreen forest[a]	7.6	144
2. Hamilton Co.	6/29/72	deciduous forest[b]	7.0	68
3. Highland Co.	6/29/72	deciduous forest[c]	5.6	80
4. Ross Co.	6/30/72	evergreen forest[d]	5.6	124
5. Franklin Co.	5/30/72	grasses	7.5	248
6. Athens Co.	7/6/72	deciduous forest[e]	4.8	264
7. Athens Co.	7/6/72	evergreen forest[f]	5.1	72
8. Athens Co.	7/7/72	grasses	5.7	64
9. Noble Co.	7/7/72	deciduous forest[g]	5.4	100
10. Belmont Co.	7/7/72	deciduous forest[h]	5.8	120
11. Belmont Co.	7/7/72	deciduous forest[i]	5.6	280
12. Muskingum Co.	7/7/72	deciduous forest[j]	5.9	148
13. Clark Co.	6/28/72	deciduous forest[k]	7.6	72
14. Athens Co.	7/6/72	deciduous forest[l]	5.8	200
15. Athens Co.	7/6/72	evergreen forest[m]	4.8	236
16. Scioto Co.	8/23/72	deciduous forest[n]	6.5	40
17. Adams Co.	8/23/72	grasses	6.0	82
18. Adams Co.	8/23/72	deciduous forest[o]	6.2	200
19. Adams Co.	8/23/72	grasses	6.8	76
20. Clermont Co.	8/23/72	deciduous forest[p]	6.1	132
21. Montgomery Co.	8/23/72	deciduous forest[q]	7.2	136
22. Union Co.	10/17/72	deciduous forest[r]	6.7	112

a. *Thuja occidentalis* L. b. *Acer saccharum* Marsh., *Morus rubra* L., *Quercus alba* L. c. *Acer saccharum*, *Carya ovata* (Mill.) K. Koch, *Cornus florida* L., *Quercus alba*. d. *Pinus resinosa* Ait., *P. strobus* L. e. *Quercus alba*, *Q. velutina* Lam. f. *Picea pungens* Engelm. g. *Acer saccharum*, *Fagus grandifolia* Ehrh. h. *Fagus grandifolia*, *Quercus alba*. i. *Acer saccharum*, *Quercus alba*. j. *Fagus grandifolia*, *Liriodendron tulipifera* L. k. *Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern., *Platanus occidentalis* L. l. *Acer saccharum*, *Quercus alba*, *Q. borealis* Michx. f., *Q. muehlenbergii* Engelm. m. *Pinus strobus*. n. *Liriodendron tulipifera*, *Platanus occidentalis*. o. *Quercus alba*. p. *Acer saccharum*, *Quercus alba*, *Quercus rubra* L., *Ulmus americana* L. q. *Celtis occidentalis* L. r. *Acer saccharum*, *Fagus grandifolia*.

Route 50; Sample 4, 9 miles northeast of Chillicothe; Sample 5, 1 mile south of Columbus on Route 23; Sample 6, southeast facing, upper part of a slope, 12 miles west of Athens; Sample 7, top of a hill, 14 miles west of Athens; Sample 8, lower part of a slope, 5 miles east of Athens; Sample 9, top of a hill, 1 mile east of Belle Valley; Sample 10, North Woods, 4 miles southeast of Belmont; Sample 11, South Woods, 4 miles southeast of Belmont; Sample 12, road side, 10 miles northwest of Zanesville on Route 146; Sample 13, 3 miles north of Springfield on Route 68; Sample 14, northeast-facing, upper part of a slope, 12 miles west of Athens; Sample 15, the middle part of a slope, 14 miles west of Athens; Sample 16, 2 miles northeast of Portsmouth; Sample 17, the middle part of a slope, 1 mile west of Lynx; Sample 18, 1 mile east of West Union; Sample 19, 1 mile west of West Union; Sample 20, one and one-half miles east of Bethel; Sample 21, 6 miles south of Dayton; Sample 22, half mile southeast of Byhalia on Route 31. At each site the surface litter and 1-2 cm of the surface soil were removed. The samples were then taken from three equidistant points (4 feet apart) of the areas thus exposed and brought to the laboratories in Columbus, Ohio. The samples from each site were mixed and air-dried for 2-5 da depending on wetness and stored at 3 C in a cold room. The pH of each sample was determined at the time isolations were made with a Beckman pH Meter from a 1:3 soil-water (v/v) mixture that had equilibrated for 20 min.

Isolations were made 1-2 mo later by four methods. Gochenaur's ammonium nitrate agar (GAN) (18) was used as the isolation medium except when hair was used as a bait. GAN contains rose bengal to reduce fungal colony spread and streptomycin to inhibit bacteria.

The dilution plate method was similar to that used by Barron (8). Twenty-five grams of each sample were mixed with sterile distilled water and diluted in four concentrations ranging from 1/100 to 1/100,000. One ml of dilution was pipetted into each of three sterile petri dishes and mixed with melted GAN. This method not only permitted the isolation of a variety of fungi but also yielded data on the number of fungi per gram of dry soil. The alcohol treatment method involving the use of soil plates was that described by Mahoney et al. (38).

The heat incubation method was designed to select

thermophilic fungi from soil. One-tenth gram of soil was placed in each of three dry, sterile petri dishes. Into these was poured a layer of warm (45 C) GAN. The plates were then gently rotated to distribute the soil particles and incubated at 47-48 C.

The hair-baiting method was used to isolate keratinophilic fungi. A sterilized petri dish was half filled with soil, to which was added sterile distilled water in an amount just covering the soil. Sterilized horse hairs cut into 1 cm lengths were placed on the surface of the soil. The petri plates were incubated at room temperature for 2-4 wk, and colonies developing on or around the hair were transferred to Sabouraud's agar slants.

Following 4-5 da incubation for dilution and alcohol-treated plates and 3 da for heated plates, hyphal tip transfers were made from all developing colonies to malt agar slants. Sub-cultures derived from the heat incubation method were incubated in a 47-48 C incubator for 7 da to assure good growth, whereas cultures obtained by the other methods were incubated in the laboratory at room temperature for two wk. The cultures were sorted into presumed specific entities on the basis of such macroscopic appearance as colony color, texture, and sporulation; and one tube representing each presumed fungal species was assigned a number. Duplicates were discarded. Identifications were made by growing the keratinophilic fungi on Sabouraud's agar, the thermophilic fungi on yeast-starch agar (17), the mucoraceous fungi on Mucor synthetic agar (23), and the others on cornmeal agar (20), Czapek-Dox, and malt extract agars (44).

RESULTS

A. Numbers of fungi

The number of fungi ranged from 40,000 to 280,000 per gram of dry soil, with an average of 136,300. Exclusive of several species of Penicillium, the number of species per sample ranged from 7 to 35 with an average of about 20. There was no relationship between pH and the number of fungi per gram of dry soil. Likewise, there was no relationship between the number of species isolated and pH or the number of fungi per gram of dry soil.

B. Kinds of fungi

A total of 180 species and one variety belonging to 84 genera were isolated and identified. These can be divided as follows: phycomycetes-26, ascomycetes-43, and deuteromycetes-112. No basidiomycetes were isolated. The species, together with the data on localities from which they were isolated, are listed in Table II. The schemes for classifying the Ohio soil fungi were those by Barron (7) for the hyphomycetes and by Ainsworth et al. (3) for the other fungi.

Species of Penicillium occurred with the highest frequency, being isolated from 22 samples, followed in a decreasing order by species of Trichoderma (21 samples), Mortierella (17 samples), and Talaromyces (14 samples). The genus which contained the greatest number of species was Penicillium, being represented by at least 32 species and accounting for about 18% of the total number of species. This was followed by Mortierella (11 species), Talaromyces (7 species), Trichoderma (7 species), Chaetomium (6 species), Mucor (6 species), and Paecilomyces (6 species).

Of the 26 species of phycomycetous fungi, only one, Brevilegnia diclina, was an oomycete. The Zygomycetes were represented by the genera Absidia, Circinella, Cunninghamella, Gongronella, Mortierella, Mucor, Rhizopus, and Zygorhynchus. The most abundant phycomycete was Mortierella nana, with Mucor hiemalis next in frequency.

Although ascomycetes were widely distributed in the Ohio soils, they occurred relatively infrequently with the exception of Talaromyces luteus and T. trachyspermus, which were isolated from 8 and 10, respectively, of the 22 collection sites. Of the 43 species of ascomycetes, 14

Table II.

Fungi isolated from Ohio soils by means of the dilution plate (D), alcohol treatment (A), heat incubation (HI), and hair-bait (HB) methods.

Locality number of soil samples	Isolation method	Fungus	Frequency[a]
		Saprolegniales	
		Saprolegniaceae	
16	D	*Brevilegnia diclina Harvey	4.6
		Mucorales	
		Cunninghamellaceae	
19, 20	D	Cunninghamella elegans Lendner	9.1
		Mortierellaceae	
1, 2, 4, 21	D	Mortierella alpina Peyronel	18.2
4, 10, 11, 18	D	M. isabellina Oud. & Koning	18.2
3, 4, 6, 7, 11, 12, 18	D	M. marburgensis Linnemann	31.8
10	D	M. minutissima van Tiegh.	4.6
20	D	+M. mutabilis Linnemann	4.6
3, 4, 6, 7, 9, 10, 11, 12, 14, 15, 16, 18, 20	A	M. nana Linnemann	59.1
4, 11	D	M. parvispora Linnemann	9.1
10, 16, 20	D	M. ramanniana (Möller) Linnemann	13.6
1	D	+[b]M. sossauensis Wolf	4.6
6, 7, 11, 12	A, D	M. vinacea Dixon-Stewart	18.2
13	D	M. zonata Linnemann	4.6
		Mucoraceae	
11	D	Absidia californica Ellis & Hesseltine	4.6
7, 15	D	A. cylindrospora Hagem	9.1
14, 19	D	A. spinosa Lendner	9.1
20	D	Circinella sp.	4.6
20	D	*Gongronella butleri (Lendner) Peyronel & Dal Vesco	4.6
3	D	Mucor corticolus Hagem	4.6

8	D	M. fragilis Bain.	4.6
18	D	M. griseo-cyanus Hagem	4.6
3, 4, 8, 15, 16, 18, 21, 22	D	M. hiemalis Wehmer	36.4
22	A	M. mucedo (L.) Fres.	4.6
9, 22	D	M. racemosus Fres.	9.1
17	D	Rhizopus arrhizus Fischer	4.6
3, 4, 6, 8	D	Zygorhynchus moelleri Vuill.	18.2
		Eurotiales	
		Eurotiaceae	
17	A	*Byssochlamys nivea Westling	4.6
5, 19	A	+*Dichotomomyces cejpii (Mil'ko) Scott	9.1
20	A	*Eupenicillium levitum (Raper & (Fennell) Stolk & Scott	4.6
18	A	Eupenicillium sp.	4.6
1, 17	A	+*Eurotium chevalieri Mangin	9.1
1, 5, 16, 17, 18, 19	A	+E. chevalieri var. intermedium (Thom & Raper) Malloch & Cain	27.3
22	A	+E. rubrum Konig, Spieckermann & Bremer	4.6
20	A	*Hamigera avellanea Stolk & Samson	4.6
21	A	*Sartorya fumigata Vuill.	4.6
11, 13, 16, 17, 18, 19	A	*Talaromyces flavus (Klöcker) Stolk & Samson var. flavus Stolk & Samson	27.3
17	A	+T. helicus C.R. Benjamin var. helicus Stolk & Samson	4.6
4, 7, 8, 11, 13, 16, 17, 19	A	+T. luteus (Sacc.) Stolk & Samson	36.4
1, 4, 5, 11, 12, 13, 16, 17, 18, 19	A	T. trachyspermus (Shear) Stolk & Samson	45.6
5	A	+T. ucrainicus Udagawa	4.6
16, 19	A	+T. udagawae Stolk & Samson	9.1
10, 11, 12, 16, 19, 20	A, D	T. wortmannii C.R. Benjamin	27.3

		Gymnoascaceae	
5, 13	A	+*Eleutherascus lectardii (Nicot) von Arx	9.1
		Pseudeurotiaceae	
16	A	+*Pseudeurotium punctatum Panasenko	4.6
16, 17, 19	A	P. zonatum van Beyma	13.6
		Thermoascaceae	
21	HI	*Thermoascus aurantiacus Miehe	4.6
		Sphaeriales	
		Diaporthaceae	
10	D	+*Gnomonia sp.	4.6
		Hypocreaceae	
5	D	+*Nectria episphaeria (Tode ex Fr.) Fr.	4.6
		Melanosporaceae	
22	A	Chaetomium cochliodes Palliser	4.6
22	A	C. funicolum Cooke	4.6
14	A	C. seminudum Ames	4.6
18	D	C. spirale Zopf	4.6
22	A	+C. subspirale Chivers	4.6
6, 10	D	+C. torulosum Bain.	9.1
22	A	+*Petriella guttulata Barron & Cain	4.6
		Sordariaceae	
16	A	*Coniochaeta sp.	4.6
15	A	+*Diplogelasinospora princeps Cain	4.6
21	A	+*Gelasinospora cerealis Dowding	4.6
10	D	Sordaria fimicola (Rob.) Cesati	4.6
22	A	+*Strattonia minor Lundqvist	4.6
22	A	+Strattonia sp.	4.6
21	A	+*Triangularia backusii Huang	4.6

		Pleosporales	
		Sporormiaceae	
1, 13	D	*Sporomiella leporina (Niessl) Ahmed & Cain	9.1
		Pezizales	
		Ascobolaceae	
16	A	+*[c]Ascobolus epimyces (Cooke) Seaver	4.6
16, 18	A	+*Saccobolus globuliferellus Seaver	9.1
		Pyronemataceae	
17, 18, 22	A	+*Ascodesmis nigricans van Tiegh.	13.6
3, 19, 20, 21	A	+A. sphaerospora Obrist	18.2
19	A	+*[d]Coprotus niveus (Fuckel) Kimbrough, Luck-Allen & Cain	4.6
22	A	*Trichophaea abundans (Karst.) Boud.	4.6
		Moniliales	
		Aleuriosporae	
19	HB	Chrysosporium keratinophilum (Frey) Carmichael	4.6
8, 11, 12, 18, 21	D, HB	+*Diheterospora chlamydosporia (Goddard) Barron & Onions	22.7
4, 12, 13, 20	HI	Humicola grisea Traaen var. thermoidea Cooney & Emerson	18.2
1, 9	A	+[e]Monosporium apiospermum Sacc. Conidial state of Allescheria boydii Shear	9.1
1	A	Mycogone sp.	4.6
17, 22	HI	Sporotrichum thermophile Apinis	9.1
13	D	+*Staphylotrichum coccosporum Meyer & Nicot	4.6
13, 16	D	+*Trichocladium canadense Hughes	9.1
20	HB	Trichophyton terrestre Durie & Frey	4.6
		Annellosporae	
16	D	+Doratomyces microsporus (Sacc.) Morton & Smith	4.6
17	D	+Scopulariopsis candida (Guéguen) Vuill.	4.6

		Arthrosporae	
17	HI	*Malbranchea pulchella Sacc. & Penzig var. sulfurea (Miehe) Cooney & Emerson	4.6
4, 7	D	*Oidiodendron flavum Szilvinyi	9.1
		Blastosporae	
2	D	Aureobasidium pullulans (de Bary) Arnaud	4.6
16	D	Candida sp.	4.6
5, 13	D	Cladosporium cladosporioides (Fres.) de Vries	9.1
5	D	C. herbarum Link ex Fr.	4.6
13, 16	A	+Periconia igniaria Mason & Ellis Conidial state of Didymosphaeria igniaria Booth	9.1
		Meristem Blastosporae	
5	D	Arthrinium phaeospermum (Corda) M.B. Ellis	4.6
		Phialosporae	
8, 9, 11, 16	HI	Acremonium alabamensis G. Morgan-Jones	18.2
5, 13	A, D	A. curvulum W. Gams	9.1
2, 3, 10, 12, 13, 19	D	A. strictum W. Gams	27.3
16	D	Acremonium sp.	4.6
19, 21	D	Aspergillus flavipes (Bain. & Sart.) Thom & Church	9.1
1, 2, 3, 9, 10, 11, 16, 21	HI	A. fumigatus Fres.	36.4
22	D	A. sydowi (Bain. & Sart.) Thom & Church	4.6
18	A	A. terreus Thom	4.6
2	D	+*Cephalosporiopsis sp.	4.6
11	D	*Chloridium chlamydosporis (van Beyma) Hughes	4.6
1, 3, 16, 19	D	+Cylindrocarpon destructans (Zins.) Scholten	18.2
18	D	Cylindrocarpon sp. I	4.6
18	D	Cylindrocarpon sp. II	4.6
19	D	Fusarium moniliforme (Sheldon) Snyder & Hansen	4.6

3, 8, 13, 16, 18, 19, 20, 21	D	F. oxysporum (Schlecht.) Snyder & Hansen	36.4
1, 8, 13	D	F. solani (Mart.) Sacc. emend. Snyder & Hansen	13.6
10	D	+*Gliocephalotrichum ohiense Huang & Schmitt	4.6
5	D	Gliocladium deliquescens Sopp	4.6
5, 8, 13, 18, 19, 21	D	G. roseum Bain.	27.3
14	D	G. virens Miller, Giddens & Foster	4.6
5	D	Gliomastix murorum (Corda) Hughes var. felina (Marchal) Hughes	4.6
3	D	*Gonytrichum macrocladium (Sacc.) Hughes	4.6
1, 8, 16, 19, 20, 21	D	*Metarrhizium anisopliae (Metsch.) Sorok.	27.3
11	D	+Paecilomyces bacillisporus Onions & Barron	4.6
3, 7, 8, 16, 20, 21	D	P. carneus (Duché & Heim) Brown & Smith	27.3
8, 16	D	P. elegans (Corda) Mason & Hughes apud Hughes	9.1
21	D	+P. fumoso-roseus (Wize) Brown & Smith	4.6
1, 5, 7, 8, 18, 20, 21	D, HB	P. marquandii (Massee) Hughes	31.8
14	A	P. varioti Bain.	4.6
19	D	Penicillium brevi-compactum Dierckx	4.6
12, 20	D	P. brevi-compactum series I	9.1
12	D	P. brevi-compactum series II	4.6
14, 15, 17	D	P. citrinum Thom	13.6
19	D	P. commune series I	4.6
20	D	P. commune series II	4.6
10, 12	A	P. corymbiferum Westling	9.1
17	D	P. cyclopium Westling	4.6
11, 18	D	+P. daleae Zaleski	9.1
11, 15, 17	D	P. frequentans Westling	13.6

14	A	P. frequentans series	4.6
20	D	P. funiculosum Thom	4.6
3, 11, 14, 18	A, D	P. granulatum Bain.	18.2
20	D	P. janthinellum Biourge	4.6
11, 15, 18, 20, 21	D	P. nigricans (Bain.) Thom	22.7
11	D	P. nigricans series	4.6
16	A	P. notatum Westling	4.6
6, 20	D	P. purpurogenum Stoll	9.1
18, 19	A	P. raistrickii Smith	9.1
20	D	P. raistrickii series	4.6
15, 17, 18, 19	A, D	P. roqueforti Thom	18.2
17, 18, 19, 21	A, D	P. rubrum Stoll	18.2
10	A	P. rugulosum Thom	4.6
14	D	P. steckii Zaleski	4.6
12	D	P. stoloniferum Thom	4.6
19	A	P. thomii Maire	4.6
10	A	P. thomii series I	4.6
3, 9, 11, 15, 18	A	P. thomii series II	22.7
12, 16, 17, 18, 19	A	P. thomii series III	22.7
7, 10, 12	D	P. velutinum van Beyma	13.6
12, 20, 21	D	P. waksmani Zaleski	13.6
1, 2, 3, 4, 5, 6, 7, 8, 13, 16, 22	A, D	Penicillium spp.	
1	A	Phialophora sp.	4.6
3, 16, 21	D	Stachybotrys cylindrospora Jensen	13.6
7, 12, 17	D	+Trichoderma aureoviride Rifai	13.6
1, 3, 4, 5, 7, 9, 12, 14, 18, 20, 22	D	T. hamatum (Bon.) Bain	50.0
2, 8, 9, 10, 11, 16, 19	D	+T. harzianum Rifai	31.8
1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, 22	D	T. koningii Oud.	77.3
21	D	T. longibrachiatum Rifai	4.6

3, 4, 6, 8, 14, 18, 20, 21, 22	D	T. polysporum (Link ex Pers.)Rifai	40.9
14	A	T. pseudokoningii Rifai	4.6
3	D	Verticillium cephalosporium W. Gams	4.6
7	D	V. psalliotae Treschow	4.6
11	D	Verticillium sp.	4.6
13	D	Volutella ciliata Fr.	4.6
		Porosporae	
5	HI	Torula thermophila Cooney & Emerson	4.6
		Sympodulosporae	
3, 6, 7, 11, 12, 18, 21	D	Beauveria bassiana (Bals.) Vuill.	31.8
18	D	+*Cordana pauciseptata Preuss	4.6
2	D	Dactylaria sp.	4.6
1, 2, 5, 8, 9, 11, 13, 16, 18, 19	A	+*Geniculisporium serpens Chesters & Greenhalgh	45.6
1, 4, 9, 10, 11, 14, 16, 18, 19	A	+*Nodulisporium sp.	40.9
17, 19	A, D	Rhinocladiella mansonii (Cast.) Schol-Schwarz	9.1
		Melanconiales	
		Melanconiaceae	
16	D	Pestalotia lespedezae Syd.	4.6
4	D	P. mangifolia Guba	4.6
		Sphaeropsidales	
		Sphaeropsidaceae	
19	D	Coniothyrium fuckelii Sacc.	4.6
1, 3, 16, 18	D	Coniothyrium sp.	18.2
15	A	Phoma prunicola (Opiz) Wollenw. & Hochapf.	4.6
1, 8, 18	A, D	Phoma sp. I	13.6
3	D	Phoma sp. II	4.6
13	D	Phoma sp. III	4.6

13	D	Phomopsis sp.	4.6
10	D	Pyrenochaeta decipiens Marchal	4.6
5	D	Pyrenochaeta sp.	4.6
		Mycelia Sterilia	
11, 14, 20, 22	A	Rhizoctonia solani KÜhn	18.2

* First report of this genus from Ohio soils.

\+ Species preceded by a plus (+) are reported for the first time from soil in the United States

[a] Frequency is expressed as the number of samples from which isolates were obtained divided by the total of 22 samples

[b] Identified by W. Gams

[c] Confirmed by J. van Brummelen

[d] Confirmed by J. W. Kimbrough

[e] Identified by M. B. Ellis

were ascocarpic Aspergilli and Penicillia belonging in the genera Eurotium, Sartorya, Eupenicillium, Hamigera, and Talaromyces. Members of the Melanosporaceae and the Sordariaceae isolated included the following: 6 species of Chaetomium, one species of Petriella, two species of Strattonia, and one species each of Coniochaeta, Diplogelasinospora, Gelasinospora, Sordaria, and Triangularia. Ascobolus and Saccobolus of the Ascobolaceae, and Ascodesmis, Coprotus, and Trichophaea of the Pyronemataceae were among the discomycetous genera whose members were isolated.

Nearly two thirds of the total 180 species isolated can be assigned to the Deuteromycetes. Isolates of Penicillium and Trichoderma dominated both in frequency and in the number of species represented. Among the Penicillia, Penicillium nigricans, P. thomii series II, and P. thomii series III had a frequency of 22.7% each, whereas Trichoderma koningii and T. hamatum had high frequencies of 77.3% and 50%, respectively. Other fungi which had a frequency of more than 22.7% included Geniculisporium serpens (45.6%), Nodulisporium sp. (40.9%), Trichoderma polysporum (40.9%), Aspergillus fumigatus (36.4%), Fusarium oxysporum (36.4%), Beauveria bassiana (31.8%), Paecilomyces marquandii (31.8%), Trichoderma harzianum (31.8%), Acremonium strictum (27.3%), Gliocladium roseum (27.3%), Metarrhizium anisopliae (27.3%), Paecilomyces carneus (27.3%), and Diheterospora chlamydosporia (22.7%). The dematiaceous fungi made up about one fifth of the total 99 species of Hyphomycetes.

C. Effect of dominant plants on distribution

A few features in the distribution data may be significant. In the main, only two kinds of vegetation were represented in the sample collection areas: forests (18 samples) and grasses (4 samples). All species of Mortierella occurred only in forested soils, whereas species of Fusarium, Eurotium chevalieri var. intermedium, and Pseudeurotium zonatum were found in both grassland and forest soils. The following fungi were obtained only from grassland soils: Arthrinium phaeospermum, Byssochlamys nivea, Coniothyrium fuckelii, Coprotus niveus, Chrysosporium keratinophilum, Cladosporium herbarum, Dichotomomyces cejpii, Fusarium moniliforme, Gliocladium deliquescens, Gliomastix murorum var. felina, Mucor fragilis, Nectria episphaeria, Rhinocladiella mansonii, Talaromyces helicus, T. ucrainicus, Penicillium brevicompactum, P. commune series I, P. thomii, and Pyrenochaeta sp.

D. Effect of pH on distribution

The pH of soil samples ranged from 4.8 to 7.6, with 4 out of 22 samples having values above 7.0. The fungi occurring exclusively in alkaline soil samples (pH 7.2-7.6) included Acremonium curvulum, Arthrinium phaeospermum, Cladosporium cladosporioides, C. herbarum, Eleutherascus lectardii, Gelasinospora cerealis, Gliocladium deliquescens, Gliomastix murorum var. felina, Mortierella sossauensis, M. zonata, Mycogone sp., Nectria episphaeria, Paecilomyces fumoso-roseus, Phialophora sp., Phoma sp. III, Phomopsis sp., Pyrenochaeta sp., Sartorya fumigata, Sporormiella leporina, Staphylotrichum coccosporum, Talaromyces ucrainicus, Thermoascus aurantiacus, Torula thermophila, Trichoderma longibrachiatum, and Volutella ciliata. Fusarium solani, Gliocladium roseum, and Mortierella alpina also occurred in alkaline samples, although they were isolated from acidic samples as well. On the other hand, all species of Mortierella except M. alpina, M. sossauensis, and M. zonata occurred only in the acidic samples.

When fungi occurring in 4 alkaline samples (pH 7.2-7.6) and 4 very acidic samples (pH 4.8-5.4) were analyzed, and frequency was expressed as percentage of a total of 4 samples from which a fungus was isolated, an interesting result emerged. Species of Trichoderma seemed to be able to tolerate a wide range of soil pH. Trichoderma koningii

and T. hamatum occurred at frequencies of 75% and 50%, respectively, in both alkaline and very acidic samples. In the very acidic samples, Mortierella nana was present at a frequency of 100%; species at a frequency of 50% were Absidia cylindrospora, Beauveria bassiana, Mortierella marburgensis, M. vinacea, and Penicillium thomii series II. In the alkaline samples, those having a frequency of 75% were Geniculisporium serpens, Gliocladium roseum, Paecilomyces marquandii, and Talaromyces trachyspermus; those having a frequency of 50% were Acremonium curvulum, Aspergillus fumigatus, Cladosporium cladosporioides, Eleutherascus lectardii, Eurotium chevalieri var. intermedium, Fusarium solani, F. oxysporum, Metarrhizium anisopliae, Mortierella alpina, and Sporormiella leporina.

E. Effect of isolation methods

One hundred and four fungi were isolated only by the dilution plate method, 57 fungi only by the alcohol treatment method, and 9 fungi by both methods. Of the 115 fungi obtained from the dilution plate method, 24 were phycomycetes, 7 were ascomycetes, and 84 were deuteromycetes. Among the 66 fungi isolated following alcohol treatment, 3 were phycomycetes, 36 were ascomycetes, and 27 were deuteromycetes. The 36 ascomycetes obtained by the alcohol treatment accounted for about 84% of the ascomycete species and nearly 20% of the total species.

Seven fungi were isolated only by the heat incubation method. Aspergillus fumigatus could be classified as a thermotolerant, with maximum temperatures for growth near 50 C but minima well below 20 C. The other six species, Acremonium alabamensis, Humicola grisea var. thermoidea, Malbranchea pulchella var. sulfurea, Sporotrichum thermophile, Thermoascus aurantiacus, and Torula thermophila, were true thermophiles in the sense of Cooney and Emerson (13). Four fungi, Chrysosporium keratinophilum, Trichophyton terrestre, Diheterospora chlamydosporia, and Paecilomyces marquandii, were obtained by the hair-baiting method, although the latter two fungi also were isolated by the dilution plate method.

DISCUSSION

The numbers of fungi per gram of soil in Ohio were lower than in forest and cultivated soils in Georgia (39)

and forest soils in southern Wisconsin (11) but were higher than in soils of sandbar willow stands in southern Wisconsin (19) and Sonoran Desert soils (43). Tresner et al. (47) and Miller et al. (39) reported that the numbers of fungi per gram of soil may vary with season and soil depth. Stotzky et al. (46) noted that numbers of fungi were higher in samples after storage from all soil depths, except from the top layer where essentially no change occurred. In addition, the disturbance of soil, such as that caused by cultivation or human activity, may have an effect on numbers.

Among the 84 genera, including 180 species and one variety, 40 are reported from Ohio soils for the first time (Table II). Williams and Schmitthenner (52), studying soil fungi of cropped fields in Ohio, isolated fungi belonging in 81 genera, some of which were either doubtful or synonymous. From his back-yard in Cincinnati, Ohio, Cooke (12) obtained at least 52 fungal species in 36 genera, while Kurup and Schmitt (33) found 9 keratinophilic fungi and 2 fungi pathogenic for humans in such areas as zoos, river banks, and picnic places in central Ohio. In total, with the addition of some soil fungi reported in the phytopathological literature, there have been at least 293 species in 141 genera reported from soils of Ohio.

The order of dominant genera whose members were isolated from Ohio samples was similar to that reported by Miller et al. (39), who found that Penicillium, Aspergillus, Cunninghamella, and Trichoderma were the chief genera in Georgia soils. Except for Aspergillus fumigatus, members of Aspergillus were poorly represented in the soil fungus populations in Ohio. The present study supports the idea that Penicillia are dominant in temperat and cool areas, whereas Aspergilli are common in tropical and subtropical soils (9, 16, 39). Comparison of the mycota of Ohio soils with those of other areas is often difficult, since there are differences in isolation techniques, isolation media, collecting seasons, depth of sampling, or combinations of any of these factors.

Although the present study is the result of using only one isolation medium and four isolation techniques, two fungi were new and many were of rare occurrence. Of the 84 genera whose members were obtained in this study,

4 (Coprotus, Gnomonia, Petriella, and Saccobolus) appear to have been unrecorded from soil previously. The genera whose members are infrequently reported from the soil include Arthrinium, Ascodesmis, Byssochlamys, Cephalosporiopsis, Cordana, Dichotomomyces, Diplogelasinospora, Eleutherascus, Geniculisporium, Hamigera, Mycogone, Nectria, Nodulisporium, Pestalotia, Pseudeurotium, Sporormiella, Staphylotrichum, Strattonia, Thermoascus, and Triangularia.

The distribution of species of Mortierella and Fusarium in Ohio soils agrees with the well documented idea that Mortierella spp. are forest fungi (11, 22, 53) and Fusarium spp. are grassland forms (16, 25). The distribution of the other fungi in the two types of vegetation, however, is not known and needs further study. The pH values obtained for Ohio soils agree closely with those obtained by Miller et al. (39) for forest and cultivated soils in Georgia, which ranged from pH 4.5 to 7.1. Many of the Ohio samples have pH values falling into the pH range (5.3-6.7) of wet-mesic forests in southern Wisconsin (11). It is not known how the soil pH affects the growth of soil fungi. Species of Mortierella appear to be very sensitive to soil pH (53). This sensitivity, however, is less clear for other fungi. Four Ohio soil fungi, Fusarium solani, Gliocladium roseum, Paecilomyces marquandii, and Volutella ciliata, have been isolated from alkaline soils (9, 16). It is possible that these fungi can grow in the soil with a wide range of pH but prefer a slightly alkaline pH.

Of the four isolation methods used in this study, the dilution plate method has been most frequently used by soil mycologists and fungal ecologists. The alcohol treatment method has been used to isolate new or rarely-occurring fungi in soil (26, 27, 28, 29). This method, together with the heat incubation method and hair-baiting method, is somewhat more selective than the dilution plate method, which, as most previous studies have revealed, is effective in selecting fast growing fungi such as the members of the Mucorales and the Hyphomycetes.

The alcohol treatment method makes possible the detection of a larger portion of the ascomycetes in the soil population. Of the 66 different fungi isolated by this method, 36 were ascomycetes. The recovery of many

ascomycetes by this procedure has been reported recently by Huang (25), Mahoney (37), and Satanimi (45). From Nigerian soils, Huang (25) secured 79 specific taxa, 35 species of which were ascomycetes; of 48 specific taxa isolated by Mahoney (37), 22 species were ascomycetes. Thirty-seven per cent of the species which Satanimi (45) obtained from Greek soils were ascomycetes. That the alcohol treatment method is very selective for soil ascomycetes is evident also from the reports of Warcup and Baker (49), Novak (41), Laube (34), Mahoney et al. (38), and Huang (26).

Although the eurotiaceous fungi (ascocarpic Penicillia and Aspergilli) usually predominate among the ascomycetes isolated from alcohol-treated soil, a diversity of small discomycetes, members of the Sphaeriales, an assortment of plectomycetous species, etc. are commonly secured in small numbers. The method has been acclaimed, for instance, for its ability to select members of the Sordariaceae. Ascospores of sordariaceous forms apparently are not numerous in the soil, but even when they are present only in low numbers, the alcohol technique often makes their detection possible. Probably because the ascospores are not very abundant and possibly also because many of them may require some sort of shock treatment before they will germinate, very few representatives of the Sordariaceae have even been reported in studies based on older isolation methods. Indeed, until recently, the Sordariaceae were considered to be almost exclusively a coprophilous group (36). There is now evidence, however, that they are relatively frequent and widely distributed in soil (25, 38). In the present study, representatives of the genera Gelasinospora, Diplogelasinospora, Strattonia, Triangularia, Sordaria, and Coniochaeta were encountered.

The isolation of 6 thermophilic fungi from soils from 12 different sites in Ohio suggests that these fungi are of widespread occurrence. In summer afternoons in Ohio, the heat from the sun might provide temperatures high enough for active growth of the thermophilic fungi (personal communication with M. R. Tansey). Although such widespread occurrence of the thermophiles in Ohio is surprising, it is worth noting that Ranzoni (43) did not obtain any thermophilic fungi from the Sonoran Desert - a place likely to provide an environment in which thermophiles might thrive. Failure to obtain thermophiles may be due to the differences

in isolation media or sampling and isolation techniques. Thus far, studies of the thermophilic microfungi of the soil have been carried out in temperate and cool areas (4, 5, 15, 40, 50).

The subsurface soils in Ohio do not appear to be rich in keratinophilic fungi. In this study only three keratinophilic fungi were obtained. Diheterospora chlamydosporia, which has been cited as a cellulose and chitin decomposer (14), appears to be previously unrecorded from soils in the United States. Kurup and Schmitt (33) reported the presence of Trichophyton terrestre and Chrysosporium keratinophilum in central Ohio soils, and Knudtson and Robertstad (32) found T. terrestre in South Dakota soils. The fact that hairs used were not defatted might contribute to failure to isolate keratinophilic fungi. Moreover, since the sampling sites included in the present study were away from areas of concentrated human or animal activity, a paucity of keratinophilic fungi might be expected.

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THE GENUS OSTREICHNION

MARGARET E. BARR

Department of Botany, University of Massachusetts, Amherst, MA 01002

SUMMARY

The genus *Ostreichnion* Duby is re-established for the type species, *O. sassafras* (Schw.) Barr, comb. nov., and for two additional species, *O. nova-caesariense* (Ellis) Barr, comb. nov. and *O. curtisii* (Duby) Barr, comb. nov. The species are known from eastern and southern North America.

The genus *Ostreichnion* Duby (1862) was created for two species, *O. europaeum* Duby and *O. americanum* Duby. Saccardo (1883) considered that *Ostreichnion* was an ill-conceived name and replaced it with *Ostreion* "Duby," with the single species *O. americanum*. However, by inference with the rejection of *Mytilidion* vs. *Mytilinidion* (Rogers 1953), *Ostreichnion* should be the name used, rather than *Ostreion*. Rehm (1886) studied Duby's specimens and recognized that *O. europaeum* was a pedicellate form of *Hysterium pulicare* Pers. ex Fries. *Ostreichnion americanum* typifies the genus, and was based upon a specimen on *Liquidambar* bark from South Carolina, sent to Duby by M.A. Curtis. Rehm found this collection to have conchate ascocarps, about 2 mm long, 1 mm wide, and up to 2½ mm high, with striate surface, overmature 4-spored asci and elongate ascospores which were 12-20-septate.

Clements and Shear (1931) consigned *Ostreichnion* (as *Ostreium* Duby) to synonymy with *Mytilinidion* Duby (as *Mytilidium*), although this genus was created later (p. 62) in Duby's monograph than was *Ostreichnion* (p. 21). Zogg (1962) used *Mytilidion*, with *Ostreion* as a synonym, basing his use of the later name on frequency of usage and the

number of species recognized in *Mytilidion* over the years since its creation. The ascospores of *O. americanum* were said to be "multiseptate," a condition which would describe ascospores of *Mytilinidion* also. Bisby (1932) noted indications of longitudinal septa in the specimens he examined -- including *Lophium sassafras* Schw., an earlier name for the species. Bisby reported that Massee had said the ascospores were muriform but he believed that the longitudinal septa were only pseudosepta. The specimens examined in the present study show many vertical as well as transverse septa in the ascospores. The ascospores differ in this character from those of *Mytilinidion* species, as well as in shape: in *O. sassafras* the large ascospores are broadly fusoid or nearly cylindric and the end cells are lighter brown to nearly hyaline, while the species of *Mytilinidion* have ascospores which are variously elliptic, narrowly fusoid, clavate, or elongate and pigmentation is ± even throughout all cells.

Ostreichnion Duby is upheld as a valid genus of the Lophiaceae. The family characters of upright, nearly superficial, ± conchate ascocarps, deeply pigmented prosenchymatous peridium (quite brittle), and centrum of asci in narrow, branched and anastomosing pseudoparaphyses are met in the genus. The large muriform ascospores of the type species, which possess many transverse and one to five vertical septa, differ from those of *Ostreola* Darker (1963). *Ostreola consociata* Darker could conceivably be the lower end of a series of as yet unknown species which culminates in *Ostreichnion sassafras*; for the present I would recognize two muriform-spored genera in the Lophiaceae.

Another fungus which seems best placed in *Ostreichnion* is *Hysterium nova-caesariense* Ellis. This species is generally regarded as a species of *Hysterographium*, or as a synonym of *H. flexuosum* (Schw.) Sacc. by Zogg (1962). However, the ascocarps are conchate with a prosenchymatous peridium, a character of members of the Lophiaceae rather than the Hysteriaceae, and the centrum differs from that of typical Hysteriaceae. The ascospores are nearly cylindric, with numerous transverse and vertical septa.

A third species now added to *Ostreichnion* is the fungus known as *Glonium curtisii* (Duby) Lohman. The ascocarps are broadly conchate and the peridium is prosenchymatous; the centrum is similar to that of *O. sassafras*. The cylindric ascospores, however, are one-septate, with the septum

submedian, and the walls at the tips, especially the upper one, are greatly thickened. When ascospores are observed in KOH, Melzer's, or Congo Red, the cytoplasm of mature ascospores is obviously divided into a number of segments. Lohman's (1937) description and illustration of ascospore germination by numerous germ tubes also gives the impression of a fungus with potentially muriform ascospores, as Lohman noted. I believe that *G. curtisii* is best regarded as a species of *Ostreichnion* in which ascospore septation is retarded and restricted to a single apparent septum.

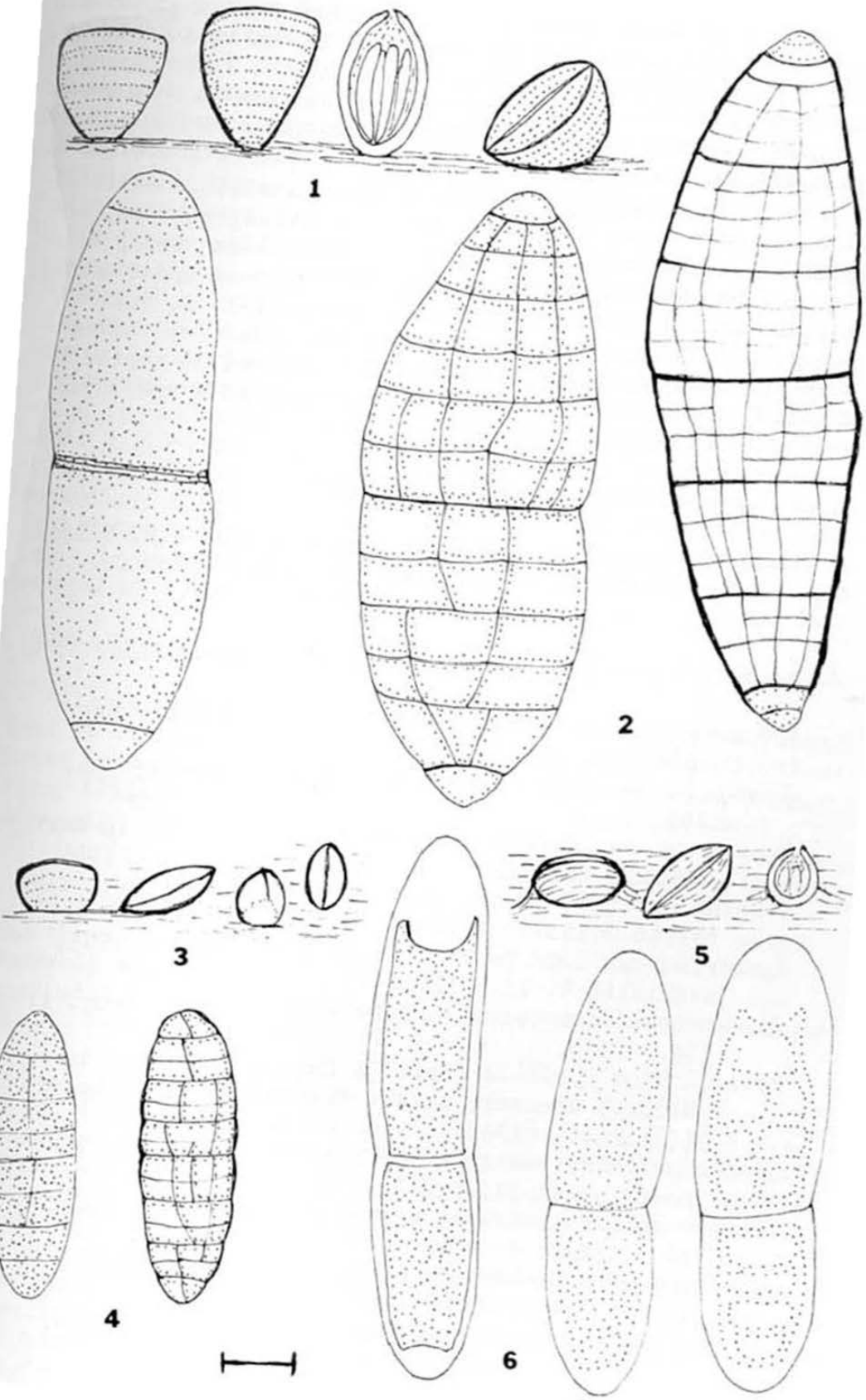
The species of *Ostreichnion* are readily separated on the bases of ascospore sizes and septation:

1. Ascospores 1-septate, septum submedian, with thickened ends, (45-)62-80 x (10-)12-15 μ; asci 4-8-spored . . . . . *O. curtisii*
1. Ascospores muriform 2
   2. Ascospores 35-45(-50) x 11-13 μ, with 7-13 transverse and 1-3 vertical septa in all or most cells; asci 8-spored . . . . . *O. nova-caesariense*
   2. Ascospores (65-)76-100(-135) x 20-32 μ, with up to 27 transverse and 1-5 vertical septa in all or most cells; asci (1-2-)4-(5-6-)spored . . . *O. sassafras*

Ostreichnion sassafras (Schw.) Barr, comb. nov. Figs.1, 2

Lophium sassafras Schw. Trans. Amer. Phil. Soc. IV, n.s. 240, n. 2018. 1832.
Mytilidion sassafras (Schw.) Zogg, Beitr. Kryptogamenfl. Schweiz 11(3): 117. 1962.
Ostreichnion americanum Duby, Mém. Soc. Phys. Hist. Nat. Genève 16: 22. 1862.
Ostreion americanum (Duby) Sacc. Syll. Fung. 2: 765. 1883.

Ascocarps superficial, bases attached to and grown with substrate, conchate to nearly dolabrate, 1-1.5 mm wide and high, or up to 2 mm high, sides compressed, ± 750 μ wide, surface matt black, not shining, horizontally striate, occasionally triradiate, apex compressed along length, opening by long slit; in section pyriform, ovoid, or vertically elongate, peridium brittle, difficult to section, prosenchymatous, cells very small, densely encrusted with pigment, ± even in width at sides, 26-40 μ wide, 52-65 μ wide above, thickened at base to 104-115 μ wide. Asci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Ascocarps superficial, bases attached to and grown with substrate, elongate and depressed conchate, up to 1 mm long, 275 μ wide and high, surface shining black, faintly horizontally striate, apex compressed along length, depressed, opening by long slit; in section ± globose, peridium brittle prosenchymatous, cells very small, densely encrusted with pigment, narrow, 20-25 μ wide, ± even in width. Asci arising from base, 100-130 x 30-40 μ, oblong-clavate, bitunicate, apex thickened, sessile on foot-like base, 8-spored; pseudoparaphyses narrow, branched and anastomosing, in gel matrix. Ascospores 35-45(-50) x 11-13 μ, dull brown, ± cylindric, tapered to rounded ends, 7-13 transversely septate, not or slightly constricted at septa, 1-3 vertical septa in most cells, usually one into end cells, wall surface smooth.

On bark of *Pinus rigida*, New Jersey.

Material examined: New Jersey: Newfield, J.B. Ellis N.A.F. 152; Newfield, April 1893, Ell.& Ev. Fungi Col. 10 (MASS).

Ostreichnion curtisii (Duby) Barr, comb. nov. Figs. 5, 6

Hysterium curtisii Duby, Mém. Soc. Phys. Hist. Nat. Genève 16: 30. 1862.
Gloniella curtisii (Duby) Sacc. Syll. Fung. 2: 766. 1883.
Hysteroglonium curtisii (Duby) Earle (as Duby in Earle) in Mohr, Contrib. U.S. Nat. Mus. 6: 163. 1901.
Glonium curtisii (Duby) Lohman, Bull. Torrey Bot. Club 64: 66. 1937.
Hysterium cyrillae Berk. & Curt. N.A. Fungi n. 795; Grevillea 4: 11. 1875.
Glonium cyrillae (Berk. & Curt.) Sacc. Syll. Fung. 2: 734. 1883.
Psiloglonium cyrillae (Berk. & Curt.) E. Müller in Müller & von Arx, Beitr. Kryptogamenfl. Schweiz 11(2): 244. 1962.
Hysterium chlorinum Berk. & Curt. N.A. Fungi n. 796; Grevillea 4: 12. 1875.
Glonium chlorinum (Berk. & Curt.) Sacc. Syll. Fung. 2: 734. 1883.
Glonium macrosporium Tracy & Earle, Bull. Torrey Bot. Club 23: 207. 1896.
Glonium gigasporum Ell. & Ev. in Herb. Ellis, ined.

conidial state is known for this or the other species of *Ostreichnion*, either associated in nature or in culture (for *O. curtisii* only).

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MYCOTAXON

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SARCINOSPORON: A NEW GENUS TO ACCOMMODATE *TRICHOSPORON INKIN* AND *PROTOTHECA FILAMENTA*

D. S. KING and S. C. JONG

Mycology Department, American Type Culture Collection
12301 Parklawn Drive, Rockville, Maryland 20852

SUMMARY

A new genus *Sarcinosporon* and a new combination *S. inkin* are proposed to accommodate *Trichosporon inkin* (Oho) Carmo-Sousa *et* van Uden. *Prototheca filamenta* Arnold *et* Ahearn is considered as a facultative synonym of *S. inkin*. *Sarcinosporon inkin* is characterized by filamentous growth and blastospores budding singly or successively in chains and by the formation of *sarcina*-like agglomerates of endospores in sporangia formed by individual blastospores or by septation of filaments in different planes.

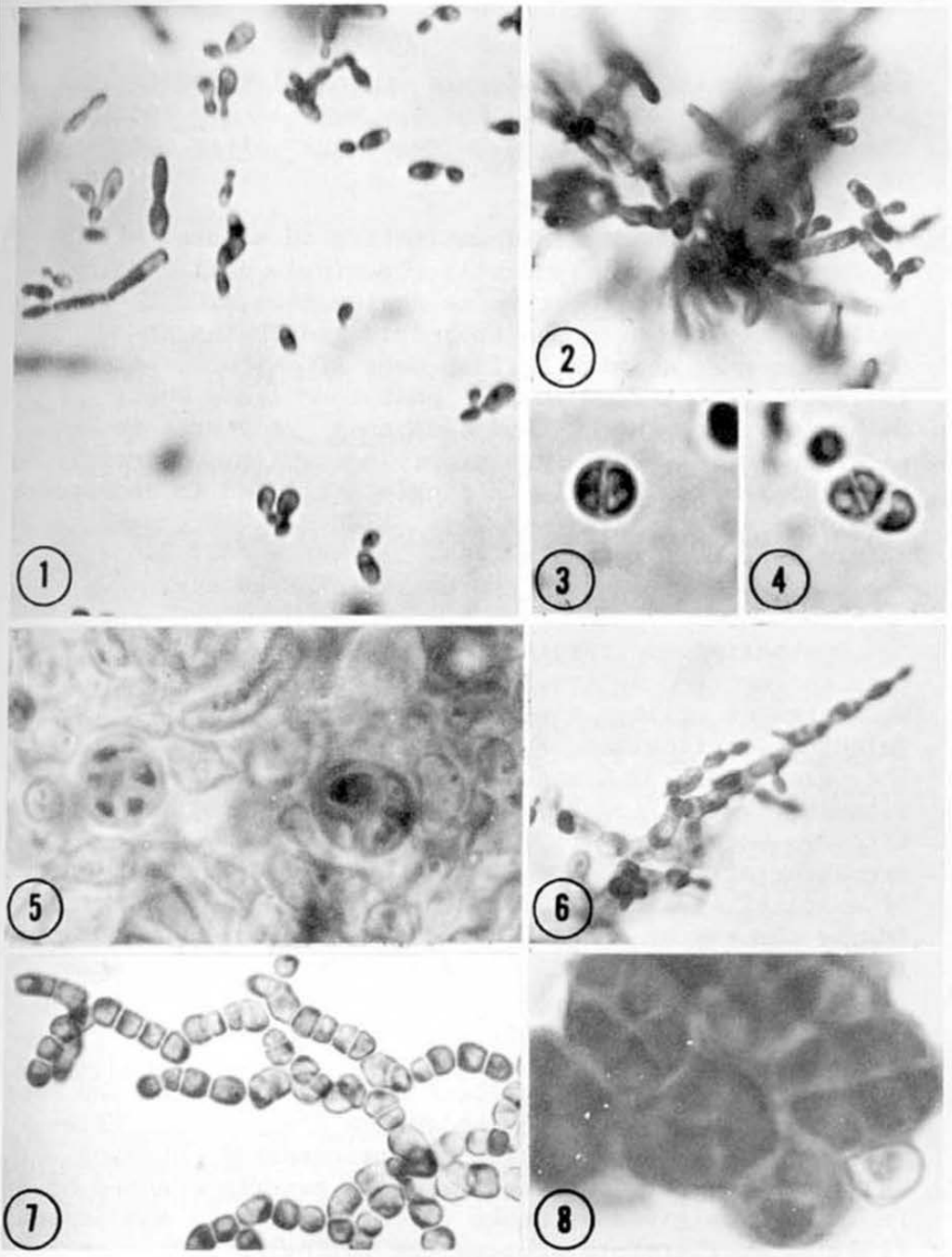
Sarcinomyces inkin Oho (1919) was first isolated and described from skin scrapings of a scrotal dermatosis frequently found in young males in Formosa. It was characterized by filamentous growth along with the formation of clusters of cells by septation in different planes. Mesones and Dodge (1960) reported on two additional cultures of this organism isolated by them from scrotal lesions of two Peruvian young males in Brasil and described some of their physiological characters. Carmo-Sousa and van Uden (1967) studied a culture isolated in 1957 from a case of "tinea cruris" caused by *Trichophyton tonsurans* Malmsten in a Portugese woman. They considered this culture to be morphologically and physiologically identical with those described by Oho and by Mesones and Dodge. However, they regarded some of the structures observed to be blastospores and arthrospores and transferred *S. inkin* to the genus *Trichosporon* Behrend. Since the cultures studied by the previous workers were lost,

Carmo-Sousa and van Uden's isolate (ATCC 18020 = CBS 5585) was designated by them as the type of *T. inkin* (Oho) Carmo-Sousa *et* van Uden. Subsequently Hedrick and Dupont (1968) and Carmo-Sousa (1970) accepted this species in *Trichosporon*.

We are currently investigating the systematics of the genus *Trichosporon* and have consequently examined the type strain of *T. inkin* ATCC 18020. We grew this strain on 6 different media, including glucose-yeast extract-peptone and cornmeal agars as described by Carmo-Sousa and van Uden, and observed blastospores (budding cells) in both the filamentous phase and the unicellular phase (Fig. 1). Although we observed septation of filaments and breakdown of the other filaments beyond the stage that the segments could reasonably be considered to function as spores, we were unable to observe arthrospores. On glucose-yeast extract-peptone and Harrold's M40Y (malt extract, 2%; yeast extract, 0.5%; sucrose, 50%; agar, 2%) agars we also observed the production of endospores by internal cleavage in several planes similar to those described for *Prototheca filamenta* Arnold *et* Ahearn (1972) (Fig. 4).

Prototheca filamenta was isolated from human skin in Cleveland, Ohio, and described as a new species of colorless alga. In addition to production of the sporangia that produce several endospores typical of *Prototheca* Krüger (1894), *P. filamenta* is morphologically distinct in that it produces filamentous growth on cornmeal agar reminiscent of that reported for *T. inkin* (Fig. 2,6). Arnold and Ahearn also investigated physiological properties of the genus, and provided a physiological key to the species of *Prototheca* recognized by them.

Comparison of the type strains of *T. inkin* ATCC 18020 and *P. filamenta* ATCC 22432 revealed many striking similarities and few differences. Both strains were isolated from humans. In macroscopic appearance both are dry, friable, and cream to brownish in old agar cultures, with a raised center and radiating furrows. Morphologically, both strains produce filamentous growth that becomes septate (Fig. 7), more-or-less globular groups of cells that divide by septation in several planes (Fig. 4,8), and filaments that produce blastospores (Fig. 2,6). The groups of cells that divide by septation are actually sporangia,



Figs. 1-5. *Trichosporon inkin* ATCC 18020. 1. Unicellular budding phase and elongate segments with truncated ends. *ca.* X 675. 2. Filaments of elongate blastospores resembling pseudomycelia. *ca.* X 675. 3. Two-spored sporangium. *ca.* X 1500. 4. Three-spored sporangium. *ca.* X 1500. 5. Multiple-spored sporangia in an old culture. *ca.* X 1500. Figs. 6-8. *Prototheca filamenta* ATCC 22432. 6. Filaments of elongate blastospores resembling pseudomycelia. *ca.* X 675. 7. Septate filaments. *ca.* X 675. 8. Multiple-spored sporangia. *ca.* X 1500.

and both strains also produce a unicellular budding phase. Filamentous growth and the unicellular budding phase are both produced on cornmeal agar after two days at room temperature (*ca.* 24 C).

The differences are quantitative in nature. ATCC 18020 produces more abundantly the single cell budding phase and more blastospores in chains than ATCC 22432, while the latter produces sporangia and chains of sporangia more abundantly than does ATCC 18020. Also, the sporangia of ATCC 18020 appear to release their endospores more quickly and thus they are scarce in older cultures. Both strains produce chlamydospores by thickening of cell walls in single cells and in endospores retained in sporangia (Fig. 5). ATCC 18020 produces mainly 2-spored sporangia (Fig. 3), while ATCC 22432 produces multiple-spored sporangia in abundance.

Comparing our results for ATCC 18020 with the results reported by Arnold and Ahearn for ATCC 22432, both strains utilize glucose, sucrose, maltose, lactose, galactose, cellobiose, xylose, trehalose, and ethanol. They grow at 25-37 C and fail to grow at 45 C or on vitamin-free media. They are both urease positive, although Carmo-Sousa (1970) reported ATCC 18020 to be urease negative. The only difference was the utilization of dulcitol by ATCC 22432 and not by ATCC 18020. According to the key of Arnold and Ahearn (1972), ATCC 18020 is referable to *P. filamenta*. We consider the differences between ATCC 22432 and ATCC 18020 to be significant only at the strain level and not at the specific level.

We are convinced that both strains represent the same species, but not that they belong in *Prototheca*. Filamentous growth and formation of blastospores (budding cells) are clearly excluded from the generic concept of *Prototheca* as given by Cooke (1968) and Tubaki and Soneda (1959). We therefore propose the following new genus and combination:

SARCINOSPORON King *et* Jong, *gen. nov.*

Cultura in agarico farinacea, albida vel brunneola. Cellulae vegetativae filamentosae vel gemmiparae. Fibrae septatae, sporangiferae et blastosporiferae. Sporangiolae

sarciniformibae, e una vel duobus vel plures endosporae constata. Endosporae schizogenae membrana et tunica communi obvolutae, dein liberatae. Sexsporae nullae.

Typus: Sarcinomyces inkin Oho

Sarcinosporon inkin (Oho) King *et* Jong, *comb. nov.*

≡ *Sarcinomyces inkin* Oho, Kyoto Igaku Zasshi *16:* 15. 1919.

≡ *Trichosporon inkin* (Oho) Carmo-Sousa *et* van Uden, Mycologia *59:* 653. 1967.

= *Prototheca filamenta* Arnold *et* Ahearn, Mycologia *64:* 270. 1972.

Colonies dry, friable, and cream to brownish in old agar cultures, with a raised center and radiating furrows. Vegetative cells unicellular or filamentous with true septa, multiplying by budding singly or successively in chains. Sporangia formed by septation in different planes of individual blastospores or of cells in filaments, *sarcina*-like, 4.5 - 13.4 x 5.4 - 16.1 µ, containing one to several endospores at maturity. Endospores ovoid or ellipsoid, 1.3 - 6.3 x 1.3 - 9.0 µ, walls of endospores thin, becoming visible upon disintegration of the sporangium wall. Some cells and endospores within sporangia producing chlamydospores by developing a thick, smooth wall. No plastid-like structures observed. No sexual reproduction observed.

Physiology as reported by Carmo-Sousa (1970) except dulcitol + or -. Urease reaction positive as reported by Arnold and Ahearn (1972).

The method of endospore production allies this organism to the algae, but its heterotrophism, filamentous growth and reproduction by budding are fungal in nature.

The type strain ATCC 18020 is preserved by being frozen and stored in liquid nitrogen at -196 C at the ATCC. The holotype, a dried cornmeal agar plate culture of this strain, has been deposited in the herbarium of the National Fungus Collections, Beltsville, Maryland.

ACKNOWLEDGMENTS

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CORTINARIUS, SECTION DERMOCYBE—CORTINARIUS CLELANDII

JOSEPH F. AMMIRATI[1]

Mycology Laboratory, Plant Protection Institute
Agricultural Research Service, U.S. Dept. of Agriculture
Beltsville, Maryland 20705

SUMMARY

A lectotype is chosen for *Cortinarius clelandii* Smith. A description of the lectotype is accompanied by photomicrographs showing the nature of the basidiospore ornamentation, including the reduced size of ornamentation in the suprahilar region.

Cortinarius clelandii Smith (1944) was published as a *nomen novum* for *C. subcinnamomeus* Cleland (1928), because *C. subcinnamomeus* Karsten (1889) antedated Cleland's use of the species epithet in *Cortinarius*. Smith (1935) reported *C. clelandii* (as *C. subcinnamomeus*) from North America, but his specimens were later found to differ from Cleland's species and were the basis for description of a new species, *C. tubarius* Ammirati & Smith (Mich. Bot. 11: 22-24. 1972).

To gain a clearer understanding of *C. clelandii*, I obtained two collections from the Waite Agricultural Research Institute (ADW) in Adelaide, South Australia, and also studied a collection on deposit at the National Fungus Collections (BPI) in Beltsville, Maryland. All three collections were made and identified by J. B. Cleland and were from Mt. Lofty, South Australia. The collection at the National Fungus Collections (BPI 70684), labeled "cotype", was received from Cleland on September 18, 1930. The two collections from the Waite Agricultural Research

[1]Present address: Erindale College, University of Toronto, Mississauga, Ontario L5L 1C6, Canada.

Institute are numbered ADW 15118 and ADW 15119.

Cleland's original notes on the fresh basidiocarps and microscopic characters are included with collection ADW 15118. The close correlation between these notes and the original description of *C. clelandii* indicates that this collection is the one from which he described the species. A notation in the original description that the species was painted by an artist (Miss Fiveash) is confirmed by the same notation with collection ADW 15118.

When I studied each basidiocarp and the fragments in collection ADW 15118, I found that the microscopic characteristics of all the elements of the collection were similar, except those of half of a basidiocarp. The discordant element of the collection was separated easily by its longer spores, 9.6-12(-12.8) µm, average 11.0 µm, and by the abundance of large interhyphal pigment deposits in the pileus and lamellar trama. It was removed from collection ADW 15118 and designated as ADW 15118a. Because Cleland did not designate a holotype, collection ADW 15118 is selected as the lectotype for *C. clelandii* Smith (synonym: *Cortinarius subcinnamomeus* Cleland, Trans. & Proc. Roy. Soc. South Australia 52: 220-221. 1928).

Collection ADW 15119 also contained two elements. Most of the basidiocarps had microscopic characteristics similar to those of the specimen designated above as ADW 15118a. However, two basidiocarps were totally unrelated and not members of the section *Dermocybe*. These were separated from collection ADW 15119 and designated as ADW 15119a. They have not been determined to species. Collection BPI 70684 contains three specimens, all microscopically similar to collections ADW 15118a and ADW 15119 and different from ADW 15118.

Collections ADW 15118a, ADW 15119, and BPI 70684 significantly differ from the lectotype (ADW 15118). Without notes on the fresh condition of the basidiocarps, they cannot be correctly determined. Also, further studies of fresh specimens are needed before the range of variation in *C. clelandii* can be determined.

Cleland (1928), in his discussion of *C. clelandii*, noted variation among his collections, especially in the color of the fresh basidiocarps and the spore size; however, he later (1934) combined these elements in one composite

900X) as a flattened and less coarsely ornamented region. A scanning electron microscope preparation of the basidiospores (a 300-angstrom coating, palladium 40%, gold 60%) of the lectotype is on deposit with the specimens at the Waite Agricultural Research Institute.

Cortinarius clelandii Smith, Lloydia 7(3): 203. 1944.

Figs. 1-5

PILEUS up to 6.2 cm broad, convex, gibbous, then expanding, the margin slightly upturned and wavy, minutely fibrillose, when young Saccardo's Umber (near dull deep yellowish brown), then near Snuff Brown (moderate brown to deep brown) passing into Bister (dark yellowish brown) in the center, later Burnt Umber (near moderate reddish brown), becoming nearly black in the center.

LAMELLAE sinuate, moderately close, 10 mm deep, when young Mustard Yellow (brilliant yellow), becoming Buckthorn Brown (strong yellowish brown).

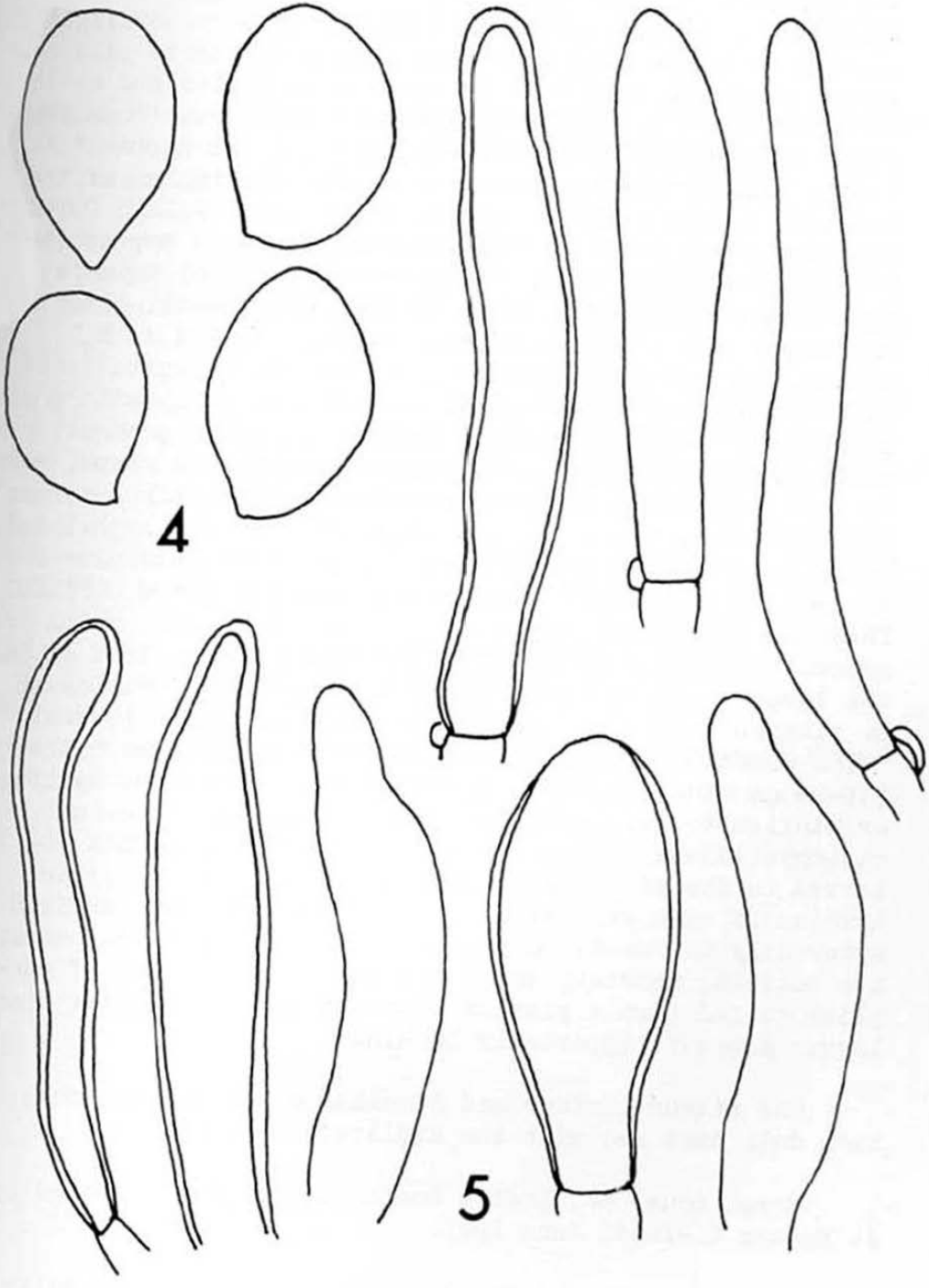
STIPE up to 7.5 cm long, 6-12.5 mm thick, slender or stout, slightly bulbous, somewhat fibrillose and striate, with tints of Naples Yellow (light yellow), markedly hollow.

FLESH yellowish, heaped up under the umbo, gradually attenuated outwards.

COBWEB VEIL (Cortina) pale yellowish.

SPORES (as described by Cleland, 1928) irregularly elliptical, slightly rough, yellowish brown, 10.5 X 6.5 µm.

SPORES 8.8-10.4 X 6.4-8(-8.8) µm, average length 9.7 µm, average width 7.2 µm, in profile inequilateral, general outline mostly broadly ellipsoid, sometimes ellipsoid or subglobose, in face view broadly ellipsoid to broadly fusoid, light to moderate yellowish brown, ornamentation darker brown, verrucose to rugulose (Figs. 1-3), ornamentation medium to coarse, sometimes coarser toward the distal end, reduced in size in the suprahilar region (Fig. 3). BASIDIA 24-36 X 8-10 µm, 4-spored, broadly clavate to narrowly clavate, sometimes slightly ventricose to irregular in outline, hyaline or containing a diffuse pale purplish to pale red purple pigment, usually containing particles or masses of purplish to red purple pigment, which may fade to paler or hyaline on standing, clamp connections present. BASIDIOLES 17.6-32 X 7.6-9.6 µm, shaped like the basidia or more narrowly clavate (primordial elements not included), color and contents as for basidia. PLEUROCYSTIDIA absent. CHEILOCYSTIDIA apparently absent (lamellar edges not easily revived, and many damaged). LAMELLAR TRAMA of subparallel



Figures 4-5. *Cortinarius clelandii*. 4. Outline drawings of basidiospores (ornamentation omitted), X2675. 5. Hyphal end cells from pileus cuticle, X1100.

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MYCOTAXON

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PHYSCIA DUPLICORTICATA WEBER & THOMSON SP. NOV. FROM CALIFORNIA

WILLIAM A. WEBER

University of Colorado Museum, Boulder, Colorado 80302

AND

JOHN W. THOMSON

Dept. of Botany, University of Wisconsin Madison, Wisconsin 53706

Preliminary to distribution of isotypes of a new species of *Physcia* from California in Lichenes Exsiccati issued by the University of Colorado this species should be described in the literature.

PHYSCIA DUPLICORTICATA W. A. Weber & Thomson sp. nov.

Descriptio typi:

Thallus tenuis, 0.2-1.5 mm crassus, membranaceus, sat laxe adnatus, virido-cinereus, laevigatus, laciniis adscendentibus, flexuosis, apices versus latioribus, ad 2.0 mm latis, margines versus minute lobatis granulosis et labriforme sorediosis, extus K+ lutescens, intus K-, extus et intus C-, P-, I-, subtus albidus, parce rhizinosus, rhizinis albidis. Apothecia sparsa, sessilia, ad 1 mm lata, epruinosa, rufescentia, marginibus crassis, inflexis, thallo concoloribus, leviter crenulatis. Pycnoconidangia sparsa, minuta, immersa, rufescentia, pycnoconidia bacilliformia, recta, 4-5 x 1 µ.

Stratum corticale superius thalli 30-70 µ crassum, incoloratum, paraplectenchymaticum, cellulis ± rotundatis, diam 10-12 µ; stratum algarum ca 70 µ crassum; algae ad Trebouxiae pertinentes, diam 5-15 µ; stratum medullare ex hyphis implexis, diam 5-6 µ, ad parte exteriore ± paral-

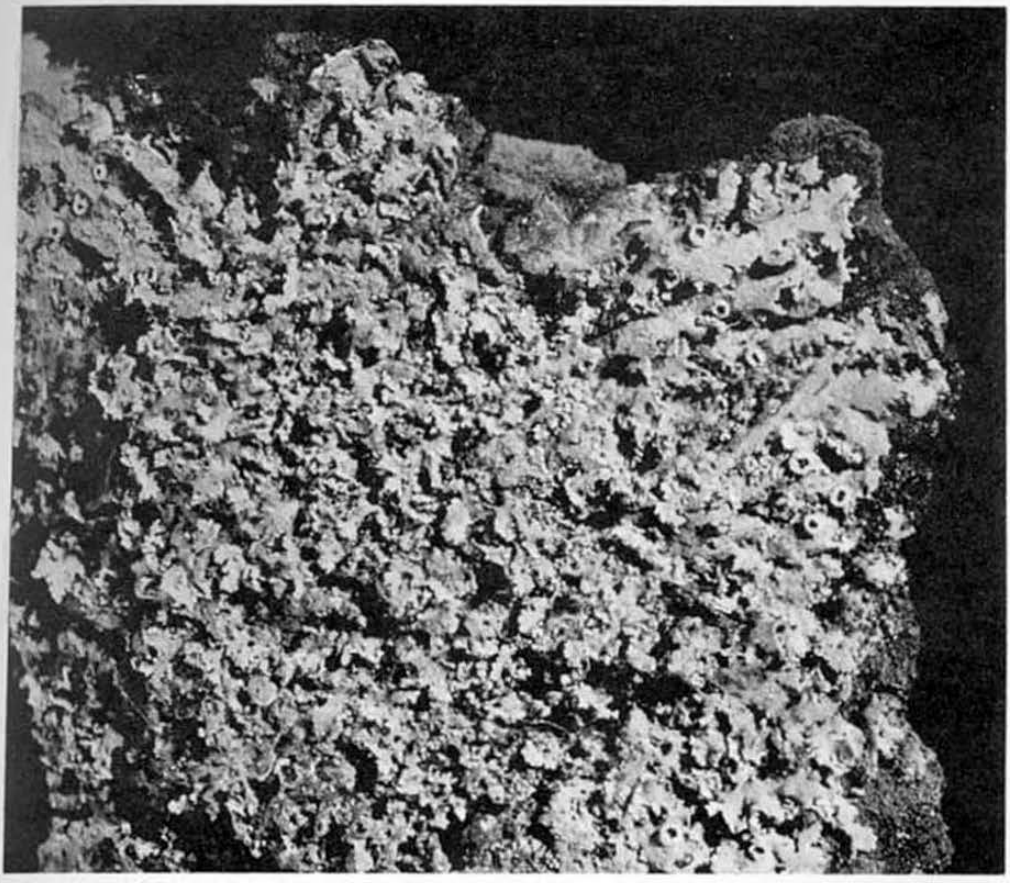

Figure 1. *Physcia duplicorticata* Weber & Thomson, n. sp., type specimen (COLO).

lelis; stratum corticale inferius paraplectenchymaticum, crassum, 50 µ.

Amphithecium subtus cortice crasso, incolorato, paraplectenchymatico, cellulis fere ut in strato corticale superius thalli, strato interiore laxo, algis repleto. Parathecium distinctum, tenue. Hypothecium incoloratum, 60 µ, hymenium 150 µ, parte superiore 15 µ fuscescens, paraphyses cohaerentes, incoloratae, 1.5 µ crassae, asci clavati 15 x 80 µ, sporae distichae, obscuratae, 1-septatae, oblongae, non constrictae, rectae vel leviter curvatae, 7-10 x 18-20 µ, episporio ± aequaliter incrassato.

Type: On *Umbellularia*, east of junction of Nicasio road and Point Reyes road, Marin Co., Calif., 12 March 1975, W. A. Weber & Greg Kunkel. Type in herb. COLO, isotypes distributed in Lich. Exsicc. COLO No. 476. Figure 1.

This species very much resembles *Physcia millegrana* Degel. and like that, belongs in the Group Tribacia (Lynge) Thomson. It appears as a slightly coarser plant with thicker thallus with the internal tissues correspondingly thicker, the upper cortex 70 µ *versus* 45 µ, the entire thallus being only about 100 µ thick in *P. millegrana*. The lower cortex is markedly paraplectenchymatous and sharply differentiated *versus* blending into the medulla with at most a single layer of superficial paraplectenchymatous-appearing cells in *P. millegrana*. The apothecia are epruinose and brown-red *versus* very blue pruinose over a black ground color in *P. millegrana*. The marginal granules on the lobes have more the appearance of minute lobules than in *P. millegrana* in which they are more granular to isidioid-granular, and are coarser than in *P. millegrana*. They also may be formed on the underside of the margins of the lobes. *Physcia tribacia* is somewhat similar in the formation of the lower cortex but does not form the labriform soralia in addition to the marginal granules.

The name is chosen in allusion to the character differentiating the new species from *P. millegrana*.

Extracts of *P. duplicorticata* yielded atranorin, no zeorin, in MC tests.

An additional specimen of this species is in WIS: On *Cupressus macrocarpa*, S end of San Andreas Lake, San Francisco Watershed, San Mateo Co., Calif., 13 Sept. 1967, Wm. Jordan 756-B. We interpret the new species as an endemic of the fog belt of the San Francisco Bay region.

MYCOTAXON

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SCANNING ELECTRON MICROGRAPHS OF ASCOSPORES OF *PACHYELLA* (DISCOMYCETES)

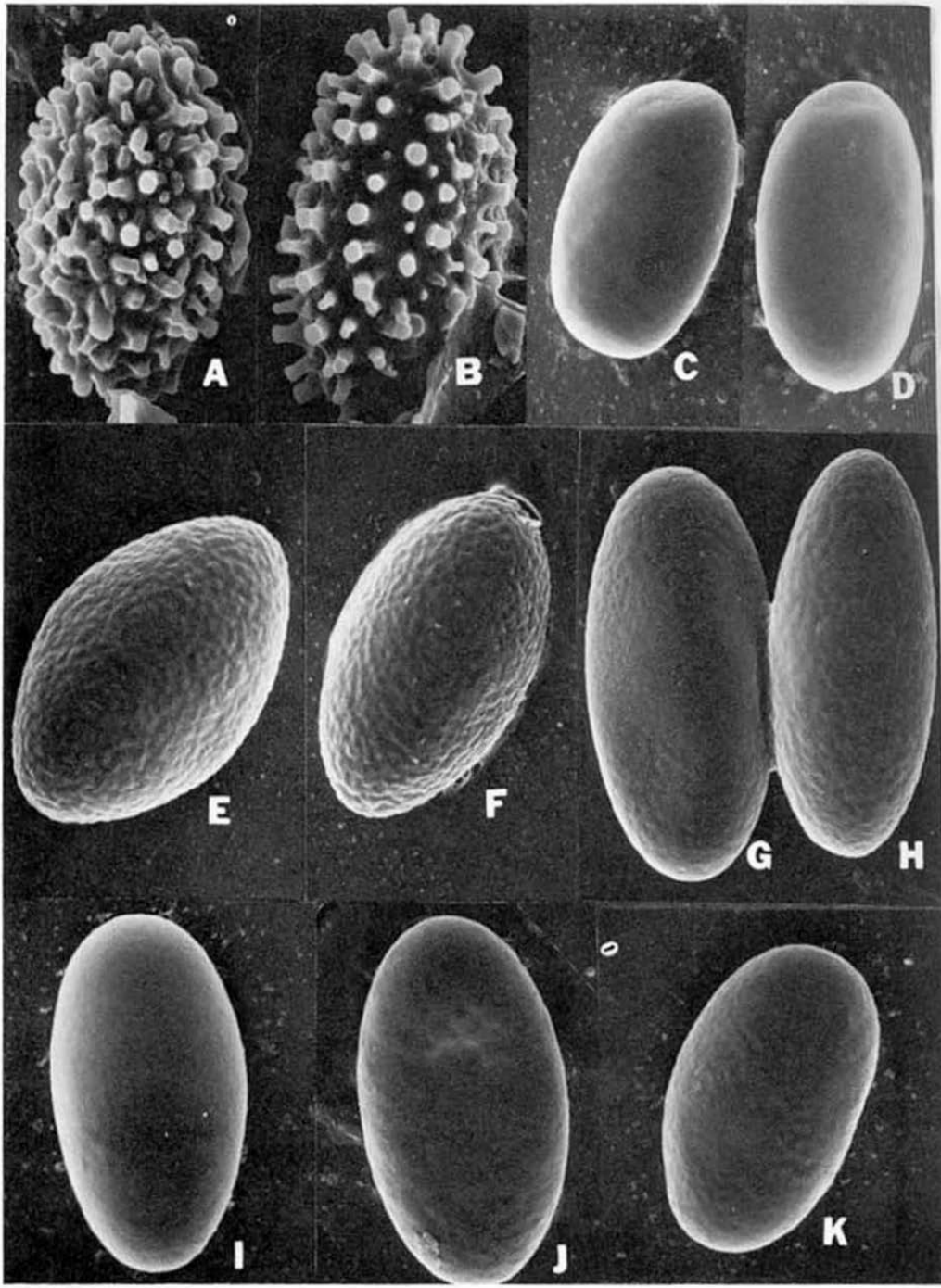
DONALD H. PFISTER

The Farlow Reference Library and Herbarium of Cryptogamic Botany and the Biology Department, Harvard University, Cambridge, MA 02138

In the recognition and delimitation of species in the family Pezizaceae *sensu stricto* wall ornamentations are important features. The production of episporal wall material in the Pezizales and the form of its deposition have been studied thoroughly by Le Gal (1947). With few exceptions, most notably Le Gal's work in the family, attempts to illustrate wall ornamentations by camera lucida or freehand drawings have failed to provide detailed and accurate representations. Recently Elliott and Kaufert (1974) have shown that spore differences in this family are accurately depicted using scanning electron photomicrographs. Two species of *Peziza* were studied in their work. In *Peziza* there is a great variety of ascospore ornamentation types. To a lesser extent these types are paralleled in the small, segregate genus *Pachyella*, the subject of this paper.

The genus *Pachyella* has been monographed by Pfister (1973). The species are well delimited by apothecial size and morphology, hymenial color, geographical range and ascospore ornamentation. With ample material of all but one of the six species, and scanning electron microscope facilities available, it was possible to photograph ascospores at 5,000x and compare these with the previously published camera lucida drawings (Pfister, 1973). These photographs are reproduced in fig. 1.

For the most part, these studies verify the earlier interpretations. The ornamentations of the grossly warted *P. adnata* (Berk. & Curt.) Pfist. are comparable in both the camera lucida drawings (see Pfister 1973, fig. 1, *d-f*) and the SEM photographs (fig 1, A and B). However, the two species with finely sculptured ascospores, *P. violaceo-nigra* (Rehm) Pfist. and *P. punctispora* Pfist., are shown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K

more accurately here than previously (see Pfister 1973, fig. 1, *g-i* and fig. 5, *b-d*).

The ornamentations in *P. violaceonigra* are dense and sometimes form low ridges through anastomosis of the warts (fig. 1, G, H, and K). Unfortunately material of *P. megalosperma* (Le Gal) Pfist., a species which has similar though more highly ornamented ascospores, was not available for study. The ornamentations of *P. punctispora* are also denser than previously shown (fig. 1, E and F). In both *P. punctispora* and *P. violaceonigra* the spores have definite raised warts. The two species are easily distinguished otherwise by their characteristic apothecial tissue organizations.

Pachyella babingtonii (Berk. & Br.) Boud. (see Pfister 1973, fig. 2, *a-e*) and *P. clypeata* (Schw.) Le Gal (see Pfister 1973, fig. 1, *a-c*), both drawn with smooth spores, are smooth-spored even at these higher magnifications. In several collections of *P. babingtonii* examined earlier there was evidence of markings. Such markings appear infrequently in this species and were not seen in this collection (fig. 1, C and D). The spore surface of *P. clypeata*, though lacking any particular organized marking, sometimes appears to be wavy or undulating (fig. 1, I and J).

These comparative studies reinforce the position taken on species delimitation in this genus. The inclusion of the photographs will supplement the illustrations presented in the monograph of the genus.

Fig. 1 (A-K). Ascospores of *Pachyella* species photographed x5,000. A and B, *P. adnata*. C and D, *P. babingtonii*. E and F, *P. punctispora*. G, H, and K, *P. violaceonigra*. I and J, *P. clypeata*.

I was aided in the preparation and observation of this material by Ed Seling of the Scanning Electron Microscope Laboratory of the Museum of Comparative Zoology of Harvard University and by Glenda Winn of the Farlow Herbarium, both of whom I wish to thank.

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ELECTROPHORETIC CHARACTERISTICS OF ENZYMES AS A TAXONOMIC CRITERION IN THE GENUS HUMICOLA

J. Moorhouse and M. de Bertoldi °

Department of Genetics, University of Birmingham, P.O. Box 363, Birmingham B15 2TT, England.

SUMMARY

Twenty-seven strains of *Humicola* were examined for the presence of variant isoenzymes of α and β esterase, acid and alkaline phosphatase, leucine amino peptidase and peroxidase. The strains studied included six species of *Humicola* and many unclassified strains. With only one exception the unclassified strains differed significantly from the type species, and were considered to belong to different species. Certain pairs if unclassified strains were very similar, showing the genetical similarity which exists between these strains.

INTRODUCTION

In a previous work, several new strains of *Humicola* have been described (de Bertoldi, Lepidi and Nuti, 1972) and a classification on the basis of DNA base composition attempted (Lepidi, Nuti, de Bertoldi and Santulli, 1972; de Bertoldi, Lepidi and Nuti, 1973). Because of the spontaneous variation in morphology that occours among these strains, classification only on morphological grounds is of doubtful value. Furthermore, no clear correlation is found between the DNA base composition (GC%) of these strains and the morphological characters used for their classification.

In order to clarify the biochemical reletionships between the new strains and the species previously described, their enzyme variation was studied using electrophoretic techniques. This method has been applied to many other fungal genera (for example see Nealson and Garber 1967, Reddy and

° Present address: Istituto Microbiologia Agraria, University of Pisa, Centro di Studio per la Microbiologia del Suolo del C.N.R., Pisa, Italy.

Threlkeld 1971, Wong and Willetts 1973), and has been shown to be an useful aid to their taxonomy. The study of enzyme variation is more discriminating than gross morphology and GC%, because similarities for these latter characters can be produced by markedly different genomes, whereas when zymograms for several different enzymes are compared, similarities must be due to genetical similarities.

MATERIALS AND METHODS

Strains. The strains and their origins are described in Table 1. Those in the culture collection of the Istituto di Microbiologia Agraria, Pisa, have been described previously (de Bertoldi *et al.*, 1972).

Culture conditions. Strains were grown for enzyme extraction in 100 ml of liquid minimal medium (Pontecorvo *et al.* 1953) supplemented with 2% yeast extract and 2% sucrose in 250 ml Erlenmeyer flasks to which 0.5 gm carborundum (320 mesh) was added before sterilisation. These cultures were grown at 26°C for 4-6 days on a rotatory shaker.

Preparation of Extracts. This was performed at 4°C. Mycelium mixed with carborundum was harvested by filtration and blotted dry with absorbent paper. The mixture was ground in a pre-cooled pestle and mortar and after centrifugation, the crude extract was deep frozen until use. Three flasks were grown for each strain, and the mycelium from these combined before extraction. Each strain was also grown on two occasions to provide replicate extracts.

Electrophoresis. Starch gel electrophoresis was carried out on the extracts using the horizontal method described by Brewbaker, Upadhya, Makinen and Macdonald (1968) using their modification of the buffer system of Ashton and Braden (1961) for the separation of the enzymes α-Esterase (α-Est), β-Esterase (β-Est) and Leucine amino peptidase (L.A.P.).A sodium hydroxide-boric acid buffer system (System II - Shaw and Prasad 1970) was used for the enzymes peroxidase (Apx), acid phosphatase (Pac) and alkaline phosphatase (Pal).

Staining methods. After electrophoresis the starch gels were sliced and stained for enzymic activity by overnight immersion in one of the following mixtures: α-Est: 100 ml 0.1 M phosphate buffer pH 6.0, 2 ml α-napthyl acetate (1% in 50:50 acetone:water) and 30 mg Fast Garnet G.B.C. (Gurrs); β-Est: as for α but using β-napthyl acetate; L.A.P.: 40 mg L. leucyl β-napthyl-amide HCl dissolved in 5 ml dimethyl formamide, 100 ml 0.1 M phosphate buffer pH 6.0 and 50 mg Blak K salt (Gurrs); Apx: 50 mg 3-amino, 9-ethyl carbazole dissolved in 5 ml dimethyl formamide, 100 ml 0;05 M sodium acetate buffer pH 5.0 and 0.5 ml 30 vol. hydrogen peroxide;

Pac: 100 ml 0.5 M sodium acetate buffer pH 5.0, 25 mg sodium α-napthyl phosphate and 100 mg Fast Red T.R.N. (Gurrs); Pal: as Pac but the buffer replaced by water.

Table 1. List of *Humicola* strains studied and their source.

ORGANISMS	ABBREVIATION	SOURCE°
Humicola grisea Traaen	GR	CBS 112.12
H. fuscoatra Traaen	FU	CBS 118.14
H. alopallonella Meyer & Moore	AL	CBS 207.60
H. brunnea Fassatiovà	BR	CBS 217.38
H. brunnea Fassatiovà	EA3	CCFP
H. brunnea v.*africana* Fassatiovà	EA4	CCFP
H. parvispora Gambogi	G5	IMAP
Humicola sp	20-31	IMAP
" "	20-31W	spont.white variant from 20-31
" "	20-31B	spont.black variant from 20-31
" "	20-31P	spont.brown variant from 20-31
" "	HT	IMAP
" "	7-7	IMAP
" "	H2	IMAP
" "	H3	IMAP
" "	2-1	IMAP
" "	2-1B	spont. morphological variant from 2-1
" "	12-2	IMAP
" "	18-16	IMAP
" "	21-3	IMAP
" "	9-9	IMAP
" "	20-1	IMAP
" "	16-2	IMAP
" "	18-13	IMAP
" "	20-4	IMAP
" "	20-4 A	spont. morphological variant from 20-4
" "	16-1	IMAP

° CBS, Centraalbureau voor Schimmelcultures, Baarn; CCFP, Culture collection of Fungi, Department of Botany, Benàtskà 2, Prague; IMAP, Istituto Microbiologia Agraria, Università di Pisa, Italy.

RESULTS

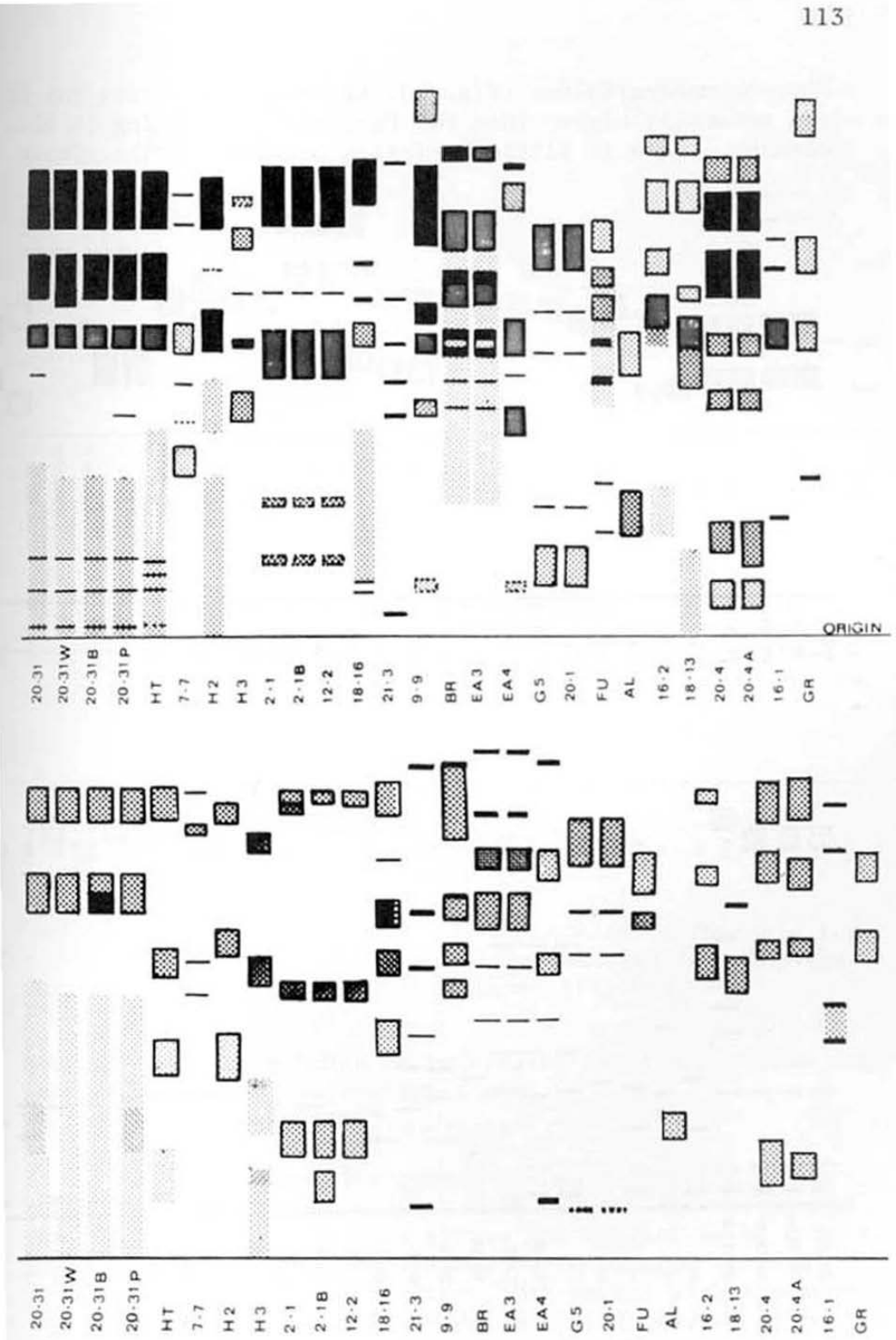
α-*Esterases* (Fig. 1). All strains produce clear bands of activity for these enzymes. Zymograms show much variation, and among the strains examined eighteen patterns were found. The six type species all give different patterns, and all the new strains are also different from these, with the exception of 20-1 which resembles *H. parvispora*. The two examples of *H. brunnea* are very similar to one another, but are quite different from *H. brunnea* var. *africana*.
The morphological segregants all show very similar patterns in their parental strains, examples being 20-31, 20-31B, 20-31P and 20-31W, 20-4 and 20-4A, and 2-1 and 2-1 B. The strains 2-1 and 2-1B also resembles 12-2. Strain HT also resembles 20-31 and its segregants although there are slight differences.

β-*Esterase* (Fig. 2). The staining for these enzymes is not as good as for α-Est, and with the exception that HT is different from 20-31, those similarities found for α-Est are present for β-Est. Nineteen patterns are found.

Leucine Amino Peptidases (Fig. 3). These enzymes give sharp banding patterns, and although there are few isoenzymes for any strain the similarities found for the esterases are present for L.A.P.. In addition the following strains gave similar patterns: 21-3 and 9-9; 7-7 and HT; *H. fuscoatra* and *H. alopallonella*; 18-16 and 2-1; 16-2 and 18-13; and *H. brunnea* and *H.brunnea* var. *africana*.

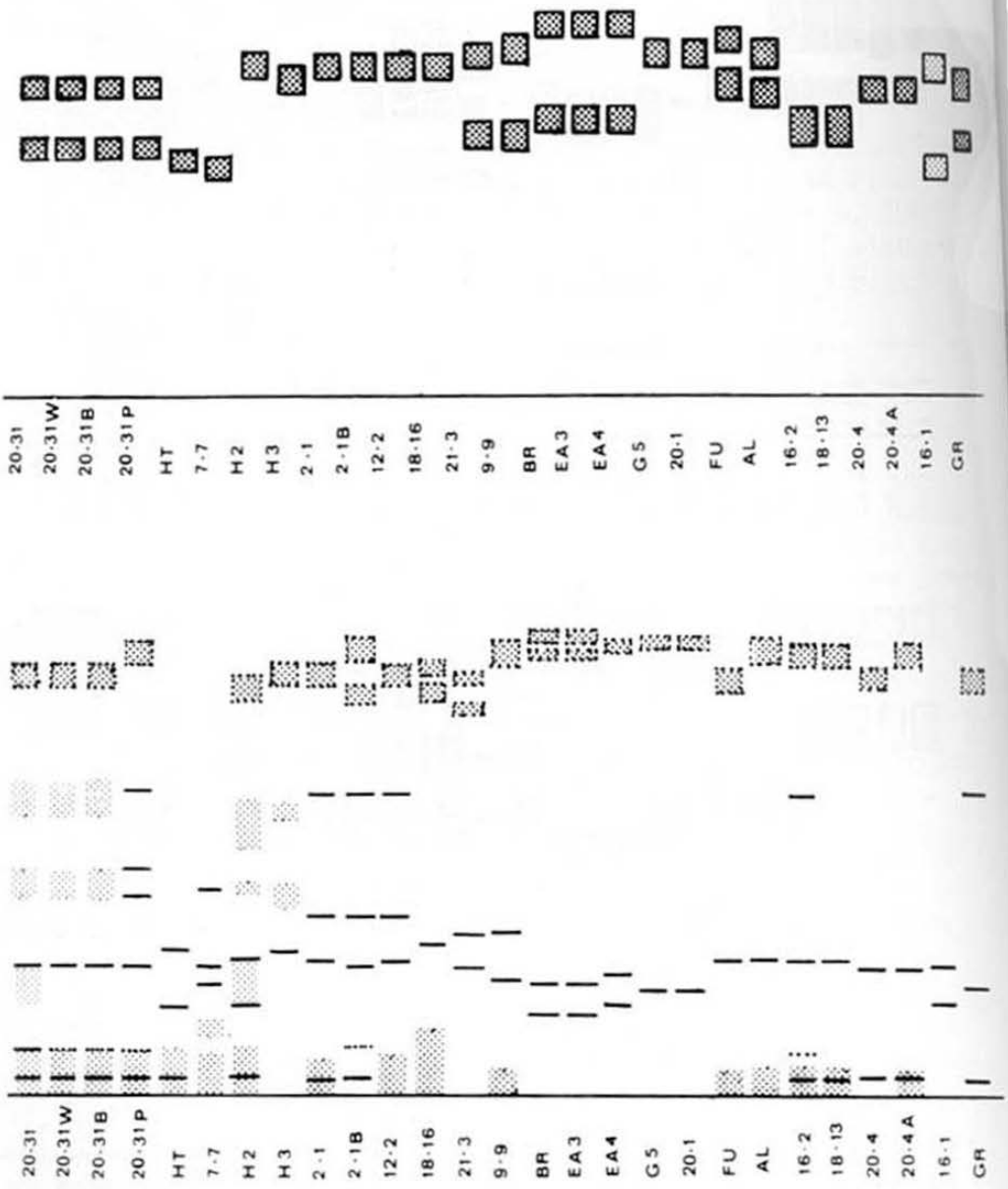
Peroxidases (Fig. 4). These enzymes do not give as clear or consistent bands as the esterases or L.A.P. however, many of the similarities observed previously are again present. *H. parvispora* and 20-1 are again similar as are 2-1 and 12-2; 20-31B and 20-31W; and the two examples of *H. brunnea*. For these enzymes 2-1B shows some differences for its parental isolate as do 20-31P and 20-4A. Some similarities not observed for the esterases are also present. In particular 16-2 and 18-13 are quite similar, and 20-31 with its segregants show several bands in common with 20-4 and its segregant.

Phosphatases-acid (Fig. 5). The level of activity of these enzymes is quite low in many strains especially H2, 16-2 and EA4, although there is in general considerable variation between strains. There are sixteen banding patterns and the groupings are essentially the same as for β-Est, with the additional resemblances of 16-2 to 18-13, 21-3 to 9-9 and *H. alopallonella* to *H. fuscoatra*.

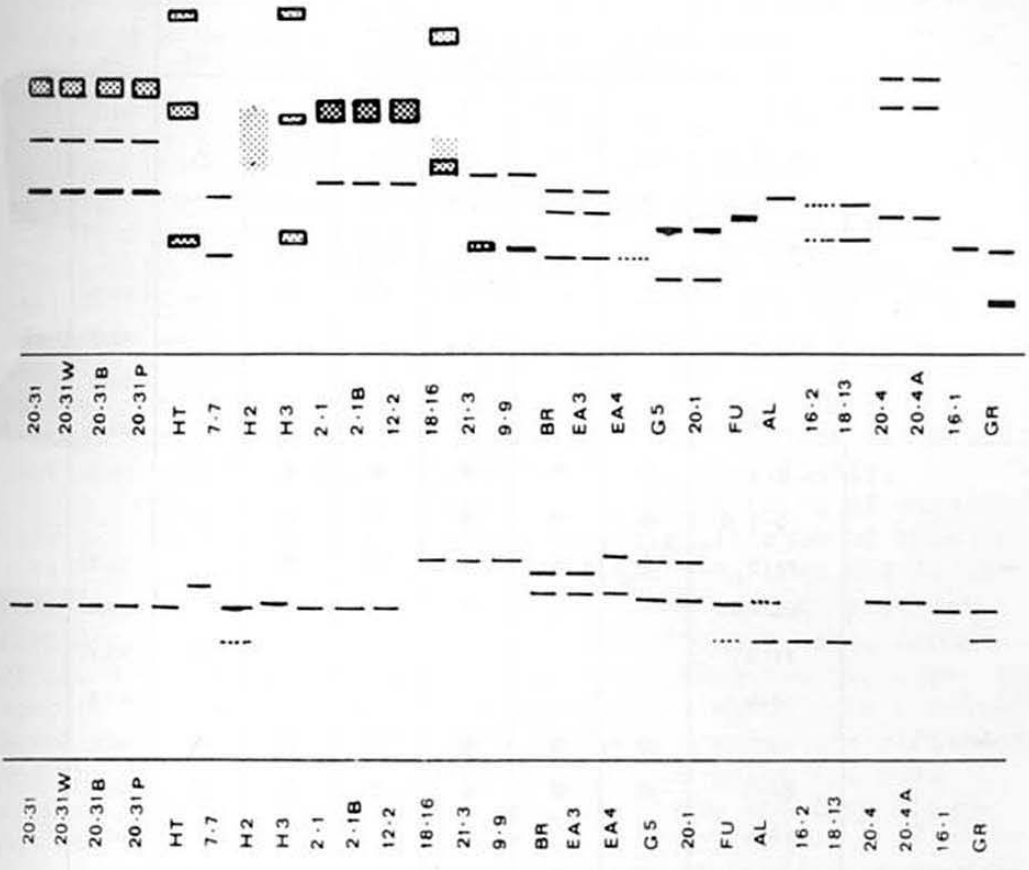


Figs. 1 and 2. Zymograms of the 27 strains of *Humicola* for the enzymes α-Esterases (Fig. 1) and β-Esterases (Fig. 2).

Phosphatases-alkaline (Fig. 6). Although activities for Pal are generally higher than for Pac, and the banding is also clearer, there is little variation between strains. Those



Figs. 3 and 4. Zymograms of the 27 strains of *Humicola* for the enzymes Leucine amino peptidase (Fig. 3) and Peroxidases (Fig. 4).



20·31
20·31W
20·31B
20·31P
HT
7·7
H2
H3
2·1
2·1B
12·2
18·16
21·3
9·9
BR
EA3
EA4
G5
20·1
FU
AL
16·2
18·13
20·4
20·4A
16·1
GR

Figs. 5 and 6. Zymograms of the 27 strains of *Humicola* for the enzymes Acid Phosphatases (Fig. 5) and Alkaline Phosphatases (Fig. 6).

strains which were found to be similar for the previous enzymes are alike for these enzymes too.

DISCUSSION

The six type species examined showed different zymograms for all enzymes, and the only new strain to resemble any of these was 20-1. This strain was similar to *H. parvispora* for all enzymes, and so may be considered an independent isolate of this species. This agrees with the morphological and biochemical evidences previously published (de Bertoldi *et al.* 1972, Lepidi *et al.* 1972).

When the enzyme characteristics are considered together with the GC% values from Lepidi *et al.* (1972) (Fig. 7) five groups of strains can be recognised. Two of these groups

STRAINS	ENZYMES						GC%
	α-est	β-est	lap	apx	pac	pal	
20·31	△	△	△	△	△	△	33.0
20·31 W	△	△	△	△	△	△	–
20·31 B	△	△	△	△	△	△	–
20·31 P	△	△	△	(△)	△	△	–
H T	△		□	⊙	⊙	△	30.0
7·7			□				45.7
H·2						△	31.6
H·3				⊙	⊙	△	28.5
2·1	◆	◆	◆	◆	◆	△	30.2
2·1 B	◆	◆	◆	◆	◆	△	–
12·2	◆	◆	◆	◆	◆		33.2
18·16			◆				29.4
21·3			○		○	○	50.1
9·9			○		○	○	47.5
BR	■	■	■	■	■	■	45.0
EA·3	■	■	■	■	■	■	46.3
EA·4			■				38.5
G·5	◇	◇	◇	◇	◇	◇	41.4
20·1	◇	◇	◇	◇	◇	◇	42.0
F U			●	●	●	●	32.5
A L			●	(●)	●	●	45.0
16·2			□	□	□	□	46.9
18·13			□	□	□	□	43.8
20·4	▲	▲	▲	▲	▲	▲	32.3
20·4 A	▲	▲	▲	▲	▲	▲	–
16·1							30.0
G R							36.3

Fig. 7. Summary of electrophoretic similarity among the 27 strains of *Humicola*. For any enzyme similar simbols represent similar banding patterns. Blanks represent unique banding patterns. GC% values from Lepidi *et al.* (1972).

consist of a wild-type and its segregants and so confirm that these segregants, while differing considerably in morphology, are nevertheless very similar genetically both to each other and to the wild isolate from which they were obtained. Another group contains, in addition to an isolate (2-1) and its segregant (2-1B), the strains 12-2 although these isolates were not previously considered as being closely related. Although the DNA base composition of these strains is not identical, they are similar enough for the difference to be ascribed to experimental error. Another group contains the isolate 20-1 and the type species *H. parvispora*, and the final group comprises the strains of *H. brunnea*. It is not surprising that the strains of *H. brunnea* are alike for all enzymes, but the lack of resemblance of the strain of *H. brunnea* var. *africana* is interesting. From this work it would seem that these taxa are not very similar genetically.

In addition to these five groups, three pairs of strains show partial similarity, although the significance of this is less clear. Two of these pairs (21-3 and 9-9, 16-2 and 18-13) contain strains which were previously seen to bear some resemblances to one another (GC% and aleuriospore size, Lepidi *et al.* 1972) although the other pair contains the two type species *H. fuscoatra* and *H. alopallonella*, which were considered very different. The GC%'s of these species are different and there is therefore no question of them being the same species, although the partial similarity may indicate a common ancestry of these two species.

In general this study has shown the 27 strains of *Humicola* to be very heterogeneous for the six enzymes examined. For most of these enzymes more than sixteen different banding patterns have been found, so there would appear to be much genetical variation present.

These results indicate the problems associated with the taxonomy of the fungi imperfecti, and taxa previously considered very similar have been shown to be quite different, while resemblances have been indicated between others thought to be very different. This method would seem to be useful for this genus, but only if a sufficent number of enzymes are examined.

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REVISION OF CERCOSPORA SPECIES (HYPHOMYCETES) PARASITIC ON PSORALEA

O. CONSTANTINESCU

Mycological Herbarium, Institute of Biological Sciences Bucureşti 17, Romania

Four taxa of *Cercospora* were described as parasitic on plants of the genus *Psoralea: C. latens* forma *europea* Fragoso (1921), *C. psoraleae-bituminosae* Săvul. & Sandu-Ville (1940), *C. psoraleae* Ray (1941), and *C. psoraleae* Petrak (1950). Chupp (1954) noted only the last three species, considering them conspecific, and regarding *C. psoraleae* Ray as being the correct name. Constantinescu (1967) proposed a new combination, *C. europea* (Frag.) O. Const., for all four taxa, but this is a superfluous name. Almost all authors follow Chupp (1954) in using Ray's name for species of *Cercospora* occurring on *Psoralea* plants.

Examination of the types of the above mentioned taxa, and of other specimens of *Psoralea* parasitized by *Cercospora*-like fungi, showed that *C. psoraleae-bituminosae* is conspecific with *C. psoraleae* Ray and *C. latens* forma *europea* Fragoso, while *C. psoraleae* Petrak is a distinct species. *C. ecuadoriana* is proposed as a new name to replace *C. psoraleae* Petrak. On plants of *Psoralea bituminosa* and *P. drupacea* collected in Spain, Romania, U.S.S.R. and Israel, a new *Cercospora* was found, described here under the name *C. nodosa*.

CERCOSPORA PSORALEAE-BITUMINOSAE Săvul. & Sandu-Ville *in* Mem. Sec. Şt. Acad. Rom., ser. 3, 15(17): 485. 1940.

= *Cercospora psoraleae* Ray *in* Mycologia 33: 176. 1941, non Petrak *in* Sydowia 4: 572. 1950.

= *Cercospora latens* forma *europea* Fragoso *in* Boln R. Soc. Esp. Hist. Nat. 21: 97. 1921.

≡ *Cercospora europea* (Frag.) O. Const. *in* Revue Mycol. 32: 106. 1967.

(FIG. 1)

Leaf spots visible on both leaf surfaces, more or less circular, brown, sometimes becoming pale or whitish in the center, with a darker margin raised on the upper surface, 1-3 mm wide, seldom confluent. Caespituli amphigenous but usually more abundant on the upper surface, composed of 3-20 divergent conidiophores. Stroma substomatal, not well developed, consisting of a few brown cells. Conidiophores macronematous, pale brown, paler towards the apex, straight or

geniculated, smooth, uniform width throughout the length or narrowed towards apex, 1-6-septate, simple, 30-100 (-225) µm long, 4-6 µm wide. Conidiogenous cells polyblastic, 1-7 conspicuous conidial scars. Conidia hyaline or faintly greenish, acicular or the young ones short and almost cylindrical, straight or curved, smooth, acute or subobtuse tip, truncate at the base, hilum 2.5-3 µm, 3-17-septate, 40-200 µm long, 3.5-5 µm wide. Few conidia bear at the basal, median, or even apical part, a short appendage on which, occasionally, secondary conidia are formed.

On leaves and stems of *Psoralea bituminosa* L., in Bulgaria, Spain, France, Israel, U.S.S.R., and on leaves of *P. digitata* Nutt., in U.S.A.

SPECIMENS EXAMINED:[1] On *Psoralea bituminosa* L.: BULGARIA, Distr. Caliacra, Balcic, 17 VI 1939, T. Săvul. & Sandu-Ville (41482 lectotype). Isotypes distributed in Săvul., Herb. Mycol. Romanicum 1245. SPAIN, Tibidabo, near Barcelona, 4 V 1919, coll. Caballero, det. Fragoso (41488a, slide *ex* MA; lectotype of *C. latens* forma *europea*); Distr. Logrono, near Arnedo, 7 VII 1930, P. Unamuno (41491 slide *ex* MA); Gran Canaria, near Mogán, 25 III 1954, J. de Urries (41489 slide *ex* MA). The host seems not to be *P. bituminosa* but the fungus agrees with the young state of *C. psoraleae-bituminosae*. FRANCE, Distr. Alpes Maritimes, Grèolières, VIII 1953, G. Durrieu (40418 slide); Distr. Aude, Quillan, 15 VIII 1956, G. Durrieu (40417 slide); Corse, route to Nonza, 27 VI 1949, E. Mayor & Viennot-Bourgin (41487 slide). ISRAEL, Kiriat Akaba, 6 V 1938, coll. (?) T. Rayss, det. O. Const. (41480). Mixed with *C. nodosa*. U.S.S.R., Crimea, Sochi, 27 VII 1912, I. Voronikhin (41477); 4 IX 1913, I. Voronikhin (41478); Gagry, 8 VIII 1912, I. Voronikhin (41479). On *Psoralea digitata* Nutt.: U.S.A., Oklahoma, Stillwater, College nursery, 7 III 1940, W. W. Ray (40419 slide *ex* CUP, holotype of *C. psoraleae* Ray); (40420 slide *ex* CUP 40653, isotype).

A specimen deposited in herb. MA, collected from Valsendera (Gran Canaria), 13 IV 1954, and identified by Urries (1957) as *C. latens* forma *europea*, shows leaves of a Leguminosae plant, parasitized by a *"Cylindrosporium."*

Cercospora psoraleae-bituminosae is a typical *Cercospora*, morphologically similar to *C. apii* Fres., the type species of the genus.

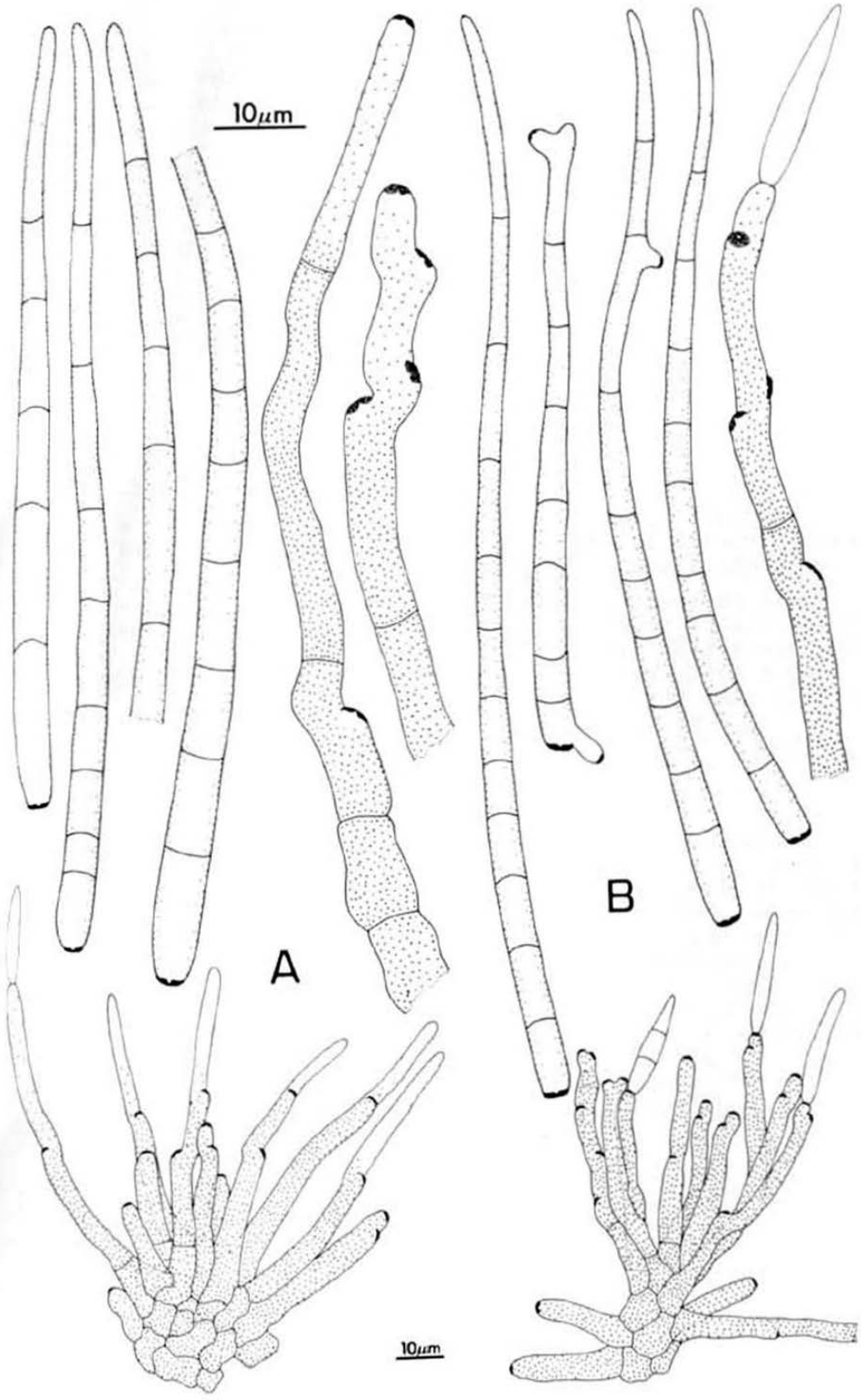
CERCOSPORA ECUADORIANA O. Const., *nom. nov.*

≡ *Cercospora psoraleae* Petrak *in* Sydowia 4: 572. 1950, non Ray *in* Mycologia 33: 176. 1941.

(FIG. 2)

[1] Throughout the text, Herb. BUCM identification numbers are given in parentheses after each collection cited.

FIG. 1. *Cercospora psoraleae-bituminosae*. Fascicles, conidia and conidiophore tips. A, from the type (41482); B, from the type of *Cercospora psoraleae* Ray (40419).


10μm
A
B
10μm

Leaf spots visible on both leaf surfaces, irregular, more or less angular. On the upper surface the central part of the spot is pale whitish, 0.5-2.5 mm wide and surrounded by a zone of brown, necrotic leaf tissue, 0.5-1 mm wide. The corresponding area on the lower surface is uniformly brown or paler in the center, 6-7 mm wide. Caespituli hypophyllous, composed of up to 40 conidiophores. Stroma substomatal, up to 40 µm wide, consisting of an aggregation of brown hyphae. Conidiophores macronematous, olivaceous-brown, sometimes paler towards apex, 2-3-septate, width uniform, smooth, straight, curved or geniculated, 30-90 µm long, 4-6 µm wide; conidiogenous cell polyblastic, 1-4 conspicuous thickened conidial scars, 2-2.5 µm wide. Conidia obclavate, faintly greenish, slightly curved, smooth, rounded at the apex, narrowed towards base, hilum thickened, 2.5-3 µm, 3-15-septate, 30-130 µm long, 5-6 µm wide. The mature conidia often bear conidial scars as the result of secondary conidia which are commonly formed.

On leaves of *Psoralea glandulosa* L., in Ecuador.

SPECIMENS EXAMINED: On *Psoralea* sp.: ECUADOR, Pichicha near Quito, 13 IX 1937, coll. P. Sydow, det. F. Petrak, holotype (41481 slide *ex* M).

The obclavate conidia and their more thickened scars differentiate this species from *C. psoraleae-bituminosae*. Although Petrak (1950) reported the host as *P. glandulosa*, the type specimen is labelled *Psoralea* sp. I was unable to identify the host from leaves only.

CERCOSPORA NODOSA O. Const., *nov. sp.*

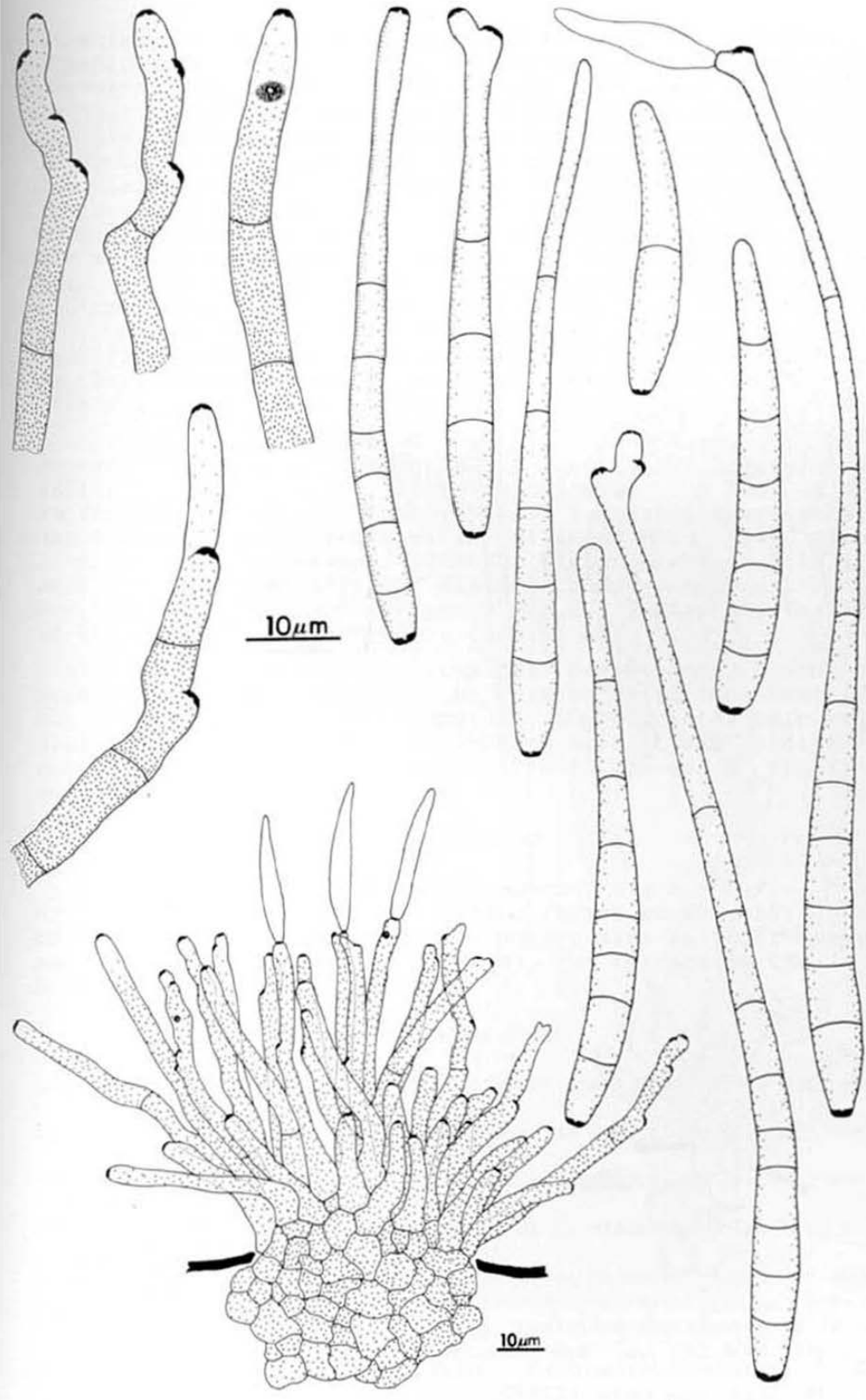
(FIG. 3)

Fasciculi praecipue hypophylli, brunneis, ex stromatibus emergentis, 4-20 conidiophora divergentes compositis. Stroma substromatica, minuta, ex paucis hyphis pallide brunneis composita. Conidiophora pallide brunnea, erecta, plerumque varie crassa, saepe apicem inflata et nodosa, laevia vel apicem verruculosa, 1-2-septata, rare ramosa, 1-4 subtilis cicatrices, 30-50 µm longa, 4-7 µm crassa, apice usque ad 10 µm crassa. Conidia pallide olivacea, obclavata vel brevia et quasicylindrica, plus minusque curvata, laevia, cellis basilaribus interdum delicate rugosus, apices rotundatis, basis truncata, hilum discretum, 2 µm crassum, 1-7-septata, 25-145 µm longa, 4-5 µm crassa.

Habitat in foliis vivis *Psoraleae bituminosae* L., Romania, Bucureşti, Hortus Botanicus, 23 IX 1966, holotypus in Herb. BUCM 41472 conservatur.

Leaf spots visible on both surfaces, brown, 1-3 mm wide, sometimes confluent, vein-limited, necrotic on the upper part and of mosaicated appearance on the lower one. Ceaspituli mostly hypophyllous, brown, emerging through stomatal opening, composed of 4-20 divergent conidiophores. Stroma sub-

FIG. 2. *Cercospora ecuadoriana*. Fascicles, conidia and conidiophore tips from the type of *C. psoraleae* Petrak (41481).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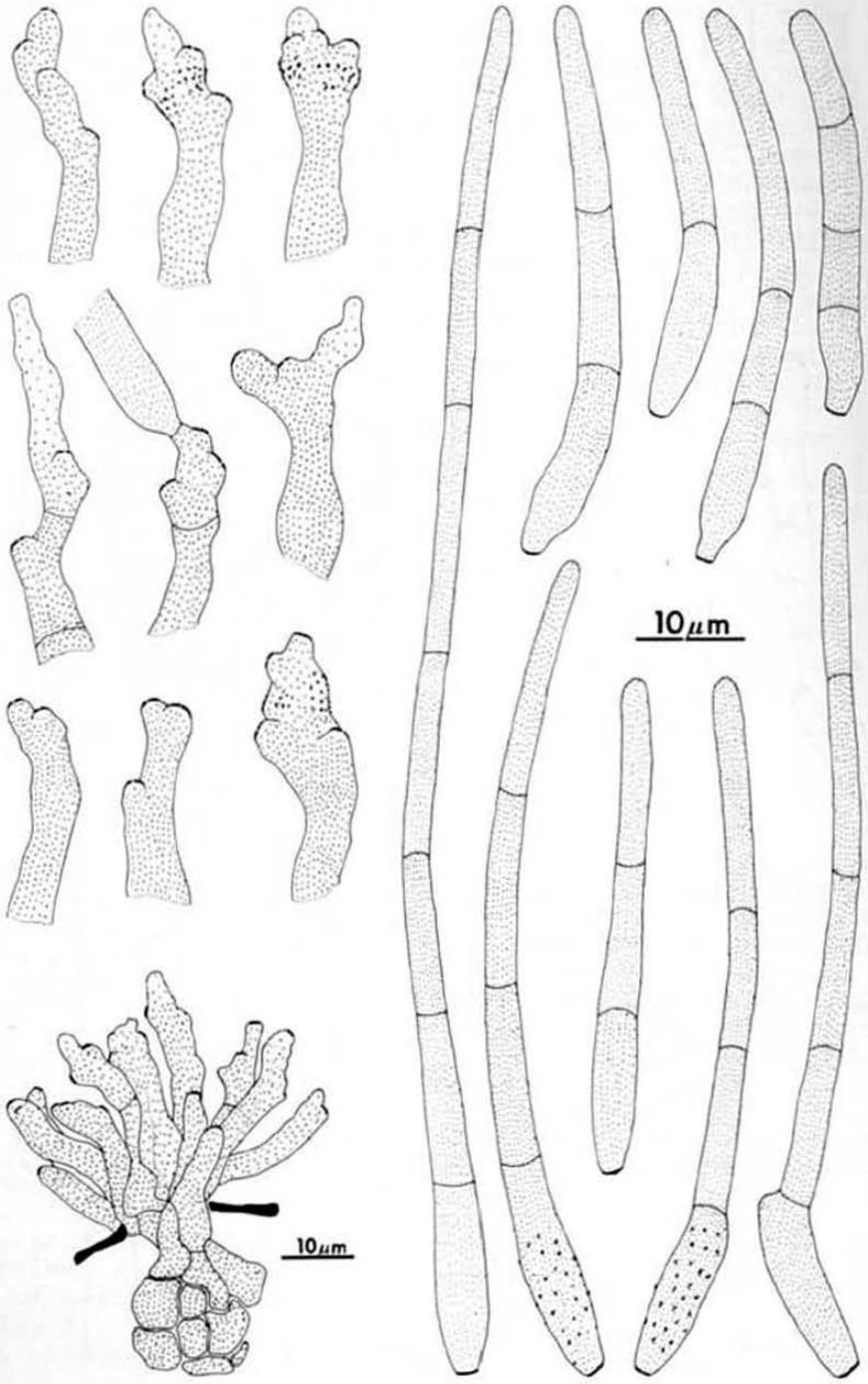

FIG. 3. *Cercospora nodosa*. Fascicles, conidiophore tips and conidia from the type (41472).

stomatal, reduced, consisting of a few pale brown hyphae. Conidiophores brown olivaceous, straight, of different width throughout the length, often swollen and nodose at the apex or just beneath it, smooth walled except some discrete verrucosities on the apical part, 1-2-septate, rarely branched, 30-50 µm long, 4-7 µm wide (up to 10 µm at the swollen tip), conidiogenous cells polyblastic, 1-4 thin, discrete, conidial scars. Conidia pale olivaceous, obclavate but the young ones almost cylindrical, more or less curved, smooth but sometimes the wall of the basal cell verrucose, tip rounded, base truncate, hilum discrete, 2 µm wide, 1-7-septate, 25-140 µm long, 4-5 µm wide.

On leaves of *Psoralea bituminosa* L., in Romania, Spain and Israel, and on *P. drupacea* Bge in U.S.S.R. Type: Romania, Bucureşti, Botanical Garden, 23 IX 1966, O. Const. (41472).

SPECIMENS EXAMINED: On *Psoralea bituminosa* L.: ROMANIA, Bucureşti, Botanical Garden, 23 IX 1966 (41472 holotype; IMI 151119 isotype; CBS 555.71 living culture); 1 X 1966 (41473); 16 VI 1967 (41474) O. Const. SPAIN, Tibidabo, near Barcelona, 4 V 1919, Caballero (41488b, slide *ex* MA). Mixed with *C. psoraleae-bituminosae*. ISRAEL, Kiriat Akaba, 6 V 1938, coll. (?) T. Rayss (41480). Mixed with *C. psoraleae-bituminosae*. On *Psoralea drupacea* Bge: U.S.S.R., Turkestan, Tashkent, 29 VII 1915, N. G. Zaprometov (41475; LE).

C. nodosa belongs to "atypical" *Cercosporae*, having colored conidia and slow growth on culture media (Constantinescu, 1969). By its colored conidia, the discrete, thin, conidial scars, and swollen conidiophore tips it can be differentiated from both *C. psoraleae-bituminosae* and *C. ecuadoriana*.

ACKNOWLEDGMENTS

I wish to thank Prof. G. Viennot-Bourgin – Paris, Dr. Guy Durrieu – Toulouse, and curators of CUP, LE, M, and MA herbaria, for making available specimens in their keeping, and Prof. E. D. Rudolph – Columbus, for correcting the English text.

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PHIALOCEPHALA GABALONGII AS A SYNONYM OF *PHIALOCEPHALA HUMICOLA*

S. C. JONG and E. E. DAVIS

Mycology Department, American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852

SUMMARY

Study of type cultures of *Phialocephala humicola* ATCC 22801 and *P. gabalongii* ATCC 26784 demonstrated that these isolates are identical. Thus, the name *P. gabalongii* Sivasithamparam, 1975, is a later, facultative synonym of *P. humicola* Jong & Davis, 1972.

Sivasithamparam (1975) recently described a new species, *Phialocephala gabalongii* Sivasithamparam, based on an isolate from roots of wheat raised on soil collected from Gabalong, Western Australia. The type culture was deposited in the American Type Culture Collection as ATCC 26784. A comparison of the figures and descriptions of *P. gabalongii* and *P. humicola* Jong & Davis (1972) revealed a similarity in morphological characters as well as in conidiogenesis. Apparently Sivasithamparam was not aware of *P. humicola*. The affinity of *P. gabalongii* and *P. humicola* is therefore discussed in this note.

Phialocephala humicola was fully described and illustrated by Jong & Davis (1972) who originally isolated it from a soil sample collected from Cape May, New Jersey. They reported that conidiogenesis in the fungus appears to be phialidic and conidia are acrogenous. The content of the conidiogenous cell passes through the opening and the conidia take shape immediately on the outside of the opening. This fungus is distinguished from other *Phialocephala* species primarily by the pattern of phialoconidium production and conidium size. According to Tubaki and Ito (1975), *P. humicola* has often been isolated from aquatic sediments of River Ichikawa and Lake Sengari in Hyogo Pref., Japan.

Cultures of *P. gabalongii* ATCC 26784 and *P. humicola* ATCC 22801 were run through a series of tests on a variety of common mycological media under various environmental conditions. The results showed that these strains are morphologically and developmentally indistinguishable (Table 1). *Phialocephala gabalongii* Sivasithamparam (Trans. Brit. Mycol. Soc. *64:* 335, 1975) thereby becomes a later, facultative synonym of *P. humicola* Jong & Davis (Mycologia *64:* 1352, 1972) and ATCC 26784 is now disposed as *P. humicola* at the ATCC.

Table 1. Characteristics of *Phialocephala humicola* and *P. gabalongii* grown on potato dextrose agar (ATCC medium 336) plates for 2 weeks at 24 C

Characteristic	*P. humicola* ATCC 22801	*P. gabalongii* ATCC 26784
Growth at 37 C	No	No
Light required for sporulation	No	No
Colony color	Olive green, reverse dark olive to black	Olive green, reverse dark olive to black
Conidiophores	Macronematous, penicillate	Macronematous, penicillate
Penicillate heads	1-3 metulae	1-3 metulae
Conidiogenous cells	Monophialidic, 8-12 X 1-2 µm	Monophialidic, 5-15 X 1-3 µm
Collarettes	Inconspicuous	Inconspicuous
Phialoconidia	1-celled, differentiated on outside of collarettes 2.5-4.0 X 1.0-2.0 µm	1-celled, differentiated on outside of collarettes 2.0-3.5 X 1.0-2.5 µm

Phialocephala humicola is now known in Australia, Japan and North America, and is well established in different climatic regions of the world. Thus, it has been shown that this species is a clearly defined fungus taxon.

This work was supported in part by National Science Foundation Grant BMS75-06286.

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NOTES ON HYPHOMYCETES. VIII.[1] *LYLEA*, A NEW GENUS.

G. MORGAN-JONES

Department of Botany and Microbiology
Auburn University Agricultural Experiment Station
Auburn, Alabama 36830, U.S.A.

ABSTRACT

Lylea catenulata Morgan-Jones, a new genus and species, is described and illustrated from a collection on twigs of *Pinus taeda*, and from agar culture.

INTRODUCTION

During taxonomic studies of dematiaceous hyphomycetes in Alabama an unusual fungus was encountered colonizing bark of dead twigs of *Pinus taeda* L. The organism makes scant growth on the substrate and is therefore not easily observed. It produces scattered, short, branched chains of thick-walled, multiseptate conidia and is, in several characteristics, unlike any other hyphomycete presently known. Since no description of a fungus corresponding to it exists in the literature it is herein treated and a new generic name is established for it. The fungus was easily isolated in pure culture on several agar media.

TAXONOMIC PART

Lylea gen. nov.

Deuteromycotina, Hyphomycetes.
Coloniae effusae, olivaceo-brunneae. Mycelium partim superficiale, partim immersum, ex hyphis ramosis, septatis, pallide brunneis laevibus compositum. Conidiophora micronemata vel semi-macronemata, singulatim ex lateribus hypharum oriunda, simplicia, cylindrica, brevia, pallide brunnea, laevia. Conidia acropetalia, catenulata, catenulis simplicibus vel ramosis, recta vel leniter curvata, cylindrica, brunnea, levia, septata, ad septa non constricta, extremis obtusis.

Species typica *L. catenulata* Morgan-Jones

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[1] Parts I-VII appeared in the Canadian Journal of Botany.

Lylea catenulata sp. nov. (Fig. 1).

Coloniae effusae, olivaceo-brunneae. Mycelium partim superficiale, partim immersum, ex hyphis ramosis, septatis, pallide brunneis, laevibus vel verrucosis, 1.5 - 2.5µm crassis compositum. Conidiophora micronemata vel semi-macronemata, mononemata, singulatim ex lateribus hypharum oriunda, simplicia, cylindrica, brevia, a mycelio vegetavio vix distincta, pallide brunnea, laevia. Conidia sicca, acropetalia, in catenis simplicibus vel ramosis, acropleurogena, recta vel leviter curvata, cylindrica, brunnea, levia, 1-11 septata, 18 - 120µm longa, 7 - 9µm crassa.

In cortice ramulis *Pini taedae*, Auburn, Alabama, VIII 1973, G. Morgan-Jones, BPI, holotypus.

The new taxon is named in honour of Dr. James Albert Lyle, Chairman, Department of Botany and Microbiology, Auburn University.

Colonies effuse, thin, olive brown, with scattered, branched, conidial chains. Mycelium partly superficial, partly immersed; superficial mycelium composed of slender, flexuous, repent, much branched, septate, pale brown, smooth-walled or minutely verruculose hyphae, 1.5 - 2.5µm wide. Conidiophores micronematous or semi-macronematous, inconspicuous, formed as very short, erect, cylindrical branches of the superficial mycelium, simple, pale brown, smooth-walled, usually separated from the mycelium by a transverse septum. Conidiogenous cells monoblastic, integrated, determinate; constituting the conidiophore, terminal or intercalary on conidia, or intercalary on hyphae. The growth of the conidiophore ceases as the first conidium is formed. A second conidium is formed apically from the terminal cell of the conidium, following which conidia may be produced from the second and subsequent conidia at terminal and intercalary loci. Initial conidia of a chain can form directly from intercalary cells of the repent hyphae, especially in culture, by lateral growth. Conidia catenate, dry, acrogenous, formed in short, frequently branched, acropetal chains, seceding readily, simple, straight or slightly curved, cylindrical, obtuse at each end, thick-walled with narrow cell lumina, guttulate, mid to dark brown, smooth, (1) 4-7 (11) septate (pseudosepta, with thick, dark, conspicuous lamellae), (18) 40 - 67 (120) X 7 - 9µm.

Colonies on 2% malt agar and potato dextrose agar slow-growing, reaching a diameter of 1½ to 2cm. after 21 days, dark olive green, with paler, mottled areas, felted to somewhat floccose in patches especially at the center of the colony, edge regular, becoming darker with age, sporulating abundantly. Reverse dark grey at blackish.

DISCUSSION

Although differing sufficiently to be recognised as a distinct genus *Lylea* bears similarity to a number of known genera. It shows affinity to *Heteroconium* Petrak and *Septonema* Corda in particular. From *Heteroconium*, the genus to which it seems most closely related, it differs in not having well defined, thick-walled, septate, macronematous conidiophores and in possessing

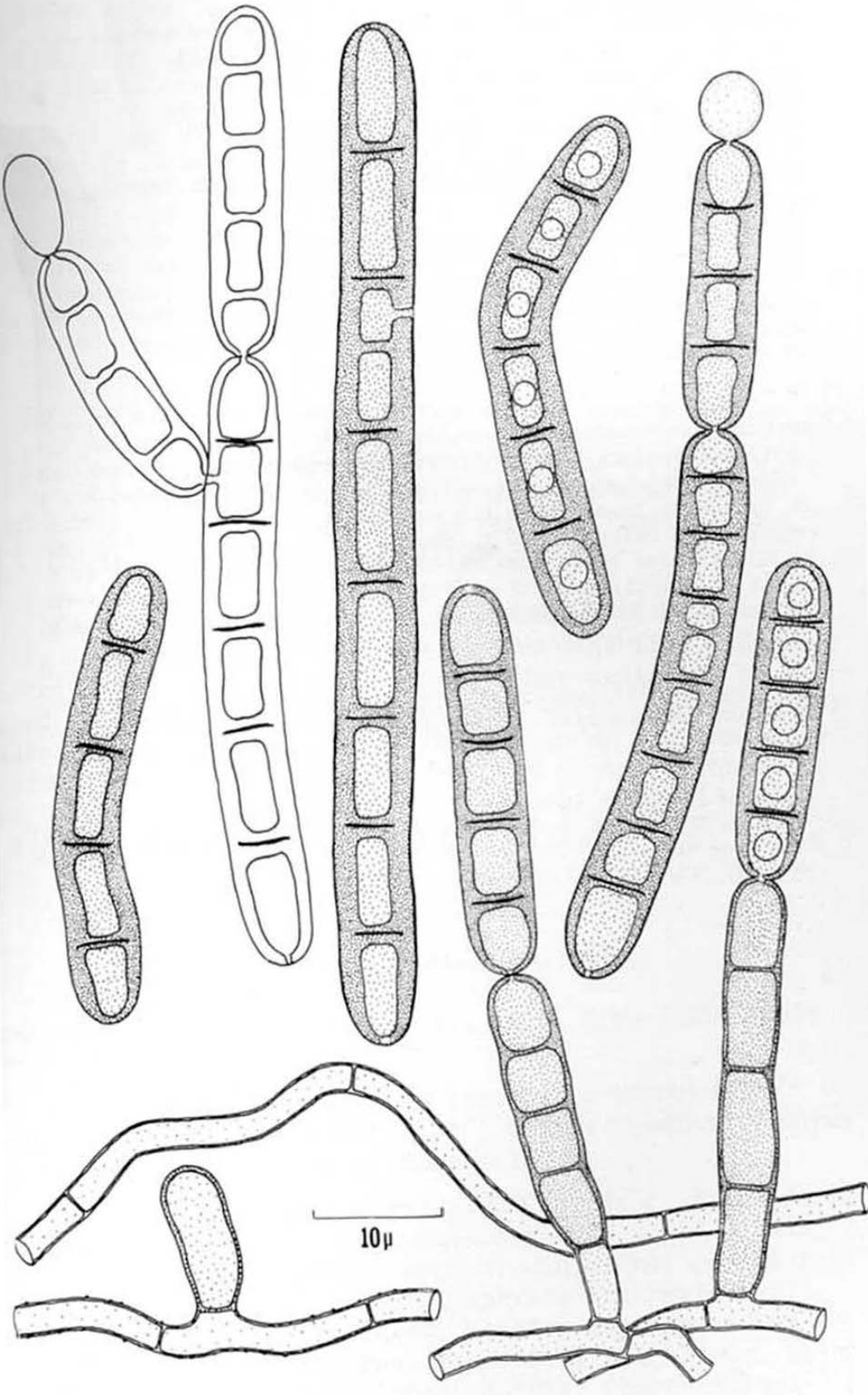

FIGURE 1. *Lylea catenulata*. Conidia and conidiophores.

conidia with thick pseudosepta and reduced cell lumina. Also, the conidial chains of *Heteroconium* are not branched and its superficial mycelium is composed of broad, robust, thick-walled hyphae. A further difference is that *Heteroconium*, as exemplified by *H. citharexyli* Petrak, has largely a superficial habit, hypophyllous on living leaves in the tropics. The name *Heteroconium* is best restricted to foliicolous hyphomycetes which possess short chains of cylindrical, septate, brown conidia that are produced on well developed, erect, septate, thick-walled, brown conidiophores, formed from brown mycelium closely adpressed to leaf surfaces. *Lylea* resembles *Septonema* in that its conidia arise in branched, acropetal chains, but in the latter genus the conidiophores are macronematous, are frequently branched, and are aggregated into a loose sporodochium-like arrangement. The conidia of *Septonema* have simple septa.

Bispora Corda and *Taeniolella* Hughes are similar to *Lylea* in that they possess semi-macronematous conidiophores but the individual conidia in these two genera are delimited from each other by transverse septa and not by complete constrictions as in *Lylea*. In *Taeniolella* the conidia secede only with difficulty. *Ampullifera* Deighton and *Xylohypha* (Fr.) Mason are other genera to which *Lylea* bears some resemblance. They differ from it in their short, ellipsoidal conidia separated by septa and formed on macronematous conidiophores. In the former the presence of hyphopodia on the mycelium in an additional distinction.

Within this complex of genera *Lylea* occupies a position somewhat intermediate between *Heteroconium* and *Septonema*.

ACKNOWLEDGEMENT

I thank Dr. M.B. Ellis, Commonwealth Mycological Institute, Kew, England, for examining this fungus and discussing with me the most appropriate taxonomic position for it.

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TAXONOMY AND NOMENCLATURE NOTES ON UREDINALES

G.F. LAUNDON

Ministry of Agriculture and Fisheries
Plant Health and Diagnostic Station
Levin, New Zealand

As well as notes on the taxonomy and nomenclature of a variety of rust genera and species, one new name is proposed and six new combinations are given.

The items included here are mostly ones which have arisen in the course of other work during the past five years or so, but which, for one reason or another could not be published along with the results of that work. Notably they relate to work on rust genera for the Index Nominum Genericorum (not yet published) and for my contribution to 'The Fungi' (Laundon, 1973c). These notes should help to explain some of the decisions made therein and elsewhere.

PART A. - MISCELLANEOUS ITEMS

Catenulopsora Mundkur, *Ann. Bot., Lond.* N.S. 7:216 (July (1943).

Cummins (1959) gives this genus as a synonym of *Cerotelium*. Thirumalachar (1960) denies Cummins synonymy and says it is a synonym of *Kuehneola*.

Part of the type specimen (HCIO 13035: *C. flacourtiae* on *Flacourtia sepiaria*, Thirumalachar, 28. x. 1940) was examined. It has erumpent open uredinia (not peridiate with central ostiole); the paraphyses are peripheral, brown, thick walled, irregular, basally septate and adherent; the urediniospores are pedicillate, brown, thin walled (pores not seen). The uredinia, though subepidermal, have a cellular basal layer so that the pedicels of

the urediniospores are borne above the epidermis. This cellular layer might be the start of telial formation but appears more likely to be an essential part of the uredinial structure. No telia were found.

Such a rust is most unlike the type species of *Kuehneola* which has non-paraphysate uredinia and urediniospores with hyaline walls. Some other species at present included in *Kuehneola* (e.g. *K. malvicola*) may be more similar but their own status is uncertain. On the other hand the uredinia of *Catenulopsora* agree fully with those of *Cerotelium* and related genera such as *Physopella* and *Phakopsora*. Until telia can be examined the taxonomic status of *Catenulopsora* cannot be resolved. A comprehensive study of *Kuehneola* species would also be desirable.

Coleopucciniella Hara ex Hirats., *J. Jap. Bot.* 13:245 (1937)

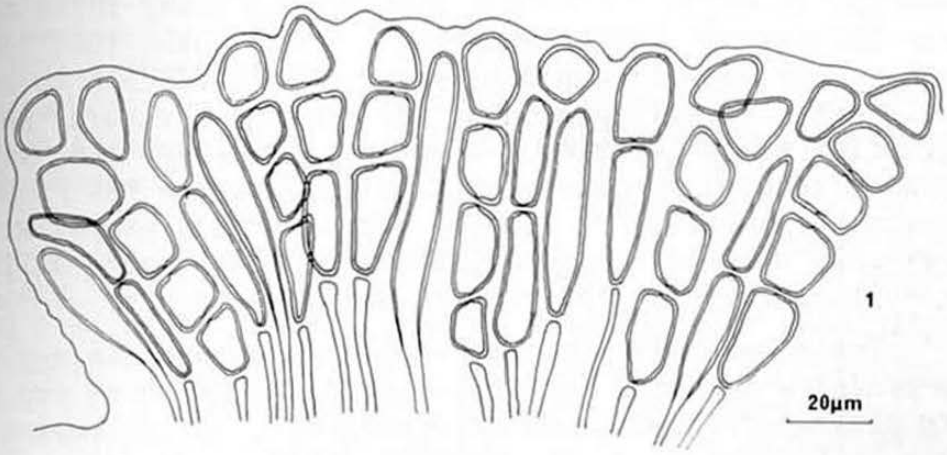
This genus was segregated from *Coleopuccinia* on the assumption that the teliospores of the type species were 1-celled. They had originally been described as 1-celled when the type species *Coleopuccinia simplex* Dietel was first described (*Annls mycol.* 7: 355, 1909), and were again treated as such when the genus *Coleopucciniella* was established. At this time there was still no mention as to how the teliospores were borne.

Later, Thirumalachar & Whitehead (1954) studied both *Coleopuccinia* and *Coleopucciniella* and stated that the two genera were very different. They said that the former had 2-celled teliospores borne on pedicels which early gelatinized and disappeared, whilst the latter had spores which were borne in chains (it appears they meant in basipetal succession).

Cummins (1959) accepted their interpretation of *Coleopuccinia* but apparently did not accept that of *Coleopucciniella* since he united the two genera, describing the teliospores as 1-2-celled and borne on pedicels.

Thirumalachar (1960) repeated the former claims of Thirumalachar & Whitehead (1954) and denied Cummins (1959) treatment of *Coleopucciniella*. To emphasize the point he claimed *Coleopucciniella* was identical with *Chrysomyxa* and made the combination *Chrysomyxa simplex* (Diet.) Thirum.

My own studies of *Coleopucciniella simplex*, and of *C. idei* Hirats. (*J. Jap. Bot.* 13:245, 1937), suggest a different structure from that of either Cummins or of Thirumalachar. My interpretation (Fig 1, 2) is that the telio-



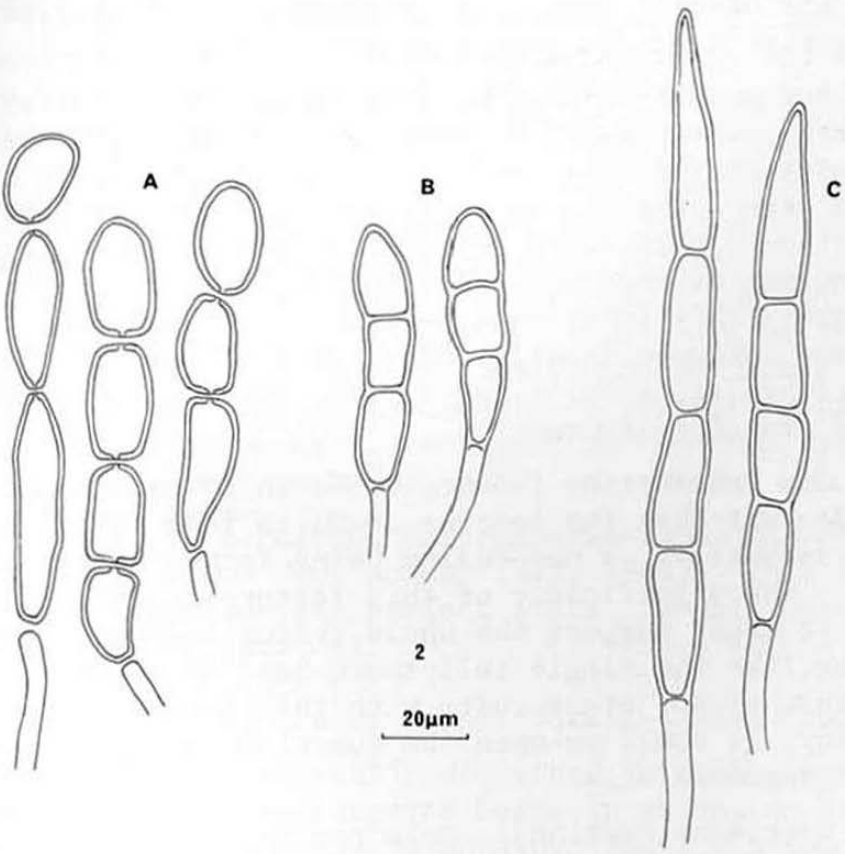


Fig. 1 *Coleopucciniella simplex*, section of part of a telium from specimen ex Herb. Hiratsuka.
Fig. 2 Teliospores of *Coleopucciniella simplex* (A) (ex Herb. Hiratsuka) compared with those of *Gymnosporangium biseptatum* (B) (ex PUR 9842) and *G. ellisii* (C) (ex PUR 10454)

spores are pedicellate phragmospores (as in *Kuehneola*) with 3-5 (or more?) cells. The cells are separate and disarranged in mature telia but sections of young telia clearly show the serial arrangement and I do not think this feature can be doubted. The pedicels are more difficult to see, their being tightly packed at the base of the sorus and agglutinated by gelatinous material. However they were seen in several specimens, most clearly so in PUR F12868; they are elongated (up to 80 μ) cylindric and narrow with very thin or gelatinized walls (narrow teliospore cells can be distinguished by their thick walls).

The general similarity between *Coleopuccinia* and *Coleopucciniella* has long led to the belief that these two genera are closely related. My interpretation is in keeping with this belief and also with Cummins (1959) suggestion that they are derived from *Gymnosporangium*, some species of which possess pedicellate phragmospores also (Fig 2).

But whether or not my interpretation of teliospore structure is correct, it seems very difficult to accept Thirumalachar's idea that *C. simplex* belongs with *Chrysomyxa:* the latter is so different, its species have non-gelatinous telia with teliospores always in a strictly catenulate arrangement and with very thin colourless walls. Moreover, they occur on a very different group of hosts whereas *Coleopucciniella* occurs on Rosaceae, the host predicted by Tranzschel's law if this microcyclic genus is derived from *Gymnosporangium*.

One interesting feature noted in my examination of *C. simplex* was that the species seems to form whole telia successionally: a new telium being formed beneath the old one. The significance of this feature is not apparent to me: it might suggest the whole telium is a unit structure rather like the single teliospore head in *Ravenelia*. I do not know of any other rusts with this feature but if there are any, it could re-open the question of the relationship of *Coleopucciniella*.

Specimens examined: *Coleopuccinia sinensis* (type of *Coleopuccinia*) PUR F1897, F1898; *Coleopucciniella simplex* PUR F12837, F12868, Herb. Hiratsuka, 4. xii. 1941; *C. idei* PUR F12864, F12866; *Gymnosporangium biseptatum* PUR 9837, 9842; *G. ellisii* PUR 10454, 51767.

Coleosporium campanulae (Strauss) Tulasne (not be be attributed to Cooke 1865, cf. Laundon, 1967a), *Ann. Sci. nat. Bot.*

IV 2:137 (1854), cited as "*Coleosporium campanulae* Lév. (*Uredo campanulae* Pers.)" However Léveillé (*Ann. Sci. nat. Bot.* III 8:373, 375, 1847) gives only "*U(redo) tremellosa* var. *campanulae* Strauss" (p. 373) and "*Uredo campanulae* DC." (p. 375). The former should be considered the basionym of Tulasne's name since it includes the perfect state (like Tulasne's name itself) whilst *U. campanulae* Pers. and *U. campanulae* DC. do not.

Coleosporium rhinanthacearum Tulasne (not to be attributed to Kickx 1867, cf. Laundon, 1967a), *Ann. Sci. nat. Bot.* IV 2:190 & pl.VIII (1854), cited as "*Coleosporium rhinanthacearum* Lév. (*Uredo melampyri* Rebent.)" on "*Melampyrum pratense* L." However Léveillé (*Ann. Sci. nat. Bot.* III 8: 373, 1847) gives only "*Uredo rhinanthacearum* DC." a name applying to the imperfect state whilst Tulasne includes the perfect state, the illustration (pl.VIII, Fig 11) showing teliospores, in accordance with Art. 44 and Art. 59, par. 4 (Stafleu, 1972) making Tulasne's use of the name validly published for a new taxon applying to the perfect state.

It will be noted however that the rust to which Tulasne's name refers is the *Melampyrum* rust, now generally known under the name *Coleosporium melampyri* (Rebent.) Karst. Moreover Tulasne's citation of *Uredo melampyri* Rebent. in synonymy, a name based on the perfect state and the basionym of *C. melampyri*, makes his name superfluous and therefore illegitimate (Art. 63). Accordingly *C. rhinanthacearum* falls into synonymy under *C. melampyri* and another name must be found for the rust on *Rhinanthus*.

Also should be mentioned "*Coleosporium rhinanthacearum* Dec." in Fries, *Summa Veg. Scand.* :512, 1849. This name, which does not include the perfect state, is not validly published (Art. 59, par. 4).

Desmotelium H. Sydow, *Annls. mycol.* 35:252 (-254) (1937).

Desmotelium was originally described as having subcuticular pycnia and teliospores borne in groups on basal cells. Later Thirumalachar & Mundkur (1949) claimed that the pycnia were subepidermal and suggested that the genus might have to be merged with *Chrysocelis* which has subepidermal pycnia.

Cummins (1959) gave *Desmotelium* as a synonym of *Chaconia* and gave the pycnia of *Chaconia* as subcuticular. Later Cummins (1960) made the combination *Chaconia coaetanea* (Syd.) Cumm. for the type species of *Desmotelium*.

Thirumalachar (1960) repeating the former claims of Thirumalachar & Mundkur (1949) made the combination *Chrysocelis coaetaneum* (Syd.) Thirum.

I examined part of the type specimen (IMI 43180) and found the pycnia to be subepidermal, but they are more or less flat and conical, belonging to type 5 of Hiratsuka & Cummins (1963). They are very different from type 4, possessed by *Chrysocelis*. The morphological similarity between type 5 and the subcuticular type 7 of *Chaconia* is more significant than the difference of position between those two types (see the first paragraph of the 'Discussion' in Hiratsuka & Cummins, 1963). *Desmotelium* should therefore be placed with *Chaconia* rather than with *Chrysocelis*.

Further support for this synonymy comes from the life cycle. *Desmotelium* is brachcyclic (with aecial uredinia and true uredinia) just like *Chaconia*, but *Chrysocelis* is demicyclic (with true aecia and no uredinia). Telial structure is a further characteristic for differentiating *Chaconia* and *Chrysocelis*. Unfortunately, from the material of *Desmotelium* available to me I was not able to determine the telial structure, but the original description gives the teliospores as borne in groups of 3-8 on a basal cell as in *Chaconia*.

Elateraecium Thirum., Kern & Patil, *Mycologia* 58:391-396 (28 June 1966).

Elateraecium was described for an unusual distinctive type of aecial state, with two species: *E. salicicola* Thirum., Kern & Patil (type) and *E. divinum* (Syd.) Thirum., Kern & Patil (=*Caeoma divinum* H. Syd., 1931). Almost simultaneously a similar rust was described under the name *Caeoma indicum* Rajendren (*Bull. Torrey Bot. Cl.* 93: 237-240, 23 Aug. 1966) and mention was made of another similar rust *C. callianthum* H. Syd., 1937.

My attempts to obtain specimens of *E. salicicola* from Herb IARI (where the material was said to be deposited), from Thirumalachar, and from Kern have all been unsuccessful. However I have obtained material of *C. divinum*, *C. callianthum* and *C. indicum*. Studies of these indicate there are probably only two distinctive species of *Elateraecium*. These are *E. salicicola* (=*C. indicum*) which forms systemic infections covering the undersides of the leaves, and sometimes also forming galls and witches' brooms, with prolific growth of elater hyphae which are very conspicuous and give a wooly appearance to the pustules, and with large elongated spores 30-80 x 10-20 µm (mostly 40-50 x 12-15 µm)

with coarsely ornamented walls; and *E. divinum* (=*C. callianthum*) which forms local infections on undersides of leaves only, with comparatively few elater hyphae not readily seen except in a slide mount so that the pustules appear powdery rather than wooly, and with comparatively short spores 20-50 x 8-18 µm (mostly 30-40 x 10-15 µm) with less coarsely ornamented walls.

This synonymy must be regarded as tentative. Recently Thirumalachar, Kern & Patil (1973) said they have found the uredinial and telial states of *E. salicicola* and accordingly intend to publish this under the new generic name *Hiratsukamyces* (*Elateraecium* must remain restricted to the aecial state).

Specimens examined: *C. divinum* Herb. S ex USDA 66754 (on *Salacia philippinensis*, Philippines, Clemens, 22 May 1923); *C. callianthum* IMI 43194a (isotype), 46419, 77559; *C. indicum* LEV 5118 ex MACS 265 (isotype on *Salacia* sp., Mysore, India, Rajendren, May 1964).

Gymnoconia Lagerheim, *Tromsø Mus. Aarsh.* 16:142 (1894).

Type species: *G. nitens* (Schw.) Kern & Thurston, *Bull. Penn. State Coll.* 239:16, (1929)
= *Aecidium nitens* Schw., *Schr. naturf. Ges Leipzig* 1:69 (1822) (cited by Lagerheim as "*C. nitens* Schwein.")
= *G. interstitialis* Lagerh. (as"(Schlechtd.) nob.") nom. illeg. (see below).

= *Kunkelia* Arthur, *Bot. Gaz.* 63:501-515 (1917).
Type species: *K. nitens* (Schw.) Arthur.
= *Aecidium nitens* Schw. (see above).

Previous treatments have given the type of *Gymnoconia* as *G. interstitialis* (Schl.) Lagerh. (sometimes referred to by its prior taxonomic synonym, *G. peckiana* (Howe) Trotter). However the basionym *Caeoma interstitialis* Schlecht., 1820, applies to the imperfect state because it is based on aecia from Kamchatka (U.S.S.R.) where only the long cycle form occurs (the short cycle (endo) form not having been recorded outside America except occasionally on imported plants). Therefore contrary to Lagerheim's treatment, this epithet is not eligible for transfer to *Gymnoconia*, a genus applying to the perfect state, and accordingly the author citation for *G. interstitialis* has to be corrected (Art. 59, par. 4).

G. interstitialis Lagerh. applies to the perfect state,

being placed in a genus characterized by the perfect state and including in synonymy other names applying to the perfect state, the earliest of which, *A. nitens*, provides the description validating *G. interstitialis* as the name of the perfect state.

A. nitens Schw. applies to the perfect state because it is based on telial aeciospores (which give rise to basidia, Art. 59) from N. Carolina (U.S.A.) far south of the range of the long cycle form. It is therefore eligible to replace *G. interstitialis*, and must do so because it was cited in synonymy by Lagerheim and has priority, both over *G. interstitialis* and over the other synonyms cited by Largerheim. Thus *G. interstitialis* is a superfluous illegitimate name (Art. 63).

The corrected typification of *Gymnoconia* means that it has the same type as *Kunkelia* and therefore that these two genera are obligatory synonyms (typonyms). Previously they have often been segregated, *Gymnoconia* for a long cycle (demicyclic) rust, and *Kunkelia*, for a short cycle (endocyclic) form of the same species. This artificial segregation has been considered not necessary by some authors (e.g. Laundon 1967b) who have treated the two genera as taxonomic synonyms, but those who wish to maintain the segregation will now need to apply *Gymnoconia* to the short cycle form previously known as *Kunkelia*, a new generic name will be required for the long cycle form and it will also be necessary to find or create a species name for the latter.

Gymnosporangium sabinae [Dicks.] Winter, *Hedwigia* 19:55 (1880).

≡ *Tremella sabinae* Dicks., *Pl. Crypt. Brit.* 1:14 (1785).

= *G. fuscum* DC., *Fl. fr.* 2:217 (1805) nom. illeg.

The name *G. fuscum* (recently being used for this species) was nomenclaturally superfluous when published as it included *Puccinia juniperi* Pers., 1801, in synonymy; therefore it is illegitimate (Art. 63). At that time the epithet *juniperi* could have legitimately replaced it; since 1825, however, the combination of this epithet with *Gymnosporangium* would itself be illegitimate owing to the earlier name *G. juniperi* Link, 1825, which applies to a different species. This suggests the possibility that the legitimacy of *G. fuscum* should be restored; however there appears to be no provision for this in the present Code. A possible solution would be to amend the Code to make this provision

by adding to the end of Art. 63 the following:

'A name is not illegitimate even if it was nomenclaturally superfluous when published, if the name which should replace it would itself be illegitimate.'

However it is doubtful if this solution could be regarded as satisfactory since it would mean that the legitimacy of the epithet could depend on the genus in which it was being placed. For example, in the case of *G. fuscum*, if the epithet *fuscum* were transferred to another genus where an earlier homonym equivalent to *G. juniperi* Link, 1825 did not exist, then it could not be regarded as legitimate since the epithet *juniperi* Pers. would be eligible to replace it.

As no other satisfactory solution appears possible, this species must be known by the next available name, which appears to be *G. sabinae*.

Hapalophragmiopsis Thirum., *Mycologia* 42:227 (1950)

This genus was established as a segregate of *Hapalophragmium* H. & P. Sydow, 1901, on the basis of its subepidermal pycnia (the type species of *Hapalophragmium* has subcuticular pycnia). Further it was implied that its gall-forming characteristic might be an additional distinctive feature.

Cummins (1959) placed the two genera in synonymy, describing the pycnia as "subcuticular or rarely subepidermal but always with conical form and flat basal hymenium." Subsequently Thirumalachar (1960) insisted that the two genera be separated on the basis of pycnial position.

Hiratsuka & Cummins (1963) listed six species of *Hapalophragmium*, including the type of *Hapalophragmiopsis*, giving two species (*ponderosum* Syd. & Butl., and *millettiae* Syd.) as having subepidermal pycnia, and four (*derridis* Syd., *mysorense* Thirum., *ornatum* Cumm., and *setulosum* Pat.) as having subcuticular pycnia (type 5 and 7 respectively on p. 496; type 9 and 11 respectively on p. 502!). They suggested that the different pycnial types appeared to be associated with different pedicel and teliospore structure: that those with subepidermal pycnia appeared to have pedicels which are septate apically and with an extension up to the upper cell, whilst those with subcuticular pycnia appeared to have pedicels non-septate and with no extension. Thus although the pycnial structure is basically the same in the two genera, a feature considered more important than

the difference in position of the pycnia - and therefore suggesting the two genera be united, the suggested correlation with teliospore structure may well justify separation of the two. Hiratsuka & Cummins did not comment on this point but if this were done, it would be necessary to examine the features of *H. pulchrum*, the type of *Triactella* which if found to have the same features as the type of *Hapalophragmiopsis* would have priority over it.

It may be noted that Thirumalachar's suggestion that the gall forming character might be characteristic of *Hapalophragmiopsis* now seems unlikely, since *H. millettiae* which is placed in the *Hapalophragmiopsis* group by Hiratsuka & Cummins (1963) does not form galls.

Kernkampella Rajendren, *Mycologia* 62:837-843 (1970)

I have investigated the taxonomic status of this genus, segregated from *Ravenelia* Berk., by examination of specimens where suitable ones were available, or failing that, checking the original descriptions. At the outset it should be said that I have not attempted a comprehensive study of *Ravenelia* but I have sought species which might be similar to *Kernkampella* and I have investigated all the species of *Ravenelia* occurring on Euphorbiaceae, the host family of *Kernkampella*.

The results of this investigation are that in my opinion *Kernkampella* is a clearly distinctive genus and that all the species of *Ravenelia* recorded on Euphorbiaceae, except one, should be placed in it. Below I give the necessary new combinations, together with comments and illustrations.

1. *Kernkampella appendiculata* (Lagerh. & Dietel) Laundon, comb. nov. (basionym : *Ravenelia appendiculata* Lagerh. & Dietel, *Hedwigia* 33:65, 1894). Fig 3 is based on Herb. S specimen on *Phyllanthus*, Guatemala, Holway 127, 27 Jan. 1915.

2. *K. brevispora* (Hirats. & Hash.) Laundon, comb. nov. (basionym : *R. brevispora* Hirats. & Hash., *Bot. Mag., Tokyo* 49:522(523), 1935). No specimens seen but the description states that the teliospores are like those of *R. appendiculata*.

3. *K. breyniae* (Syd.) Rajendren (*Mycologia* 62:839, 1970) Fig. 4 is based on IMI 58945.

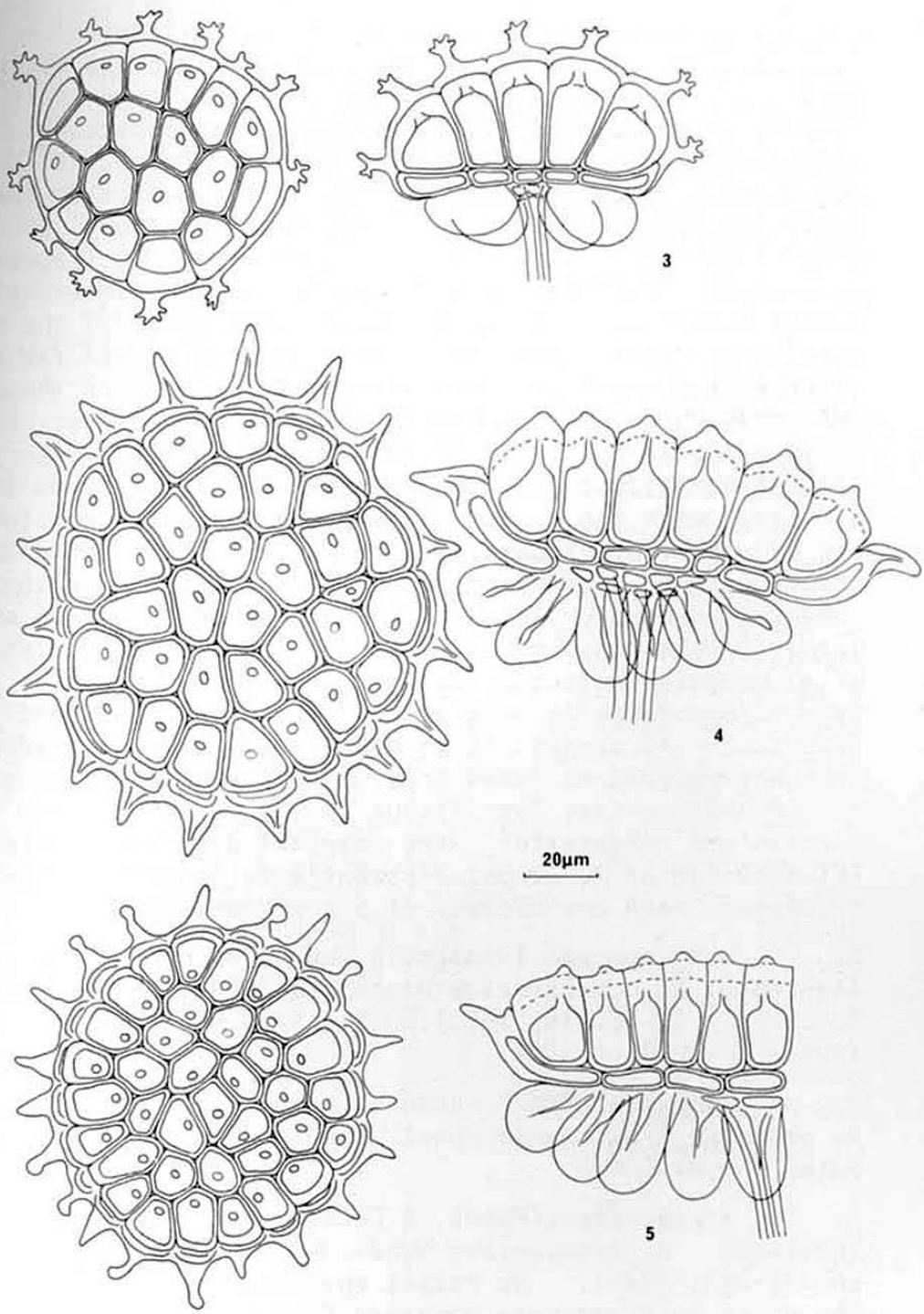


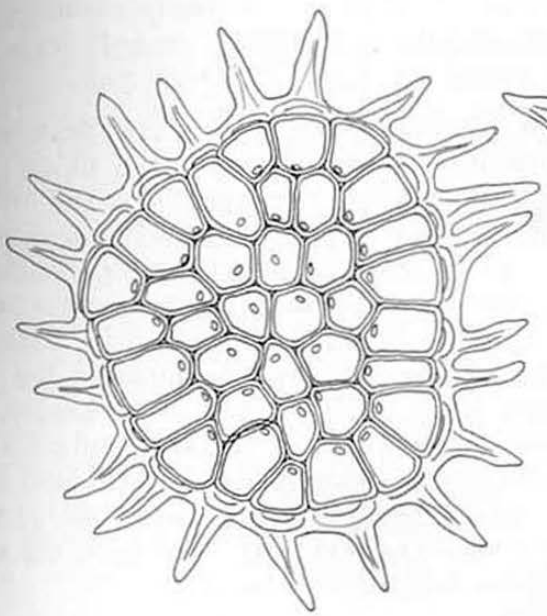
Fig. 3 *Kernkampella appendiculata* teliospore heads.
Fig. 4 *Kernkampella breyniae* teliospore heads.
Fig. 5 *Kernkampella coimbatorica* teliospore heads.

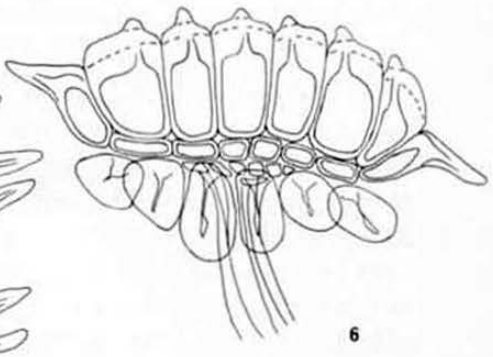
4. *K. breyniae-patentis* (Mundk. & Thirum.) Rajendren (*Mycologia* 62:839, 1970). The type specimen was obtained from Herb. IMI but no teliospores could be found on it, however J. Walker loaned a slide with one teliospore which he had previously obtained from the type specimen from IMI, and another slide showing numerous teliospores from IMI 58496 (ex Sydow, Fungi exotici exs. 223, *R. breyniae* on *Breynia patens*, Ceylon, 1913, ?= misdet. for *R. breyniae-patentis*). The teliospore from the type specimen was rather distorted but clearly agreed with those of the other species of *Kernkampella* which were studied, in so far as a surface view could provide; the same is true of those from IMI 58496 which were in better condition. However, as pointed out by Tyagi (1974) it is clear that the material studied and illustrated by Rajendren under this name does not agree with the type. It appears Rajendren's material may belong to *R. kirganellae* (the only species known to occur in India with branched projections on the teliospores like those shown by Rajendren) although the hosts do not agree. This misidentification does not affect the status of *K. breyniae-patentis*, and although this species is the type of *Kernkampella*, the status of that genus is not affected. At present it is not clear whether the genus must be regarded as based on *K. breyniae-patentis* or on *R. kirganellae* (see Part B) but in any case these two species are congeneric: the original description and illustration of *R. breyniae-patentis* together with the one teliospore seen are clearly of a *Kernkampella*.

5. *K. coimbatorica* (Ramakr. & Sund.) Laundon, comb. nov. (basionym: *R. coimbatorica* Ramakr. & Sund., *Proc. Indian. Acad. Sci.* B. 35:119, 1952). Fig 5 is based on IARI 19817 (type).

6. *K. emblicae* (Syd.) Laundon, comb. nov. (basionym: *R. emblicae* Syd., *Annls mycol.* 4:438, 1906). Fig 6 is based on IMI 76063.

7. *K. kirganellae* (Mundk. & Thirum.) Laundon, comb. nov. (basionym: *R. kirganellae* Mundk. & Thirum., *Mycol. Pap.* 16:22(-24), 1946). No telial specimens seen (the type and one other specimen were obtained from Herb IARI but no teliospores could be found), however the original description and illustration are clearly of a *Kernkampella*; moreover this may well be the species which Rajendren studied as the type of *Kernkampella* (see under *K. breyniae-patentis*, above.)





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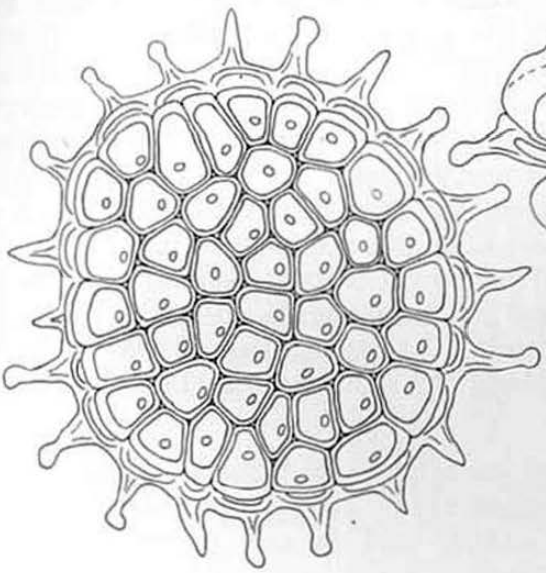

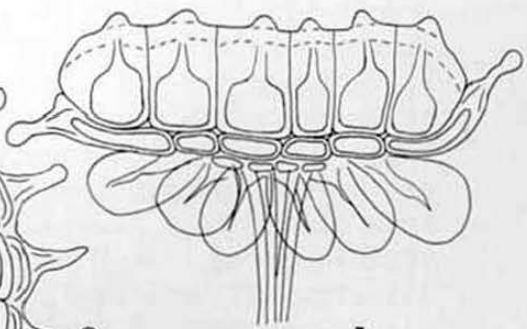

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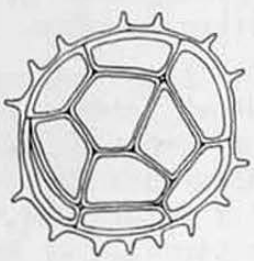

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Fig. 6 *Kernkampella emblicae* teliospore heads.
Fig. 7 *Kernkampella phyllanthi* teliospore heads.
Fig. 8 *Ravenelia pygmaea* teliospore heads.

8. *K. phyllanthi* (Mundk. & Thirum,) Laundon, comb. nov. (basionym *R. phyllanthi* Mundk. & Thirum., *Mycol. Pap.* 16: 24, 1946). Fig 7 is based on IARI 10241 (type).

For the purpose of identification the key feature of *Kernkampella* appears to be the presence of the so-called 'epipatella' layer between the teliospores and the hygroscopic cysts. The peripheral epipatella cells are particularly characteristic, elongated in shape and extending a little beyond the margins of the spore head; they have no pores (unlike the teliospore cells) and each one bears a single pointed or branched process at the outer edge, thus providing the teliospore head with a ring of ornamentation. Two features appear to provide rapid recognition of *Kernkampella*, one is the ring of ornamentation with only one projection to each marginal (epipatella) cell, as already mentioned, the other is the presence of a single conspicuous pore for each of the teliospore cells.

Ravenelia sensu stricto has teliospore heads with no epipatella layer and the hygroscopic cysts are joined directly to the teliospores. The central teliospores may be 2-celled but the lower cells are clearly teliospore cells and could not be confused with the epipatella. In those species which have ornamented teliospore heads there are several projections to each marginal cell. I do not know of any true *Ravenelia* species whose teliospores have visible pores. For comparison two *Ravenelia* species are illustrated: the type, *R. epiphylla* (Schw.) Diet. (=*R. glandulosa* Berk. & Curt.) based on IMI 92496 (Fig. 9), and an 'ornamented' species, *R. ornata* Syd. based on IMI 76065 (Fig 10).

I have satisfied myself that *Kernkampella* is quite distinct from *Nothoravenelia* Dietel by examination of *N. commiphorae* (IMI 42558) and do not intend to comment further on this.

There remains one species of *Ravenelia* recorded on Euphorbiaceae which apparently is not a *Kernkampella*. This is *R. pygmaea* Lagerh. & Dietel. However very few teliospores were seen and the structure could not be satisfactorily determined. The teliospores (Fig. 8) differed from *Kernkampella* in having numerous projections for each marginal cell and no visible pores for the teliospore cells. As this species is apparently known only from the type collection and it is the only one recorded on Euphorbiaceae which is not a *Kernkampella*, one wonders if the host has been misidentified. In this connection it is interesting

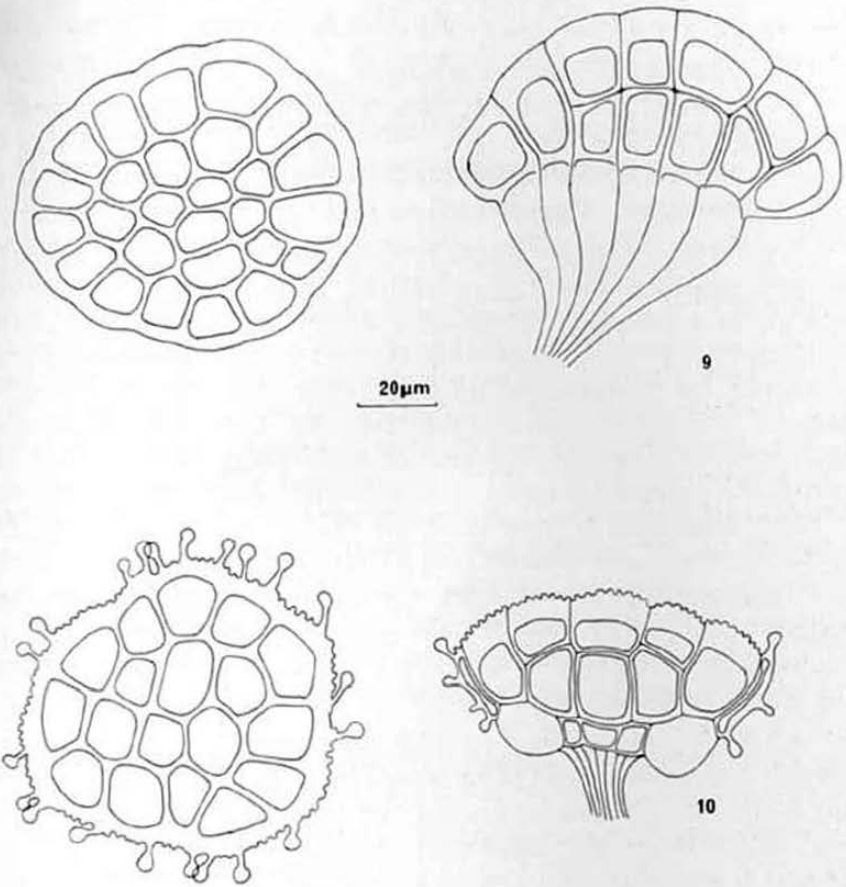

Fig. 9 *Ravenelia epiphylla* teliospore heads.
Fig. 10 *Ravenelia ornata* teliospore heads.

to note that one of the type packets in Herb. S bears the name *Cassia* deleted, suggesting uncertainty about the identity of the host.

Tranzschelia discolor (Fuckel) Tranz. & Litv., *Bot. Zh. SSSR* 24:248 (247-253) (1939).

≡ *Puccinia discolor* Fuckel, *Fungi rhenani exs*. 2121 (1867)
≡ *Puccinia pruni-spinosae* (Pers.) Dietel f. *discolor* (Fuckel) Fischer, *Beitr. krypt. - Fl. Schweiz* 2(2): 157-159 (1904).
≡ *Tranzschelia pruni-spinosae* var. *discolor* (Fuckel) Dunegan, *Phytopath.* 28:424 (411-427) (1938).

P. discolor is validly published since a description is included on the label of the exsiccatum. However both Winter and Dunegan (Dunegan, 1938) have pointed out that the material in packets of Fuckel's exsiccatum of *P. discolor* is of *Tranzschelia pruni-spinosae* (var. *pruni-spinosae*). Dunegan concluded that *P. discolor* could not be the basionym of the subsequent combinations and proposed instead *P. pruni-spinosae* f. *discolor* Fischer as a substitute. I also examined a specimen of Fuckel's exsiccatum from Herb. K. with the same result as Winter and Dunegan. However a different solution to the one Dunegan adopted has been suggested by D.M. Henderson (pers. comm.) and later found to be also suggested by Tranzschel & Litvinov (1939). This solution is as follows:

It is clear that Fuckel described *P. discolor* with the intention of recognizing a species distinct from *P. pruni-spinosae*. As the material in the packets of Fungi rhenani exs. 2121 does not agree with the description on the label of this exsiccatum, then it must be that an error was made in preparing the specimens and the type material of *P. discolor* was mislaid elsewhere. Thus the material in 2121 should not be regarded as the type material.

Tranzschel and Litvinov make the same point (translated from p. 247, last paragraph): "In 1869 Fuckel described and published from his exsiccatum of Fungi Rhenani under the number 2121 (with diagnosis) a new species, *Puccinia discolor*[2], distinguishing it from *Puccinia prunorum* (*Tranzschelia pruni-spinosae*) ..."; (and p. 247 footnote:) "[2] Dunegan (1938) points out that under no 2121 in Fungi Rhenani the samples do not correspond to the description of *Puccinia discolor*. It was the same with the sample of Fuckel's exsiccatum in the Botanical Institute of the Academy of Sciences of the USSR but here there was a handwritten note with leaves of *Prunus spinosa* which reads: "This is to be attached to 330 II, the one of *Puccinia instititia* to no 221"; and in fact under no 330 there were two leaves of *Prunus instititia* with *Puccinia discolor*" (presumably "*Puccinia instititia*" is an error for

Prunus instititia and "221" is an error for 2121).

In view of this I checked the specimen of 330 in Herb. K.; however it contained only *T. pruni-spinosae* (var. *pruni-spinosae*). Despite this it does seem quite reasonable to regard the type material as mislocated so that the status of *P. discolor* as basionym is not affected.

Regarding the status of the other *discolor* combinations: (1) Tranzschel & Litvinov clearly base their combination on *P. discolor* Fuckel: "*Tranzschelia discolor* (Fuckel) n. comb." and they cite the basionym, *P. discolor* Fuckel, and its place of publication. (2) Fischer gives his combination without any author citation and without explicitly indicating the basionym; however *P. discolor* Fuckel is given as a synonym and there is no reason to doubt it was intended as the basionym. (3) Dunegan rejected *P. discolor* Fuckel as basionym and instead gave "*T. pruni-spinosae* forma *discolor* Fischer" (presumably "*T*" is an error for *P*); however since Dunegan's rejection of *P. discolor* was unnecessary and since f. *discolor* was itself based on Fuckel's name, it seems commonsense to regard Dunegan's combination as based on Fuckel's name.

Uromyces fallens (Arthur) Barth., *Handb. N. Amer. Ured.* :61 (1928) (as "(Desm.) Kern").

≡ *Nigredo fallens* Arthur, *N. Amer. Fl.* 7:254 (1912) (as "(Desmaz.) Arthur").
≡ *Uromyces trifolii* var. *fallens* (Arthur) Arthur, *Rusts U.S. Canada* :305 (1934) (as "(Desm.) n. comb.")
= *Uredo fallens* Desm., *Pl. Crypt. Fr.* no. 1325 (1843).
≡ *Uromyces fallens* (Desm.) Kern. *Phytopathology* 1:6 (1911) not validly published.

A specimen of Desmazieres *Pl. Crypt. Fr.* 1325, *Uredo fallens* from Herb. K. was examined. Some teliospores are present but were apparently not seen and described by Desmazieres so that the name is to be regarded as uredinial. Concerning the identity of the specimen, both the urediniospores and teliospores agree with the modern concept of this species; the urediniospores with 4-5 pores (average 4.2) of which 73% are in the equatorial position (compare Laundon 1973a); the host agrees with *Trifolium pratense*.

The name *Uromyces fallens* (Desm.) Kern is not validly published because Kern did not describe the telia or teliospores (Art. 59, par. 4). Thus the epithet *fallens* is not preoccupied in *Uromyces* and the later name *U. fallens* (Arthur) Barth. is not affected.

Nigredo fallens is to be considered the basionym for the perfect state since it constitutes the first description of telia. Bartholomew appears to be the first author to include telia under the *Uromyces* combination (he cited *N. fallens* in synonymy), therefore that combination must be attributed to him. Similarly Arthur's variety *fallens* includes telia and *N. fallens*, cited in synonymy by Arthur, must be regarded as the basionym.

Guyot's rejection (1957) of the name *Uromyces fallens* in favour of *U. trifolii* is incorrect. Guyot regarded *Uromyces fallens* as based on *Uredo fallens*, which as shown here it is not; furthermore his assumption that the identity of *Uredo fallens* is no more definite than that of *Uromyces trifolii* is incorrect, as also shown here and pointed out by Kern (1911), i.e. the material of *Uredo fallens* is available for study and readily confirmed to agree with the modern concept of the species. The case against the use of the name *U. trifolii* for this species is given below.

Uromyces nerviphilus (Grognot) Hotson, *Publ. Puget Sound Biol. Stat.* 4:368 (1925).

≡ *Puccinia nerviphila* Grognot, *Pl. Crypt. Saone-et-Loire* :154 (1863).
= *U. flectens* Lagerh., *Sv. Bot. Tidskr.* 3:36 (1909).

The name *U. nerviphilus* has been the subject of some confusion and error. A few early authors (e.g. Sydow, 1910; Grove, 1913) were apparently too uncertain of its identity and used instead the name *U. flectens*. Apparently Arthur (1921) was the first to reintroduce the name, as *Pucciniola nerviphila*. Here the confusion started since Arthur gave the species as a demicyclic one although Grognot had described only telia (Wilson & Henderson, 1966; Jørstad, 1967). Cunningham (1931) and Gaumann (1959) followed Arthur in ascribing aecia to the species but Cunningham stated that he had found only telia and Gaumann gave both a demicyclic species (*U. nerviphilus*) and a microcyclic one (*U. flectens*). Others (e.g. Tranzschel, 1939; Wilson & Henderson, 1966; Jørstad, 1967) have pointed out the error of treating *U. nerviphilus* as demicyclic whilst Guyot (1957) considered the name too uncertain to be used.

The investigations of Jørstad (1967) have indicated that when aecia have been attributed to *U. nerviphilus* this has been because of misidentification of *U. trifolii*-

repentis with suppressed uredinia or of mixed infections of aecia of *U. trifolii-repentis* with microcyclic telia of *U. nerviphilus*. Jørstad concluded that the latter name had to be rejected as a nomen confusum (Art. 69); however I feel this is not necessarily so: it appears to me that both of the examples under Art. 69 are cases where the confusion has been much more serious than for *U. nerviphilus*. Thus this name has been (a) correctly applied to microcyclic telia, (b) correctly applied to telia but with aecia of another species included, (c) incorrectly applied to aecia and telia of another species in an abnormal state, which however is well known by its correct name in its normal state. This is not a case where two distinctive species have been confused, both are correctly known under their respective names, but rather certain abnormal *specimens* have been confused and have led to wrong *descriptions* being given to the species. Moreover it appears the confusion can easily be cleared up since in spite of the apparent non-availability of the type material and the claim of at least one recent author (Guyot 1957) to reject the name as a nomen dubium, there really does seem to be very little doubt about the identity of the species.

It may be worth mentioning that although Jørstad and others use the name *U. flectens* in preference to *U. nerviphilus*, that name (*U. flectens*) was equally confused by Arthur (1921, 1934) and others (e.g. Cunningham 1931) who treated it as a synonym under their demicyclic concept of *U. nerviphilus*. True, by now, *U. flectens* may be less confused than *U. nerviphilus* but perhaps this indicates how easily confusion can be eliminated without the need to resort to Art. 69.

There are two other species in a similar situation to *U. nerviphilus*, these are *U. affinis* Winter and *U. iresines* Lagerh. ex Syd. to which uredinia have been wrongly ascribed. I did not think it necessary to propose new names for these two species (Laundon, 1965b). Probably there are still other species in like situations which other authors have dealt with similarly.

Uromyces trifolii (Hedw. ex DC.) Fuckel, *Symb. Myc.* :63 (1870).

≡ *Puccinia trifolii* Hedw. ex DC. *Fl. fr.* 2:225 (1805).
≡ *Uredo trifolii* (Hedw. ex DC.) DC. in Lamark & Poiret, *Encycl. Meth. Bot.* 8:223 (1808), and in *Fl. fr.* 6:66 (1815).

Three hosts were included under *Puccinia trifolii* Hedw. ex DC. These were *Trifolium repens*, *T. filiforme* and *T. hybridum*. As pointed out by Jørstad (1958) these three hosts are now known to carry various rust species. *T. repens* is host, principally of *Uromyces nerviphilus* and *U. trifolii-repentis* Liro, but also possibly of *U. anthyllidis* Schroet. and *U. striatus* Schroet. (Guyot, 1957). *T. filiforme* (= *T. micranthum*) is host, principally of *U. anthyllidis* and *U. striatus* (Guyot, 1957) but also of *U. minor* Schroet. (Laundon 1973b). *T. hybridum* is host of *U. trifolii-repentis* (although *U. fallens* has also been recorded on this host there is considerable doubt as to the accuracy of these reports, see Laundon 1973a). In an attempt to determine which species were included under *P.trifolii*, J. Walker (pers. comm.) requested De Candolle's material from Herb. G. He received three sheets which might be expected to correspond to the three hosts concerned. However there is nothing to indicate this and it appears that all of them are in fact *T. repens*; certainly none are *T. filiforme* or *T. hybridum*. Only one rust species was present, this being *U. nerviphilus*. Although a further request was made to Herb. G., in the hope that material of the other hosts could be obtained, none was forthcoming.

My conclusions are as follows: (i) the type material is almost certainly heterogenous and one cannot apply Recommendation 7B to the name; thus it is to be rejected under Art. 70. In regard to this conclusion I see no reason to accept the views of Arthur (1912) and Jørstad (1958) that the first listed host, *T. repens*, must be considered to be the type host. (ii) It appears likely that the name has persistantly been used in a different sense (for *U. fallens*, e.g. Sydow, 1909; Grove, 1913; Cunningham, 1931; Wilson & Bisby, 1954; Gaumann, 1959) from that of any of the original material; also it has sometimes been used in other different senses (e.g. for *U. trifolii-repentis*, Kern, 1911; Wilson & Henderson, 1966), thus it has become a long persistant source of error and is to be rejected under Art. 69.

Concerning the author citation for this species and its nomenclatural history, though the combination *U. trifolii* is often ascribed to Léveillé 1847 it was not made by him (cf. Laundon 1967a) but rather was first made by Fuckel (Deighton, pers. comm.). Fuckel gave the basionym as *Uredo trifolii* DC., 1815, but this in turn refers to *Uredo trifolii* in Lamark and Poiret, 1808, and to *P. trifolii*

Hedw., ex DC. 1805. Thus the latter must be regarded as the primary basionym.

PART B. - GENERA DESCRIBED FOR A SPECIES DIFFERENT FROM THAT GIVEN AS THE TYPE SPECIES

Conflicting views have been put forward in regard to the typification of generic names which were described for species different (or possibly different) from those designated as the type, i.e. the species name designated was (or may have been) misapplied (incorrect). On the one hand we have the view that a genus is to be based on the species for which it was described although this species may, at the time, be anonymous (not yet named) (Donk, 1952; Furtado, 1964; Bullock & Hunt, 1966; Bullock, 1966). On the other hand there is the view that a genus is to be based on the type species name designated (Rogers, 1944; Moore, 1966; Weresub, 1967). These views culminated in two proposals (Art. 10, prop, A & C., Stafleu & Voss, 1969) to amend the Code but subsequently no action was taken as it was felt the solution of the problem was not clear and it was decided to postpone a decision until 1975.

In the past I have inclined to the view that a genus is naturally typified by the species which was described ('described' typification). However more recently I have appreciated how seriously this contravenes the type method - one of the most basic tenets of the Code - by throwing into uncertainty the typification of many generic names. Thus I am presently of the opinion that this cannot be permitted and that the 'designated' typification should be upheld. Below I draw attention to a number of rust genera in which this situation occurs and show the consequences of the designated typification. Some of the rust genera given here are of special interest because their situation differs slightly from that in other genera; they involve a genus described for one state being designated with a type based on another state. Thus the typification affects the state to which they apply (perfect or imperfect) rather than (sometimes as well as) their taxonomic status. In addition there are sometimes some other complications.

Argotelium Arthur, *Result. sci. Congr. internat. Bot. Vienne* 1905: 343 (1906).

Designated type "*Uredo hyptidis* Curt." *Amer. J. Sci.* II 6:353 (1848).

Described type: *Argomyces parilis* Arthur, *N. Amer. Flora* 7:217 (1912).

≡ *Puccinia parilis* (Arthur) Arthur, *Amer. J. Bot.* 5:484 (1918).

The typification of *Argotelium*, which included a description of the perfect state (teliospores) is complicated by the type species name being misapplied in two ways. Not only was an imperfect state (uredinial) name misapplied to its type species but also a different species name from the one intended. By designated typification *Argotelium* applies to the uredinial state: *Uredo hyptidis*. This was the approach taken by Arthur (1912a) himself and he therefore proposed the genus *Argomyces* based on *A. parilis* for the concept he originally intended for *Argotelium*. Neither *Argotelium* nor *Argomyces* is in use today, both being treated an synonyms of *Puccinia*.

The nomenclature of the type species is somewhat involved. The name "*Puccinia hyptidis* (Curt.) Tracy & Earle" (*Bull. Miss. Exp. Sta.* 34:86, 1895) must be regarded as a new name based on telia of *P. gibertii* Speg. which was the only telial material included (Art 59, par. 4). Therefore it is to be cited as *P. hyptidis* Tracy & Earle and relegated to the status of an illegitimate synonym of *P. gibertii* (Art. 63) which is now considered to be different species from that of *Uredo hyptidis* (Baxter, 1961). But despite being illegitimate it is validly published and has to be taken into consideration in regard to later homonyms (Art. 64). Thus the perfect state of *Uredo hyptidis* now regarded as a *Puccinia* species has to be given a new name and I propose *P. neohyptidis* Laundon, nom nov., based on *Gymnoconia hyptidis* Lagerheim (*Tromsø Mus. Aarsh.* 17:83, 1895) which constitutes the first description of the perfect state. The name *Agrotelium hyptidis* is presumably in the same position as *P. hyptidis* since the latter name was given in synonymy by Arthur: thus it should be cited *A. hyptidis* (Tracy & Earle) Arthur and is to be relegated to the status of an illegitimate synonym of *P. gibertii*.

Coleosporium Léveillé, *Ann. Sci. nat. Bot.* III 8:373 (1847).

Designated lectotype: "*Uredo rhinanthacearum* DC." in Lamark & Poiret, *Encycl. Meth. Bot.* 8:229 (1808). New lectotype: *Uredo tremellosa* var. *campanulae* Strauss, *Ann. Wetter. Ges.* 2:90 (1810).

≡ *C. campanulae* (Strauss) Tulasne, *Ann. Sci. nat. Bot.* IV 2:137 (1854).

The genus *Coleosporium* which included a description of the perfect state (telia) had an imperfect state name misapplied to its lectotype species chosen by Arthur (1906) and accepted by subsequent authors (e.g. Laundon, 1965a). In this case the problem can be solved by choosing a new lectotype and I propose *Uredo tremellosa* var. *campanulae* which from its description is clearly telial despite its *Uredo* name.

Frommea Arthur, *Bull. Torrey Bot. Cl.* 44:503 (501-511) (1917).

Designated type: *Uredo obtusa* Strauss, *Ann. Wetter. Ges.* 2:107 (1810) (see note 1, below).
≡ *Puccinia potentillae* Persoon, *Syn. Meth. Fung.* :229 (1801) (see note 2, below).
≡ *Phragmidium potentillae* (Persoon) Greville, *Scot. Crypt. Fl., Syn.* :3 (1828?) (see note 3, below).
≡ *F. obtusa* (Strauss) Arthur (see note 4, below).
Described type: *Phragmidium tormentillae* Fuckel, *Symb. Myc.* :46 (47) (1870) (see note 5, below).

Numerous early authors confused two species which are now regarded as clearly distinctive and which are generally known under the names *Frommea obtusa* and *Phragmidium potentillae*. Unfortunately both of these names, now shown to be based on *Puccinia potentillae*, are obligatory synonyms. Thus by designated typification *Frommea* becomes a taxonomic synonym of *Phragmidium* and a new generic name is required for Arthur's concept of *Frommea* to be based probably on *Phragmidium tormentillae*. Alternatively, by described typification, *Frommea* would be retained distinct from *Phragmidium* with its type replaced by *P. tormentillae*.

Note 1: Like most other authors of his time Strauss confused the two species since he gave their two hosts: *Potentilla argentea* (host only of *Phragmidium potentillae*) and *Tormentilla erecta* (= *Potentilla erecta*) (host only of *Phragmidium tormentillae*). However since Strauss cited *Puccinia potentillae* Persoon in synonymy his name is typified by this (but is not superfluous owing to the prior names *Uredo potentillae* Schum. 1803, and *U. potentillae* DC. 1805, with different types). Why Arthur should have chosen such a name for the type of *Frommea* is a mystery; perhaps he thought that Strauss saw only material of *T. erecta* and that therefore the name could be restricted to that rust only, but, even if this is his reasoning, such a view cannot be upheld.

Note 2: The identity of *Puccinia potentillae* is precise since it includes only one host, *Potentilla argentea*, and the pustules are described as 'nigra', the correct deep black colour for this host (those of *Phragmidium tormentillae* are distinctly paler: chestnut or umber brown).

Note 3: Karsten (*Bidr. Kanned. Finl. Nat. Folk.* 31:49 (1879) is the author usually given as responsible for making the combination *Phragmidium potentillae*, but there were at least two earlier authors of which Greville appears to be the first. Greville's 'Synopsis' which gives this combination, appears to be a summation with revision of his views on the genera in his 'Cryptogamic Flora' (Henderson, pers. comm.). Under *Phragmidium potentillae* he gives the name *Puccinia potentillae* and refers to 'I. Tab. 57' of the Flora (Vol. 1, 1823) where *Puccinia potentillae* is dealt with in more detail. Here the basionym is given: '*Puccinia potentillae* Pers., Syn. Fung. p. 229' together with *Uredo obtusa* Str. There is no doubt that, just like Strauss, Greville confused the two rust species but this does not affect the legitimacy and validity of his *Phragmidium* combination.

Note 4: The combination *F. obtusa* is apparently not illegitimate even though the prior synonymous epithet *potentillae* Pers. should have been used (see the last two paragraphs of Art. 63).

Note 5: Fuckel is apparently the first author to clearly distinguish between the two rust species and he applied the names '*P.(hragmidium) obtusum* Tul.' (see note 6, below) and '*P. tormentillae* Fckl.' to them, with hosts, respectively, *Potentilla argentea* and *P. tormentilla* (= *P. erecta*). Unfortunately he confuses the situation by citing *Ph. potentillae* Cd.' under *P. tormentillae*. Hopefully however, the citation of this name can be regarded either as an error or else intended only to include that part of Corda's 'species' on *T. erecta*. The exsiccatum cited by Fuckel (F. rhen. 2227) is the type material of *P. tormentillae*, and a sample of this obtained on loan from Herb. G. agrees with the species hitherto known as *F. obtusa*.

Note 6: Tulasne (*Ann. Sci. nat. Bot.* IV 2:148, 1854) is not responsible for the combination *Phragmidium obtusum* and the credit for this should apparently (as cited by Tulasne) go to Schmidt & Kunze (*Deutsch. Schwämme* 5:5, 1816 - this publication not cited by Tulasne). Note that Fuckel uses the epithet '*obtusum*' in the contrary sense to that to which the name *Frommea obtusa* has been applied. Since the

combination *P. obtusum* is based on *Uredo obtusa* Strauss, it is an obligatory synonym of *P. potentillae* but like *F. obtusa is* not illegitimate (see note 4).

Kernkampella Rajendren, *Mycologia* 62:837-843 (1970)

Designated type: *K. breyniae-patentis* (Mundk. & Thirum.) Rajendren.
≡ *Ravenelia breyniae-patentis* Mundk. & Thirum., *Mycol. Pap.* 16:21 (22) (1946)
Described type: *?R. kirganellae* Mundk. & Thirum., *Mycol. Pap.* 16:22 (-24) (1946).

In regard to the misapplication of the type species name, see above, the taxonomic account of *Kernkampella*.

Physopella Arthur, *Result. sci. Congr. internat. Bot. Vienne 1905*:338 (1906).

Designated type: *"Uredo vitis* Thuem." *Pilze des Weinstockes*: 182 (1878).
Described type: *Phakopsora vitis* Sydow, *Hedwigia (Biebl.)* 38:141 (1899).

The genus *Physopella*, which included a description of the perfect state (telia) had an imperfect state (uredinial) name misapplied to its type species. Subsequently Cummins & Ramachar (1958), perhaps unaware of the controversy on this matter, substituted the designated uredinial type with the described telial one, *Phakopsora vitis* Sydow. If it is eventually decided that such substitution will be disallowed then the genus *Angiopsora* Mains will need to be reinstated with *Physopella* applying to its uredinial state. Also depending on the typification of *Physopella* is the status of the name *Physopella vitis*. If substitution of the designated type is not allowed then the name is validly published as a new combination: *P. vitis* (Thümen) Arthur, applying to the uredinial state, but if substitution is allowed so that the genus is telial then *P. vitis* is not validly published neither as a new combination (Art. 59, par. 4), nor as a new name (because it would then be a nomen nudum).

Trichobasis Léveillé in Orbigny, *Dict. Hist. Nat.* 12:785 (1848).

Designated lectotype: *Uredo fabae* Pers. in Roemer, *Neues Mag. Bot.* 1:93 (1974) devalidated name.

Uredo fabae Pers. was chosen as lectotype by Laundon (1967c), who at the time regarded it as uredinial; later it was shown that this species was telial (Laundon, 1968). As *Trichobasis* is an 'imperfect' (uredinial) genus, it therefore conflicts with this lectotype. Although a new lectotype is required I do not feel able to make a choice at present and, as the genus is not now in use there is no urgency on the matter.

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ARTHROBOTRYS ENTOMOPAGA IN PURE CULTURE

J. E. ROXON and S. C. JONG

Mycology Department, American Type Culture Collection
12301 Parklawn Drive, Rockville, Maryland 20852

SUMMARY

Arthrobotrys entomopaga, a fungus described by Drechsler as capturing springtails and destroying nematodes, is reported for the first time in pure culture. The strain ATCC 28704 of the fungus produces distinctive predaceous organs that are adhesive knobs rather than the rings and networks in the other species of the genus.

In 1944, Drechsler described a new species, *Arthrobotrys entomopaga* Drechsler (1944), that captured minute springtails and destroyed various nematodes. It is the only species of *Arthrobotrys* that produces predaceous organs which are adhesive knobs rather than the rings and networks which are usual in the genus. Due to its sparse sporulation, Drechsler was unable to obtain it in pure culture. His description and illustrations were based on mixed plate cultures planted with discolored rootlets of *Polygonum pennsylvanicum* L. freshly collected from moist ground near a brook in Arlington, Virginia. As far as we are aware, it has not been reported since then. Citations in literature have been repetitions of Drechsler's original description (Castaner & O'Leary, 1968; Haard, 1968; Rifai & Cooke, 1966).

During a study of *Arthrobotrys* species in culture, we received a culture very similar to *A. entomopaga*. It was originally isolated by J. McCulloch in 1969 from soil in Australia and deposited in the Commonwealth Mycological Institute in England as *Arthrobotrys dactyloides* Drechsler IMI 143,686. The production of aerial sticky knobs on the mycelium suggests that the culture is *A. entomopaga* rather than *A. dactyloides* in which the predaceous organs are of the constricting ring type. Because it represents the second record and the first pure culture of the species and because morphological characters of the fungus can vary

considerably between axenic and mixed cultures, the features found in pure culture are described herein.

Colonies on Difco cornmeal agar at 30 C spreading to 7 cm in 7 days, prostrate, hyaline to white. Hyphae smooth, hyaline, septate, often anastomosing, developing numerous upright predaceous organs, consisting of hyaline, globose cells, 6-10 µm in diameter, usually supported by a stalk-like lower cell, varying in length from 4-20 µm. Occasionally a globose cell is developed as the terminal cell of a hypha.

Conidiophores hyaline erect, up to 300 µm, occasionally branched, bearing conidia singly on short sterigmata, grouped in nodes, of which there may be several on a single conidiophore. Nodes may elongate irregularly as additional conidia are produced.

Conidia sympodial-holoblastic, hyaline, cylindrical, rounded at the distal end, tapered at the proximal end, uniseptate, often slightly constricted at the spetum, 11-22 x 5-6 µm (av. 14.5 x 5.9 µm), occasionally developing an adhesive knob at the tapered end.

Chlamydospores intercalary, in chains, hyaline, oval.

According to Drechsler's illustrations and species diagnosis, the adhesive knobs of *A. entomopaga* were ovate to ellipsoid, but in pure culture they are globose. There is no sign of any inner ovoid structure. The conidia of *A. entomopaga* were cited as being 15-28 x 4.5-5.5 µm, longer and more slender than the ones we observed.

In Drechsler's description, the sterigmata of *A. entomopaga* were longer, 2-7 µm and spreading out from the node, leading Rifai and Cooke (1966) to suggest that it belonged in the genus *Candelabrella* Rifai *et* R. C. Cooke, but in the pure culture they are short and irregularly produced, lengthening the node as they increase in number.

Despite these differences, the coupling of typical *Arthrobotrys* conidia with the distinctive predaceous knobs not otherwise known in the genus *Arthrobotrys*, leads to the conclusion that this culture is indeed *Arthrobotrys entomopaga*, and it has been accessioned in the American Type Culture Collection as ATCC 28704.

Since no type material of the species exists, ATCC 28704 is designated as the neotype. A dried plate culture of the isolate is deposited in the Herbarium of the National Fungus Collections, Beltsville, Maryland. At the ATCC the type culture is being frozen and stored in liquid nitrogen at -196 C.

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VARIATION IN ASCOMYCETE IODINE REACTIONS: KOH PRETREATMENT EXPLORED

LINDA M. KOHN AND RICHARD P. KORF

Plant Pathology Herbarium, Cornell University, Ithaca, NY 14850

and

Exe Island Biological Station, Portland, Ontario K0G 1V0

SUMMARY

Dried apothecia of species of 3 Inoperculate Discomycete genera, *Pezicula, Dermea,* and *Chloroscypha,* all showed non-reactive ascus apices when rehydrated in water and mounted in Melzer's reagent, but when rehydrated instead in dilute KOH solutions displayed intensely blue apical ascus mechanisms. Other anomalous iodine reactions in Ascomycetes are reviewed here, and some other chemical pretreatments noted. Workers are urged to use KOH pretreatment routinely before concluding that asci are iodine-negative. The dangers of using existing keys that stress iodine reactions are evident, since authors have not indicated whether they rehydrate in KOH or not.

Iodine solutions, usually in combination with potassium iodide (Lugol's solution) or with potassium iodide and chloral hydrate (Melzer's reagent), have been used by lichenologists for well over a century following their popularization by Nylander to effect differential blue staining of hymenial elements. Many mycologists later adopted the use of iodine, in particular the Melzer's formulation.

THE MELZER'S REACTION

Among the significant positive reactions in Melzer's reagent reported in the literature, and some convenient references to these, are:

(1) blueing of the ascus pore in some Inoperculate Discomycetes and in some Pyrenomycetes (Dennis, *1968*);

(2) blueing of the ascus apex in *Peziza* and related genera of the Operculate Discomycetes (Dennis, *1968*), and in some members of the Tuberales (Trappe, *1975*);

(3) diffuse blueing of the ascus surfaces in *Pachyella* (Pfister, *1973*) and in *Iodophanus* and its allies (Kimbrough and Korf, *1967*), members of the Operculate Discomycetes;

(4) intense blueing of various hymenial elements in many lichens (Poelt, *1973*) and in some members of the Ostropales (Dennis, *1968*);

(5) blueing of ascocarp tissues in some species of *Lambertella* (Dumont, *1971*), in some species of *Vibrissea* (Sánchez, *1967*), and of apothecial gels in *Pezoloma iodocyanescens* (Dennis & Korf) Korf (Dennis and Korf, *1958*), all Inoperculate Discomycetes, and blueing of subhymenial tissues in some Ostropales (M. A. Sherwood, *pers. comm.*);

(6) blueing of ascospores in *Strossmayeria* (Korf, *1973*), an Inoperculate Discomycete;

(7) the violet or red reaction of the spore contents in some lichens (M. A. Sherwood, *pers. comm.*, but termed "I+ blue" by Hale, *1974*);

(8) the amber ("dextrinoid") reaction of the ascus contents in *Pachyella* (Pfister, *1973*), an Operculate Discomycete, and in some basidiospores (Singer, *1975*);

(9) the black reaction of basidiospore ornamentation in the Russulaceae (Singer, *1975*).

Of these reactions, we are primarily concerned in this paper with Melzer's reagent induced blueing of the ascus pore and ascus walls in Discomycetes, and in the effects of chemical pretreatment, particularly with potassium hydroxide, on the expression of such Melzer's reactions. The term "amyloid," traditionally used for the blueing reaction (or for the black reaction of Russulaceae epispore ornamentation), is avoided here in favor of the terms "blueing in iodine" and "iodine positive." Because the reaction and its specificity is poorly understood, and because "amyloid" specifically implies the presence of amylose or of a substance chemically related to amylose, the accuracy of the term is dubious. Similarly the terms "dextrinoid" and "pseudoamyloid," used for the amber reaction in iodine solutions, are equally misleading.

Some Melzer's reactions, such as those noted above, are quite stable throughout a taxon. Korf (1962) stated that "Natural genera are remarkably constant in regard to the presence or absence of [the iodine positive blueing reaction] ... which thus appears to offer some fundamental criterion in

classification, perhaps linked to ascospore discharge mechanisms."

REPORTS IN THE MYCOLOGICAL LITERATURE OF VARIATION IN THE MELZER'S REACTION WITHIN A SPECIES

Over the years some workers, Seaver (*pers. comm.* to the junior author) for example, have chosen not to use iodine perhaps because they felt the reaction was too variable. While the earliest reported variations in the reaction were by lichenologists, Nannfeldt, as reported by Munk (*1957*) was apparently the first mycologist to do so when he reported that, unlike other members of the Xylariaceae, *Hypoxylon serpens* (Pers. ex Fr.) Kickx failed to have ascus apices turning blue in iodine in some collections. Munk studied ascus apices of three collections of this species: the first was iodine negative, the second turned faint purplish brown, and the third gave a distinct blackish blue reaction. Eriksson (*1966*) reported that he could get all ascus apices in *H. serpens* to blue uniformly in Melzer's reagent if he pretreated first with sodium hydroxide and then with nitric acid. Although this technique was first reported by Minks (*1881*), a lichenologist, it had hitherto been overlooked by mycologists.

Korf (*1962*) drew attention to Sydow's report of *Sarcotrochila balsameae* (Davis) Korf, an Inoperculate Discomycete, as iodine negative, whereas all collections he examined had iodine-positive asci, including material that Sydow had examined. As he pointed out, Sydow may have missed seeing the reaction, may have incorrectly reported it, or Sydow's comment might not even have been in reference to asci.

Müller and Hütter (*1963*) drew attention to a collection of *Chloroscypha sabinae* (Fuckel) Dennis, an Inoperculate Discomycete, which had iodine-positive asci; Dennis (*1956*) had described the species as having iodine-negative asci. Parker and Reid's (*1969*) examination of a portion of this collection in the Herbarium of the Royal Botanic Gardens, Kew, and their comparison of it to the iodine-negative collections cited by Dennis proved the collections identical in every respect except pore reaction. They discovered a second iodine-positive collection in the same herbarium.

Variation in the iodine reaction within a species may sometimes indicate morphological differences of a profound nature, and may lead to taxonomic improvements. While Weir (*1917*) and Brandt (*1960*) both published reports of iodine-positive asci in *Rhabdocline pseudotsugae* Sydow, others re-

ported only iodine-negative asci. An explanation was offered in the monograph of the genus *Rhabdocline* by Parker and Reid (*1969*), who reported that the iodine-negative collections of *R. pseudotsugae* completely lacked both a thickened apex and an apical pore, while iodine-positive collections bore asci with an apical starch-like cylinder perforated by a central pore. On this basis they designated a new species of *Rhabdocline*, *R. weirii*, to accommodate iodine-positive collections. Parker and Reid tried KOH pretreatment to induce an iodine positive reaction in *R. pseudotsugae*, but failed to do so since the absence of an apical ascus pore in this species was the actual reason for this perplexing variation in blueing.

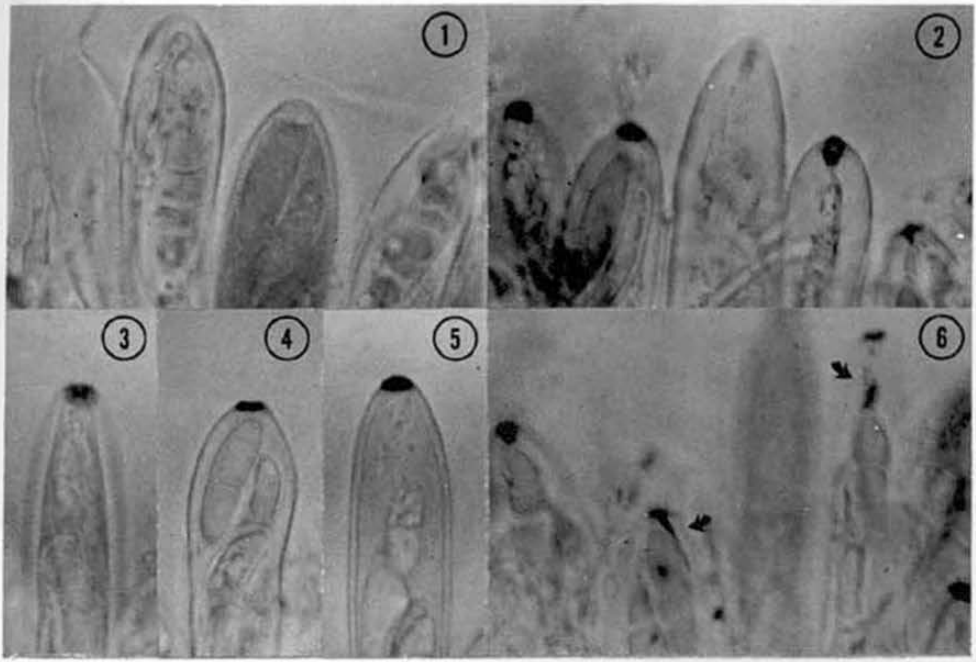
VARIATION IN MELZER'S REACTION INDUCED BY PRETREATMENT WITH POTASSIUM HYDROXIDE

In our laboratory we came upon a clue to one type of variation in the Melzer's reaction through our frequent use of a 2% aqueous solution of KOH as a rehydrating agent for dried material. On two independent occasions, once by the senior author, once by Martha A. Sherwood, we discovered, quite by accident, that dried collections of species referable to the Inoperculate Discomycete genus *Pezicula*, when rehydrated in water did not blue in iodine (FIG. 1), but when rehydrated in KOH, all ascus pores blued dramatically (FIG. 2).

Only very recently have we discovered that Minks (*1881*) had already observed exactly the same phenomenon in three species, *Patellaria rubi* Lib., *P. livida* Berk. & Br., and *Dermatea laricicola* Fuckel, all of which today are considered members of *Pezicula*, the same genus in which we rediscovered the phenomenon, nearly a century later.

Accordingly, we looked at several species of *Pezicula* and at species of several other genera to determine whether pretreatment with KOH might induce blueing in the ascus pore. Apothecia from each collection were rehydrated in distilled water and in 2% and 10% aqueous KOH solutions for at least 15 minutes. Such prolonged exposure to KOH is not required, at least in *Pezicula*, since material blued in Melzer's reagent after instantaneous immersion in either KOH solution. Prior to mounting in Melzer's reagent (our formula: 0.5 gm iodine, 1.5 gm KI, 20 gm chloral hydrate, 20 ml distilled water), apothecia were rinsed in distilled water to remove excess KOH.

We found KOH-induced blueing in all species which we examined of *Pezicula*, of *Dermea*, and of *Chloroscypha*, three large Discomycete genera. In none of the collections of any of these



FIGS. 1-6. Asci of *Pezicula acericola* (Peck) Sacc., rehydrated as noted and then mounted in and photographed in Melzer's reagent, CUP 54700. 1. Asci in several stages of development, rehydrated in water. 2. Asci in several stages of development, rehydrated in 2% KOH. 3. Young ascus rehydrated in 2% KOH. 4. Nearly mature ascus rehydrated in 2% KOH. 5. Fairly mature ascus rehydrated in 10% KOH. 6. Several asci showing disruption of the apical mechanism, with trailing portions of iodine-positive material (arrows), rehydrated in 10% KOH.

three genera was there a positive reaction when rehydrated only in water.

If, indeed, Dennis rehydrated *Chloroscypha sabinae* in water, and Müller and Hütter as well as Parker and Reid rehydrated those collections in KOH, the variation in iodine reactions may be thus explained. More likely, it may be that, as in *Hypoxlon serpens*, real variation in the iodine reaction occurs among collections, even though we have not demonstrated this in material we have examined.

We noted that exposure to 10% KOH tends to produce a much more blue-black reaction (FIG. 5) on iodine-positive asci than does exposure to 2% KOH (FIGS. 2, 3, 4). Also 10% KOH clearly disrupts the apical mechanism in some species (FIG. 6), a fea-

ture we did not see in pretreatment with 2% KOH.

Anomalous Melzer's Reactions Unchanged by KOH Pretreatment

Cases exist in which an anomalous reaction to Melzer's reagent cannot be changed by pretreatment with KOH. Recently, while evaluating the Tuberalean genus *Caulocarpa*, Trappe (*1975*) acquired fresh specimens of *C. montana* Gilkey from the type locality. He found that while his collection was in other respects identical to the type collection, in fresh material the asci blued strongly in Melzer's reagent while in the type material, long preserved in glycerol-ethanol, the asci were iodine-negative. Fortunately, some dried-out microscopic mounts prepared from the type collection when it was fresh were found among Dr. Gilkey's slides, and this material blued beautifully. We examined a portion of the gylcerol-ethanol preserved type collection in our laboratory and found KOH pretreatment useless in inducing a blue reaction in Melzer's reagent; long immersion in glycerol-ethanol apparently alters the composition of some substance reactive in iodine.

Variation in fresh and dried material has also been reported in the literature. Pfister (*1973*) observed that in some species of *Pachyella* the asci blue diffusely when fresh, but fail to blue when dried and rehydrated. Again in our laboratory KOH pretreatment failed to induce blueing in such dried material. Just the opposite effect was found by Dennis as reported by Parker and Reid (*1969*). In this instance a collection of *Peziza repanda* Pers., normally expected to blue in iodine, failed to do so when fresh, but on drying showed a positive reaction to Melzer's reagent. We have not noted such a phenomenon in our collections of *Peziza*, and offer no explanation for it.

Variation in Melzer's Reactions Induced by Chemical Pretreatments Other than Potassium Hydroxide

Our preliminary studies of chemical pretreatments other than KOH have demonstrated that while 2% aqueous sodium hydroxide pretreatment induced blueing in *Pezicula acericola* comparable to that induced by KOH, pretreatment with 10% aqueous ammonium hydroxide, 2% aqueous potassium chloride, and 2% aqueous sodium nitrate all failed to induce blueing in the same collection. Though more work clearly needs to be done, it appears that neither the potassium/sodium nor the hydroxide component seems to be completely responsible in the pretreatment for the positive reaction induced by KOH and

NaOH in Melzer's reagent.

CONCLUSIONS

When mounting in Melzer's reagent, four possible consequences of KOH pretreatment, and perhaps other chemical pretreatments, may be anticipated:

(1) Induction of blueing where no blueing occurred with rehydration only in water, as in *Pezicula*, *Dermea*, *Chlorosceypha*, and perhaps other genera.

(2) Enhancement of an existing reaction. At the Mycological Society of America's Ascomycete Workshop held in August, 1975, at the University of Oregon, after our oral presentation on this topic, J. W. Kimbrough established that in living material the weakly diffuse blueing of the ascus wall in *Iodophanus carneus* (Pers. ex Pers.) Korf when grown in culture is enhanced by KOH pretreatment.

(3) No effect. In many genera which we examined the reaction achieved with KOH pretreatment did not vary from that without pretreatment.

(4) Detraction of the blueing reaction. We have not observed this phenomenon, although we have seen that the amber reaction of the ascus contents in both *Peziza* and *Pachyella* is paler with KOH pretreatment.

The authors hope that in the future taxonomic workers will routinely turn to KOH pretreatment as a check when determining whether a species which appears to be iodine-negative when rehydrated in water is truly iodine-negative. We also caution workers to beware of existing keys that stress the iodine reaction (for example: Dennis, 1956, 1968; Korf, 1972, 1973), since none of these authors have indicated whether they pretreat with KOH or not.

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STUDIES ON THE LICHEN FAMILY THELOTREMATACEAE. 3.*

Mason E. Hale, Jr.
Department of Botany, Smithsonian Institution
Washington, D.C. 20560

OCELLULARIA CARNEODISCA, sp. nov.

Thallus corticola, epiphloeodes, tenuis, albus, 8-11 cm latus; apothecia semi-emergentia, apice plana, decorticata, carnea, 0.5-0.7 mm diametro; ostiolum irregulare, excipulo interiore projectente, 0.1-0.2 mm diametro; columella nulla; hymenium 100 µm altum; sporae 8:nae, incolores, transversim 4-5 loculatae, 4-5 X 11-14 µm.

Chemistry: No substances present.

Holotype: Virgin dipterocarp forest, Sungei Assan, about 15 km south of Sibu, Sarawak, elev. 1-2 m, *M. E. Hale* 30409, 11 March 1965 (US) (Figure 1).

This species has an apical structure similar to that in *O. lopezii* Hale (see below) but is at most only pruinose rather than pulverulent. The pale reddish flesh-colored apical area contrasts sharply with the light ashy thallus when viewed with low power magnification. The pore is round or may appear only as an irregular fissure.

OCELLULARIA GROENHARTII, sp. nov.

Thallus corticola, epiphloeodes, nitidus, viridi-albus, 8-10 cm latus; apothecia semi-emergentia, 0.8-1.2 mm diam-

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*All chemical tests were done with thin-layer chromatography in two solvent systems (hexane-ether-formic acid and benzene-dioxane-acetic acid) with development in H_2SO_4. Contribution No. 1 in this series was published in *Phytologia* 26:413-420, 1973, and No. 2 in *Phytologia* 26:490-501, 1973.

etro; ostiolum rotundatum, 0.2-0.3 mm diametro, plus minusve albocinctum; columella evoluta, ca. 180 µm diametro; hymenium 160 µm altum; sporae 4:nae vel 8:nae, incolores, transversim 15-20 loculatae, 8-14 X 60-80 µm, I+ coerulescentes.

Chemistry: "Olivacea" and "chonestoma" unknowns.

Holotype: Bay of Nglijep, South Malang, Java, elev. 5 m, *P. Groenhart* 502, 21 August 1932 (L; isotype in US).

Additional specimens examined. Solomon Islands: Guadalcanal, *Hill* 8022 (BM, US). India: Kerala, Wyanad Forest, *Patwardhan and Nagarkar* 73.2777 (Poona, US) (Figure 2).

The thallus of this species is typically greenish and shiny. The ascocarps are numerous with a large depressed pore, within which the more or less white pruinose apex of the columella is visible. The two unknown P- substances are identical with those in *O. chonestoma* (Lgt.) Zahlbr., which has smaller, more emergent apothecia and small spores (about 25 µm long). *Ocellularia nylanderiana* Hale has a thicker, granular thallus and emergent ascidioid apothecia. *Ocellularia groenhartii* occurs widely in Asia at low elevations (100-400 m). It is named in honor of Dr. P. Groenhart, who contributed so much to our knowledge of tropical Asian lichens.

OCELLULARIA LOPEZII, sp. nov.

Thallus corticola, hypophloeodes, 8-12 cm latus; apothecia aggregata, semi-emergentia, 0.3-0.5 mm diametro, alba, decorticata, pulverulenta; ostiolum rotundatum, 0.05 mm diametro; columella nulla; hymenium 120 µm altum; sporae 8:nae, incolores, transversim 4-loculatae, 5 X 15 µm.

Chemistry: Psoromic and conpsoromic acids.

Holotype: Remnants of cloud forest, La Carbonera, Estado Mérida, Venezuela, elev. 2200 m, *M. E. Hale* 44138, 19 March 1975 (US) (Figure 3).

The clustered apothecia remind one of a *Trypethelium* but the apical area is decorticate and a distinct pore is visible. There are no comparable species in the genus, excepting perhaps *O. carneodisca* Hale described above. It is

named in honor of Dr. M. Lopez-Figueiras of the Universidad de los Andes, whose generous support and assistance in my field studies in Venezuela is gratefully acknowledged.

OCELLULARIA MAURETIANA, sp. nov.

Thallus corticola, epiphloeodes, nitidus, verruculosus, aetate rimosus, ca. 6 cm latus; apothecia emergentia, irregulariter aggregata, basin constricta, 1.5-3.0 mm diametro, amphithecio corticato, verruculoso; ostiolum apertum, 0.5-2.0 mm diametro, disco late actinoideo-diviso; hymenium 120 µm altum; sporae 8:nae, incolores, transversim 4-6 loculatae, 8-10 X 15-18 µm, I+ coerulescentes.

Chemistry: Protocetraric acid.

Holotype: Ponce, Mauretius, *Dr. Ayres* (BM; isotype in US) (Figure 4).

The apothecia are very large and in part aggregated and anastomosing. The disc is partially actinoid but with very weak carbonization. It seems unrelated to any other species of *Ocellularia* containing protocetraric acid. It is probably endemic to the wet higher forests still remaining on Mauretius.

PHAEOTREMA FOLIICOLA, sp. nov.

Thallus foliicola et muscicola, epiphloeodes, tenuis, viridi-albus, 6-8 cm latus; apothecia vix emergentia, 3-5 mm diametro; ostiolum rotundatum, 0.1-0.2 mm diametro, albocinctum; columella nulla; hymenium ca. 80 µm altum; sporae 8:nae, obscurae, transversim 4-5 loculatae, 10 X 20 µm.

Chemistry: Psoromic and conpsoromic acids.

Holotype: Kolombangara Island, Solomon Islands, elev. 2600-2800 ft., *D. J. Hill* 10525, 3 September 1965 (BM; isotype in US) (Figure 5).

No other species in *Phaeotrema* with psoromic acid have immersed apothecia. The foliicolous habit over mosses may be obligate, but very few foliicolous species in the family, outside of *Chroodiscus*, are known.

PHAEOTREMA STICTICUM, sp. nov.

Thallus corticola, epiphloeodes, cinereo-albus, 10 cm latus; apothecia emergentia, basin leviter constricta, 0.7-1.0 mm diametro, apice decorticata, minute pulverulenta; ostiolum rotundatum, 0.2-0.4 mm diametro; columella evoluta, ca. 200 µm diametro, apice pruinosa; hymenium ca. 140 µm altum; sporae 8:nae, obscurae transversim 4-6 loculatae, 8-10 X 18-24 µm.

Chemistry: Stictic acid.

Holotype: Mist forest, Pico Avila, Distrito Federal, Venezuela, elev. ca. 2000 m, *M. E. Hale* 43391, 9 February 1974 (US) (Figure 6).

The apothecia have a broad pore filled with the pruinose columella apex. The rim is thick and uneven, lightly pruinose but lacking any raised margin. There are no similar stictic acid-containing species in the genus.

THELOTREMA CONFERENDUM, sp. nov.

Thallus corticola, epiphloeodes, tenuis, olivaceo-albus, 6-8 cm latus; apothecia immersa vel semi-emergentia, 0.7-1.1 mm diametro, excipulo interiore distincto; ostiolum latum, 0.4-0.5 mm diametro; columella nulla; hymenium ca. 250 µm altum; sporae 1-2:nae, incolores, 25-35 X 100-140 µm, multiloculares, I-.

Chemistry: Stictic and constictic acids.

Holotype: On trees in open places in montane rain forest, Mount Gallego, Guadalcanal Island, *D. J. Hill* 8180, 7 July 1965 (BM; isotype in US) (Figure 7).

Externally this species is identical with *Ocellularia exanthismocarpa* (Lgt.) Zahlbr., especially with regard to the distinct inner exciple which forms a kind of double pore with the main apothecial rim. The spores, however, are muriform, larger than the transversely septate spores of *O. exanthismocarpa*, and negative with iodine.

THELOTREMA EITENII, sp. nov.

Thallus corticola, epiphloeodes, tenuis, albidus, 6-8 cm latus; apothecia sessilia, orbicularia vel elongata,

1.0-1.5 mm diametro, margine erecto, crasso, recurvo, disco aperto, plano, dense pruinoso; columella nulla; hymenium 100-120 µm altum; sporae 1-2:nae, incolores, 25-30 X 80-100 µm, multiloculares.

Chemistry: Protocetraric acid.

Holotype: 2 Km west of Ouro Preto, Minas Gerais, Brazil, elev. 1200 m, *G. Eiten* 6961, 28 November 1965 (US) (Figure 8).

This species has a typical chroodiscoid apothecium. The main exciple is quite thick, as in *Ocellularia dilatata* Müll. Arg., and the open disc is heavily pruinose. *Thelotrema leprocarpum* Tuck. and *T. colobolicum* Nyl. are similar in spore size but both are smaller species lacking any lichen substances.

THELOTREMA EMINENS, sp. nov.

Thallus corticola et muscicola, epiphloeodes, cinereo-albus, 4 cm latus; apothecia valde emergentia, eminentia, cylindrica, ca. 0.4 mm diametro, 0.4-0.5 mm alta, omnino corticata; ostiolum rotundatum, 0.1-0.2 mm diametro, depressum; columella nulla; hymenium ca. 200 µm altum; sporae 1-2:nae, 70-80 X 150-170 µm, multiloculares.

Chemistry: Stictic and constictic acids.

Holotype: Mossy oak forest, Gunong Brinchang, Pahang, Malaya, elev. 2000 m, *M. E. Hale* 29947, 3 March 1965 (US) (Figure 9).

The tall cylindrical apothecia are similar to those in *T. tuberculiferum* Vainio except that the apical area is entirely corticate. It is also unusual in producing stictic acid, for most of the large-spored species in this group contain no lichen substances.

THELOTREMA INDICUM, sp. nov.

Thallus corticola et muscicola, tenuis et pro parte hypophloeodes, albidus, 6-10 cm latus; apothecia emergentia, prominentia, 0.4-0.6 mm diametro, alba, primo verruciformia, aetate pulverulenta, pro parte radiato-divisa, apice fuliginea; ostiolum rotundatum, 0.2-0.3 mm diametro; columella nulla; hymenium ca. 200 µm altum; sporae 1-2:nae, 25-

36 X 80-120 µm, multiloculares, I+ coerulescentes.

Chemistry: No substances present.

Holotype: On *Cupressus* along road to Dodapetta, Tamil Nadu, India, elev. 2600 m, *M. E. Hale and P. G. Patwardhan* 40185, 8 November 1973 (US; isotype in Poona) (Figure 10).

This species was common on planted roadside cypress trees. The apothecia are completely decorticate at maturity and lack carbonization. It belongs in the *T. tuberculiferum* group and is differentiated by the smaller spores and apothecia.

THELOTREMA ISIDIATUM, sp. nov.

Thallus corticola vel muscicola, tenuis, pro parte hypophloeodes, viridi-albus, 4-6 cm latus, modice vel dense isidiatus, isidiis simplicibus vel ramosis, fragilibus, ca. 0.5 mm altis; apothecia valde emergentia, alba, basin constricta, ca. 0.5 mm diametro, pro parte isidiata, superne pulverulenta, apice fusca; ostiolum rotundatum, 0.2-0.3 mm latum; columella nulla; hymenium 200 µm altum; sporae 1-2:nae, 30-40 X 120-150 µm, multiloculares.

Chemistry: No substances present.

Holotype: Area of small trees in paramo, Páramo La Negra, Mérida, Venezuela, elev. 2900 m, *M. E. Hale* 42425, 2 February 1974 (US) (Figure 11).

Additional specimen examined. Venezuela: Mossy tree in cloud forest, Pico Avila, Distrito Federal, Venezuela, elev. 2000 m, *Hale* 43382 (US).

Thelotrema isidiatum is distantly related to the *T. tuberculiferum* and *T. decorticans* Müll. Arg. group because of the strongly emergent, almost globose apothecia which become white-pruinose apically, but the black ascocarp wall is still visible beneath the pruina. The isidia are often branched and rather fragile with a minutely roughened surface, not smooth and corticate as in *T. insigne* Zahlbr., for example, which has noncarbonized apothecia and contains psoromic acid.

THELOTREMA MERIDENSE, sp. nov.

Thallus corticola, epiphloeodes, pallide viridis, 4-5 cm latus; apothecia emergentia, primum orbicularia sed aetate stellata, 0.4-0.7 mm diametro, superne ambitu decorticata et pulverulenta, alba, radiato-divisa; ostiolum discretum, 0.05-0.1 mm diametro; columella nulla; hymenium 140 µm altum; sporae 2-4:nae, incolores, 17-20 X 65-75 µm, 1-2 X 12-15 loculatae.

Chemistry: Stictic and constictic acids.

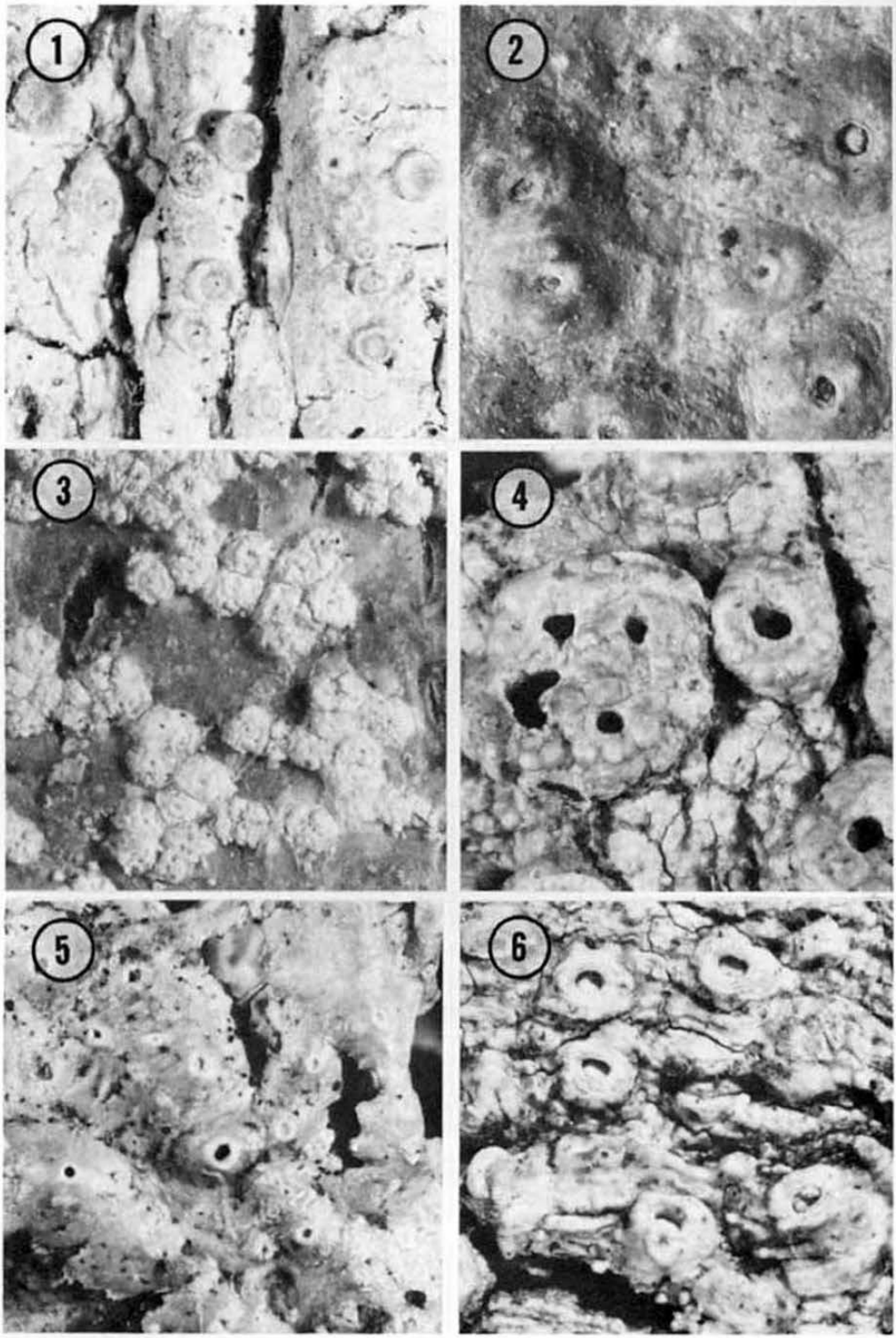
Holotype: Near base of large tree in dense cloud forest, trail between La Montaña and La Aguada, Teleférico, Mérida, Venezuela, elev. 2600 m, *M. E. Hale* 46104, 13 April 1975 (US; isotype in Mérida) (Figure 12).

This remarkable species is unique in having star-shaped apothecia. The young apothecia are initially orbicular with a decorticate apex. The amphithecium soon becomes radially rugose and finally grotesquely star-shaped. The apical area has a pulverulent, almost sorediate-granular surface. This is the only apically decorticate species with stictic acid.

LEGENDS FOR THE PLATES

Figures 1-6. Specimens of Thelotremataceae: 1, *Ocellularia carneodisca* Hale (*Hale* 30409); 2, *O. groenhartii* Hale (*Patwardhan and Nagarkar* 73.2777); 3, *O. lopezii* Hale (*Hale* 44138); 4, *O. mauretiana* Hale (*Ayres*); 5. *Phaeotrema foliicola* Hale (*Hill* 10525); 6, *P. sticticum* Hale (*Hale* 43391). All specimens about X10.

Figures 7-12. Specimens of Thelotremataceae: 7, *Thelotrema conferendum* Hale (*Hill* 8180); 8, *T. eitenii* Hale (*Eiten* 6961); 9, *T. eminens* Hale (*Hale* 29947); 10, *T. indicum* Hale (*Hale and Patwardhan* 40185); 11, *T. isidiatum* Hale (*Hale* 42425); 12, *T. meridense* Hale (*Hale* 46104). All specimens about X10.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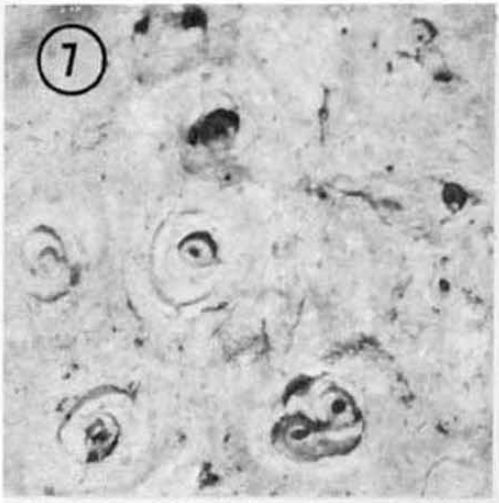
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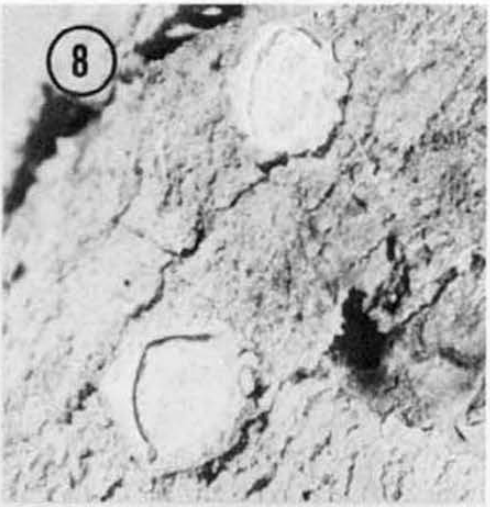
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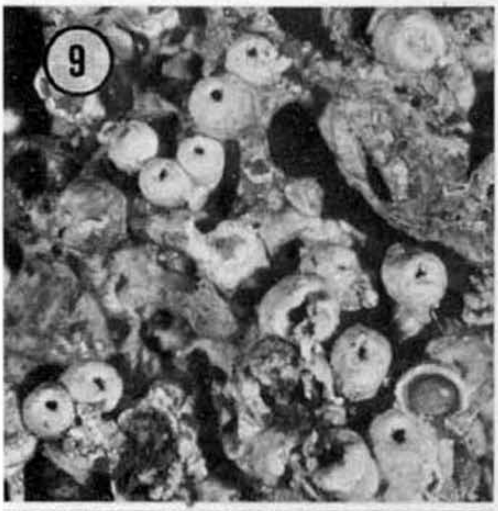
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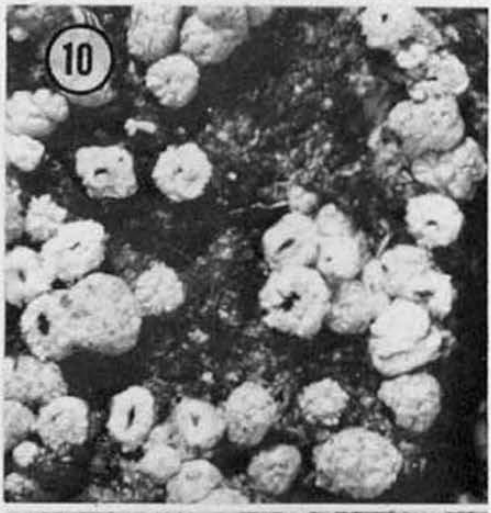
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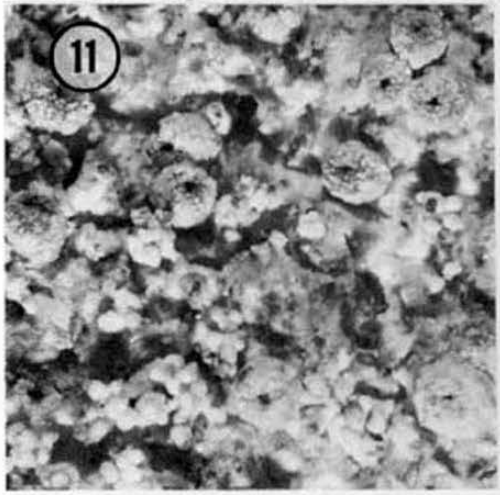
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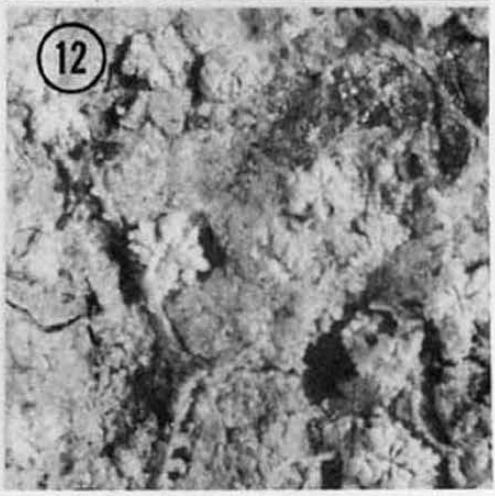
12

MYCOTAXON

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BOOK REVIEWS

by

G. L. HENNEBERT

Book Review Editor, Huttelaan 36, B-3030 Heverlee, Belgium

DIAGNOSTIC DE LABORATOIRE EN MYCOLOGIE MEDICALE, by G. SEGRETAIN, E. DROUHET and F. MARIAT, 3rd ed., 144 p., 35 fig., 13.5 × 21 cm, glued paperbound, 1974, Collection "Techniques de Base," Maloine s.a., 27 rue de l'Ecole de Médecine, 75006 Paris. FF 40.-

Professors at the Pasteur Institute in Paris and responsible for the same, the authors of this presentation of new techniques intend to make easier the diagnosis of the mycoses and the identification of the pathogenic fungi. The practicioner will find information on the methods of sampling, staining or isolating the fungi as well as on the establsihment of the immunological, physiological or pathogenic characteristics of the fungi. Specific methods in the study of the cutaneous, subcutaneous and deep mycoses are detailed in the second half of the manual. Special attemtion is given to the identification of *Trichophyton* and *Candida* species. One can only regret that the nomenclature of the fungi is not brought up to date.

THE FUNGI OF PUERTO RICO AND THE AMERICAN VIRGIN ISLANDS, par John A. STEVENSON, Contribution of the Reed herbarium No. 23, 743 p., 15 × 23 cm, paperbound, 1975, 10105 Harford Rd., Baltimore, Md., US $6.80.

Cet ouvrage est certainement une contribution majeure à la flore mycologique de Porto Rico et des Iles Vierges. Il remplace avantageusement le premier relevé de la même flore publié par l'auteur en 1918 et qui déjà comprenait 1025 espèces. Le présent ouvrage compile en effet une flore de 2300 espèces et 30 variétés, résultat de 160 années de récoltes et d'etudes. On y trouve associés des grands noms, tels Klotsch, Cook, Bresadola, Lloyd, Earle, Stevens, Ashford, Fawcett, Arthur, Johnson, Petrak, Seaver, Chardon, Carrion, Whetzel, Olive, Kern, Toro. La liste des espèces suit un ordre taxonomique et une nomenclature aussi moderne que possible, l'auteur s'étant efforcé de tenir compte de la plus récente littérature et au besoin d'établir des combinaisons nouvelles. Chaque espèce est citée avec référence et synonymie, sans description mais avec un commentaire sur les hôtes, l'habitat et la distribution géographique.

THE BOLETI OF NORTH CAROLINA, par W. C. COKER et Alma H. BEERS, 96 p., 66 pl. (6 en couleurs), 15.5 × 23.5 cm, broché. Dover Publ., 180 Varik St., New York, NY 10014. US $ 3.50.

Cet ouvrage, un des classiques sur les Bolets, est la réimpression de l'ouvrage original "The Boletaceae of North Carolina" publié en 1943 par the University of Carolina Press. 68 espèces de *Boletus*, genre pris au sens large, 4 de *Boletinus* et 1 de *Strobilomyces* sont décrites. Si le titre de l'ouvrage a été modifié, on s'étonnera de trouver un contenu inchangé, dans le même style traditionel, où même les termes "plant" et "stem" n'ont pas été remplacés par "carpophore" et "stipe."

THE GENERA OF FUNGI SPORULATING IN PURE CULTURE, by J. A. von ARX, 2nd ed., 315 p., 134 fig., bound, 1974. J. Cramer & A. R. Gantner Vg., FL-9490 Vaduz, Liechtenstein. DM 100.-

A fully revised edition of the book published in 1970. More than 780 fungus genera, versus 635, are included now, with full reference, type species, conidial or sexual state and important literature. The fungi covered are the Lower Fungi, the Ascomycetes and the Fungi Imperfecti. Dichotomous keys and line drawings are provided as guides to the identification. A very helpful book for mycologists, microbiologists, plant pathologists.

METODE ŞI TEHNICI ÎN MICOLOGIE, par Ovidiu CONSTANTINESCU, 214 p., 31 fig., 24 × 17 cm, relié, 1974. Ed. Ceres, Bucarest. Lei 18.

L'auteur décrit les méthodes d'études des champignons, méthodes de récolte, d'isolement, d'éxamen microscopique, de culture et de conservation. Le contenu, qui est detaillé et bien illustré, se base sur plus de 1000 publications. Plus de 200 formules de milieux de culture sont données avec leurs variantes, préparation et applications. Ouvrage très utile à tout laboratoire de mycologie, de phytopathologie et de microbiologie, mais en roumain.

MOISISSURES TOXIQUES DANS L'ALIMENTATION, by Claude MOREAU, 2nd ed., 480 p., 31 fig., 16 × 24 cm, cloth bound, 1974. Masson & Cie., Paris. FF 180.-

Not only wild mushrooms but many of the microscopic moulds are toxic. An exact knowledge of each fungus and of its toxicity is today more important than ever. The book is an expanded and up to date edition of the original version published in 1968. Because of the abundant data, emphasis is given to the toxicoses by *Aspergillus flavus* and *Penicillium islandicum*, but fungus characteristics and toxin detection, properties and action are given for many other species of *Aspergillus, Penicillium, Fusarium, Pithomyces, Stachybotrys, Mucor, Rhizopus, Byssochlamys, Chaetomium, Cladosporium, Wallemia, Trichothecium, Gliocladium, Trichoderma*, etc.

A REEVALUATION OF THE BITUNICATE ASCOMYCETES WITH KEYS TO FAMILIES AND GENERA, par J. A. von ARX et E. MULLER, *in* Studies in Mycology, n° 9, 159 p., 66 fig., 15.5 × 24 cm, broché, 1975. Centraalbureau voor Schimmelcultures, Baarn. HFl 30.-, souscription annuelle HFl 40.-.

Tous les genres d'ascomycètes bituniqués connus des auteurs sont repris dans 34 familles et forme l'ordre unique des Dothideales. Chaque famille est décrite avec ses caractéristiques, ses affinités et sa synonymie. Les genres reconnus sont donnés avec référence, espèce-type, espèces principales, genres synonymes, stades conidiens et hôtes. Nombreuses sont les nouvelles combinaisons proposées suite aux nouvelles synonymies. Les auteurs reconnaissent dans cette étude la fragilité des caractères admis comme fondamentaux. Plutôt que de réaffirmer une classification phylogénique incertaine, ils ont choisi une subdivision en famille basée sur des caractères aisément observables. Cette intéressante classification, pragmatique mais claire, des Bituniqués aura certainement la faveur de ceux qui ceulent efficacement aborder ce groupe.

ON THIELAVIA AND SOME SIMILAR GENERA OF ASCOMYCETES, par J. A. von ARX, *in* Studies in Mycology, n° 8, 31 p., 4 fig., 3 pl., 15.5 × 24 cm, broché, 1975. Centraalbureau voor Schimmelcultures, Baarn. HFl 10.-.

Le genre *Thielavia* Zopf pris au sens large couvre un groupe hétérogène de champignons dans lequel l'auteur met un ordre nouveau. Il y reconnaît 10 genres, dont deux nouveaux, *Melanocarpus* v. Arx et *Corynascella* v. Arx & Hodges, sur la base de la forme et du nombre des pores germinatifs, la nature fine ou épaisse des parois ascomatales à texture épidermoïde ou parenchymateuse, le caractère pileux des ascomata et la nature du stade conidien.

DIFFERENCIATION FONGIQUE, by G. TURIAN, *in* Monographies de Physiologie végétale, by P. E. PILET, ed., vol. 5, 144 p., 30 fig., 2 pl., 10 tab., 16.5 × 21.5 cm, paperbound, 1969. Masson & Cie., Paris. FF 50.-.

No publication has compiled all the available data on the biochemical mechanisms of morphogenesis in the fungi. The work of G. Turian has been a major step in that way. A very interesting emphasis is given to the dimorphism yeast/hypha in yeasts and other fungi and to the sexual/conidial sporulation in *Neurospora*. The author demonstrates the dependence or independence of the fungi on their chemical environment. These data are susceptible to enlighten the behavior of fungi in artificial culture.

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COMMENTS ON THE SCLEROMYCETI SUECIAE IN THE FARLOW HERBARIUM

Donald H. Pfister

The Farlow Reference Library and Herbarium of Cryptogamic Botany and the Biology Department, Harvard University

Holm and Nannfeldt (1962) have given an excellent account of Fries's *Scleromyceti Sueciae*. In compiling their information they relied heavily on the herbaria at Uppsala (U), Kew (K), Paris (PC), and Beltsville (BPI). Considering the importance of the exsiccata and in cognizance of irregularities involved in its publication, discussion of its representation in other herbaria seems worthwhile. The following account deals with the three sets of this exsiccata located in the Farlow Herbarium.

A letter in which L. C. Shear mentioned that decades 1-8 of the exsiccata are present in the Farlow Herbarium is quoted by Holm and Nannfeldt (1962). However, there is no published account which indicates that other specimens from this exsiccata are present in the Farlow collections. The set mentioned by Shear, except for the absence of specimen nos. 185-274, is complete and is mounted in its original booklet form. But besides that set there is also an incomplete set containing only 47 specimens. These specimens, apparently received on loose sheets and mounted locally in a single book, were purchased from Jean Étienne Duby, a 19th century cryptogamist and accumulator of specimens, by William Gilson Farlow in October 1879. Unfortunately, search through the Duby-Farlow correspondence discloses no information about Duby's source of these specimens.

As Holm and Nannfeldt pointed out there are two editions of the exsiccata. Specimens of the first edition, at least those in fascicles 1-8, were mounted in small books with title pages and indices. The second edition was not uniformly prepared (some labels having been handwritten or corrected) and involved numbers 1-300 (fascicles 1-8) and those of higher numbers. Fascicle 9 presents a number of

questions. Holm and Nannfeldt believe it was never issued in booklet form and that the specimens composing it may never have been issued together.

Of the Farlow collections there is no question that the set mounted in booklets is of the first edition. In my opinion, the specimens from Duby were also derived from the first edition. This opinion is supported by the following observations. First, although the 47 specimens are not mounted in booklets the paper to which they are glued is the same as that of the bound copy. The watermarks, texture, and color agree between the two. Second, the specimens are mounted in the same general manner. This is especially evident in those cases where two specimens were mounted on a single page. Also, some of the sheets have obviously been folded along one edge as if they were removed from booklets. Third, although some of the sheets are annotated there are no nomenclatural changes in Fries's handwriting or in that of the "secretary's" (see Holm and Nannfeldt, fig. 3) as is common in the second edition.

In neither of the two W. G. Farlow sets mentioned above are there numbers from the ninth fascicle (300-340) or any above 340. However, numbers from the ninth fascicle as well as some above 340 have been found in the Curtis herbarium. This set though containing only 209 specimens is interesting because it amplifies, verifies, and clarifies some of the information given by Holm and Nannfeldt. The following discussion is based on this material.

Fries's Scleromyceti Sueciae in the Curtis Herbarium

Information, in Curtis's hand, on the packets of a number of specimens from this exsiccata in the Curtis herbarium indicate that the specimens were sent by Fries. Unfortunately, all of these specimens have been drastically remounted. The specimens were removed from the original sheets as were the original labels. Both labels and specimens were reglued to small sheets apparently by Curtis. He then annotated the sheet, generally making a drawing of some microscopic feature, usually spores. It is impossible to determine in what form the original specimens were received. They were undoubtedly sent to Curtis sometime after the originals were distributed. There also are a number of miscellaneous specimens in the Curtis herbarium which, though not a part of the exsiccata, were sent by Fries. According

to Shear and Stevens (1919) Curtis did not seriously engage in mycological studies until 1845 or 1846. It would have been unlikely for him to have exchanged specimens earlier. According to Holm and Nannfeldt fascicle nine of the *Sclero-myceti Sueciae* may have been published in 1825 and the entire second edition must have been completed by 1841. It is not surprising then that the Curtis set is incomplete nor that there are a large number of specimens from the second edition (that is, those easily distinguished on the basis of handwritten labels).

Of 143 specimens from the first 8 fascicles only a few warrant comment, which follows.

8b - *Sphaeria ambiens* - Holm and Nannfeldt did not list the existence of this number. Number 8 is also *Sphaeria ambiens*. Whether this notation indicates that Fries attempted to denote a new collection of the species or a new concept of the species remains an unresolved question. The label is handwritten. There is also a printed label for another specimen of number 8.

26 - *Sphaeria tubeformis* - The label is handwritten. The spelling as listed here is as it appears on this label. Holm and Nannfeldt have it as "*tubaeformis*."

48 - *Sphaeria filicina* - The label is handwritten, undoubtedly a second edition specimen.

71 - *Sphaeria disciformis* - Two specimens are present; one with a printed label and one handwritten.

73 - *Sphaeria lanciformis* - The label is handwritten.

88 - *Sphaeria excipuliformis* - The handwritten label reads *Sphaeria*; other specimens from the original edition with printed labels read *Lophium*.

95 - *Stictis parallela* - In the original edition this was issued under *Hysterium*.

102 - *Tympanis frangulae* - The label is handwritten.

104 - *Sphaeronema hemisphaeria* - The label is handwritten by Fries.

112B - *Sphaeria lejoplaca* - This is one of the second edition specimens issued under this name rather than under *Sphaeria lata* as in the original edition. According to Holm and Nannfeldt other second edition specimens of this number are located in K and PC.

119 - *Sphaeria abducens* - This is a second edition specimen but apparently does not agree with the one cited by Holm and Nannfeldt in Kew since it is not labeled *Sph. abducens minor*.

162 - *Sphaeria mutilaria* - A handwritten label by Fries.

187 - *Sphaeria ocellata* β - This handwritten label is at variance with the printed label which reads *S. tessella* in the first edition. Holm and Nannfeldt state that there is a specimen, labeled as listed above, in PC.

226 - *Sphaeria prunastri* - The label is handwritten.

229b - *Sphaeria suffusa* - Holm and Nannfeldt do not record this number. This presents the same problem as 8b.

230B - *Sphaeria nucula spuria F. platystoma* - Holm and Nannfeldt point out that this was probably meant to be 238 but that due to a misprint in SM and Fries's own errors in writing subsequent labels the error became entrenched.

242 - *Sphaeria fimbriata* - A handwritten label.

295 - *Ditiola radicata* - The Curtis specimen was apparently received from de Notaris; the label bears his seal and is in his hand.

In table 1, I have listed those numbered specimens in the Curtis herbarium bearing numbers above 300. The few to which I can add comment are listed below; these are marked with an asterisk in the table.

315 - *Sphaeria vibratilis* - There are two examples bearing this number. One is a printed label with the name *Sphaeria vibratilis* as listed by Holm and Nannfeldt.

TABLE 1

306 - *Sphaeria favacea*
307 - *Sphaeria spiculosa*
308 - *Sphaeria dothidea*
*315 - *Sphaeria vibratilis*
317 - *Sphaeria pupula β philadelphi*
318 - *Sphaeria strobilina*
*319 - *Sphaeria semitecta*
*320 - *Sphaeria arbuticola*
321 - *Sphaeria doliolum*
324 - *Sphaeria uda*
325 - *Sphaeronaema subulatum*
*326 - *Phacidium rugosum β*
*328 - *Dothidea asteroma*
332 - *Peziza flammea*
334 - *Peziza resinae*
342 - *Sphaeria bullata*
345 - *Sphaeria macrostoma*
346 - *Sphaeria cirrhosa*
347 - *Sphaeria uberiformis*
348 - *Sphaeria alligata*
*349 - *Sphaeria lonicerae*
*351 - *Lophium aggregatum*
*358 - *Leptostroma spiraeae var. rubi*
369 - *Phacidium patella*
381 - *Sphaeria fibrosa*
*382 - *Sphaeria omalogramma*
383 - *Sphaeria prorumpens β*
384 - *Sphaeria thelebola*
385 - *Sphaeria mutila β*
386 - *Sphaeria tristis*
387 - *Sphaeria mammaeformis*
388 - *Sphaeria applanata*
389 - *Sphaeria pertusa*
390 - *Sphaeria brevirostris*
391 - *Sphaeria corticis*
392 - *Sphaeria cerasorum a*
*393 - *Sphaeria cerasorum b*
394 - *Sphaeria inquinans*
397 - *Sphaeria mammillana minor*
398 - *Sphaeria clypeata*
399 - *Sphaeria oppilata*
*401 - *Sphaeria calvescens*
404 - *Sphaeria galii*
*405 - *Sphaeria caulium*
406 - *Sphaeria lirella*
*407 - *Sphaeria deplanata*
408 - *Sphaeria complanata β minor*
409 - *Sphaeria cormi suecicae*
*410 - *Sphaeria salicina*
412 - *Phacidium shizoxylon*
417 - *Eustegia ilici*
420 - *Excipula punctiformis*
423 - *Eustegia robertiani*
430 - *Dermea cerasi*
437 - *Phragmotrichum aceriunum*
439 - *Conoplea olivacea*
441 - *Sphaeria melogramma*
*442 - *Sphaeria stellulata*
*443 - *Sphaeria lejoplaca β*
444 - *Sphaeria xanthostroma*
*447 - *Sphaeria diminuens*
*448 - *Sphaeria eutypa var.*
449 - *"Sphaeria rigida"*
*451 - *Peziza sanguinea*
*458 - *Sphaeria craterium*

The other is a handwritten label (in Fries's hand) which bears the name *Sphaeria stricta* var. This latter species was issued as 314, the handwritten label is apparently a *lapsis calimi*.

319 - *Sphaeria semitecta* - A handwritten label.

320 - *Sphaeria arbuticola* - A handwritten label.

326 - *Phacidium rugosum* β - Holm and Nannfeldt indicate that in the first edition this was called *Dothidea vaccini* and indicate a confusion with number 353. The Curtis specimen is as listed above and is clearly numbered 326.

328 - *Dothidea asteroma* - Holm and Nannfeldt point out the confusion about this number. In our collection the label is damaged and only "28" is print; the "3" is in hand.

349 - *Sphaeria loniceri* - The label is handwritten but lacks a number. The label was annotated, apparently by Curtis with "349?"

351 - *Lophium aggregatum* - An annotation on the Curtis specimen by M.L. Lohman reads "351 *Lophium aggregatum* Fries Sel. Suec. 1836' in Duby Herb. at Strasbourg, wood is coniferous - not oak as Rehm stated."

358 - *Leptostroma spiraeae var. rubi* - The label is as indicated by Holm and Nannfeldt.

382 - *Sphaeria omalogramma* - Holm and Nannfeldt report only a specimen in BPI.

393 - *Sphaeria cerasorum* β - Holm and Nannfeldt list K and PC as the herbaria in which this number was located.

401 - *Sphaeria caevescens* - Holm and Nannfeldt list K and PC as also having a specimen under this number.

405 - *Sphaeria caulium* - as above.

407 - *Sphaeria deplanata* - Holm and Nannfeldt discuss the problems related to the confusion over this species. The specimen in the Curtis herbarium bears the name *Sphaeria deplanata* Fr. but this is annotated in pencil

(by Curtis ?) so that it reads *"complanata"*.

410 - *Sphaeria salicina* - Holm and Nannfeldt state that the only specimen located was in K.

442 - *Sphaeria stellulata* - The only other material reported is in K and PC.

443 - *Sphaeria lejoplaca* β - The only other material reported is in K, BPI, and PC.

446 - *Sphaeria picea* - The specimen has a printed and corrected label obviously taken from no. 194.

447 - *Sphaeria diminuens* - There are two specimens with this number. One specimen has a printed, corrected label taken from no. 15 of the original edition. This corrected label reads *Sphaeria eutypa* var. The varietal name is given but I was unable to decipher the name. *Sphaeria eutypa* is listed by Holm and Nannfeldt as no. 448 but without reference to the varietal name. Another specimen in the Curtis collection numbered 447 has a handwritten label which reads *Sphaeria diminuens*. This agrees with the name Holm and Nannfeldt have given for number 447. The label with the name *Sphaeria eutypa* var. is probably a *lapsis calami* and should read 448. Material of *Sphaeria diminuens* number 447 was seen by Holm and Nannfeldt at K and PC.

448 - *Sphaeria eutypa* - The only material with this name is the misnumbered specimen discussed above. Holm and Nannfeldt have apparently seen material properly numbered at K.

451 - *Peziza languinea* - The only material listed by Holm and Nannfeldt is in K.

458 - *Sphaeria craterium* - The label on the specimen in the Curtis herbarium reads *"Sphaeria craterium"* Dec. The accepted name, however, that was used in Summa Veg. Scand. was *Trochila craterium*.

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Holm, L., and J.A. Nannfeldt. 1962. Fries's "Scleromyceti Sueciae" a study on its editorial history with an annotated check-list. Friesia 7: 10-59.

Shear, C.L., and N.E. Stevens. 1919. The mycological work of Moses Ashley Curtis. Mycologia 11: 181-201.

CO-EDITORS OF MYCOTAXON

G. L. HENNEBERT
FRENCH LANGUAGE EDITOR
& BOOK REVIEW EDITOR

Huttelaan 36
B-3030 Heverlee, Belgium

RICHARD P. KORF
ENGLISH LANGUAGE EDITOR
& MANAGING EDITOR

P.O. Box 264
Ithaca, NY 14850, USA

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