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GLOMUS GLOBIFERUM: A NEW SPECIES OF ENDOGONACEAE WITH A  
HYPHAL PERIDIUM

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In a study of species of vesicular-arbuscular mycorrhizal (VAM) fungi associated with sand dune colonizing plants of the Atlantic Coast of the United States of America, a new species of Glomus with individual chlamydo-spores surrounded by an unusual peridium was discovered. Spores were extracted by the wet-sieving/filtration method (Koske & Walker 1984) from soil sampled from around the roots of American beachgrass Ammophila breviligulata Fern. The new species was found originally in only one sample from more than 500 taken from dunes of the North and Mid-Atlantic coast, but was later discovered in sand dune samples from Virginia and Michigan.

Specimens have been deposited in the herbaria at Oregon State University (OSC) the Farlow Herbarium (FH), and Kew (K). Wall descriptions and terminology are those suggested by Walker (1983, 1986), and descriptions are based on the appearance of specimens in a polyvinyl alcohol mountant (Koske and Tessier, 1983, Walker, 1983).

## SPECIES DESCRIPTION

GLOMUS GLOBIFERUM Koske et Walker sp. nov.      Figures 1-12.

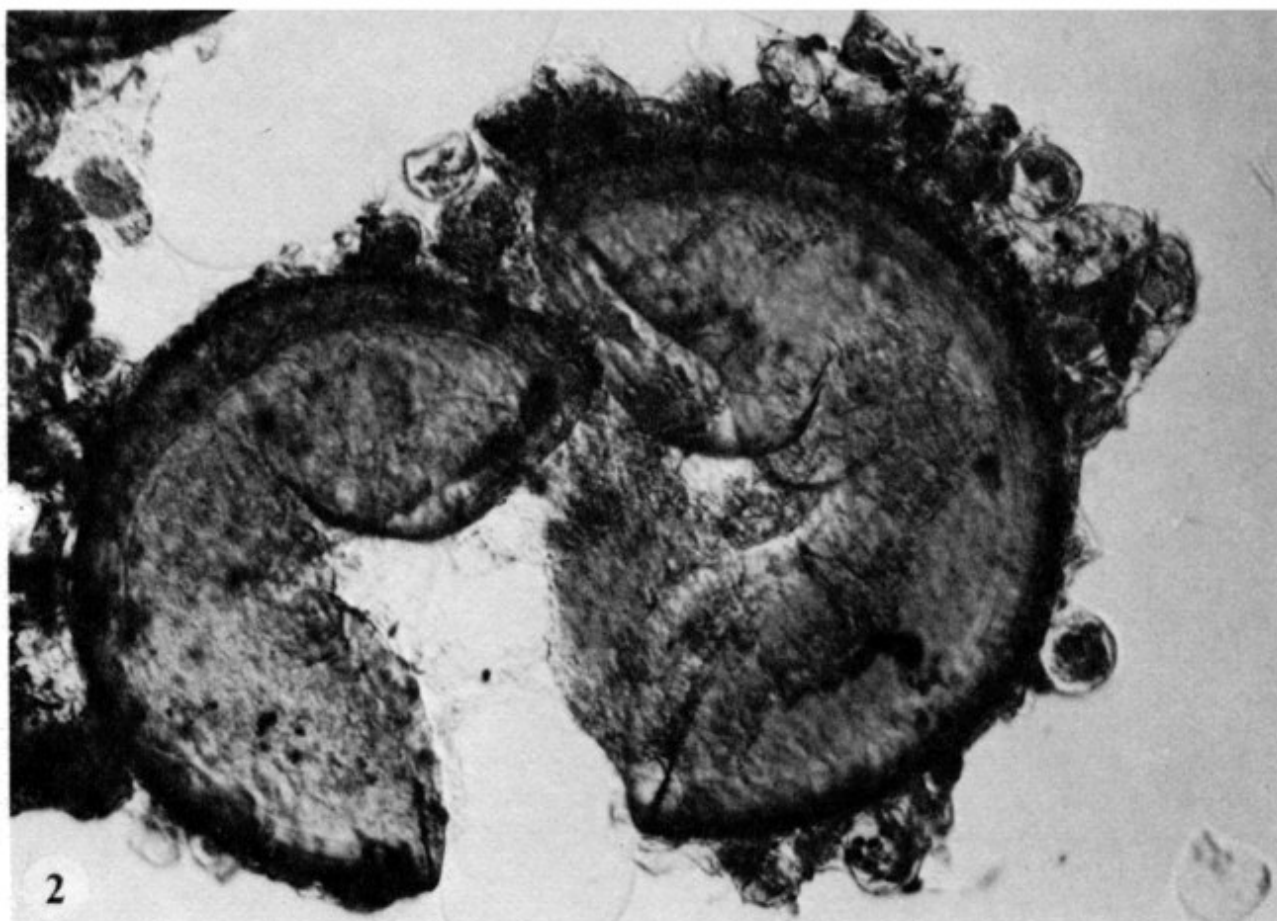
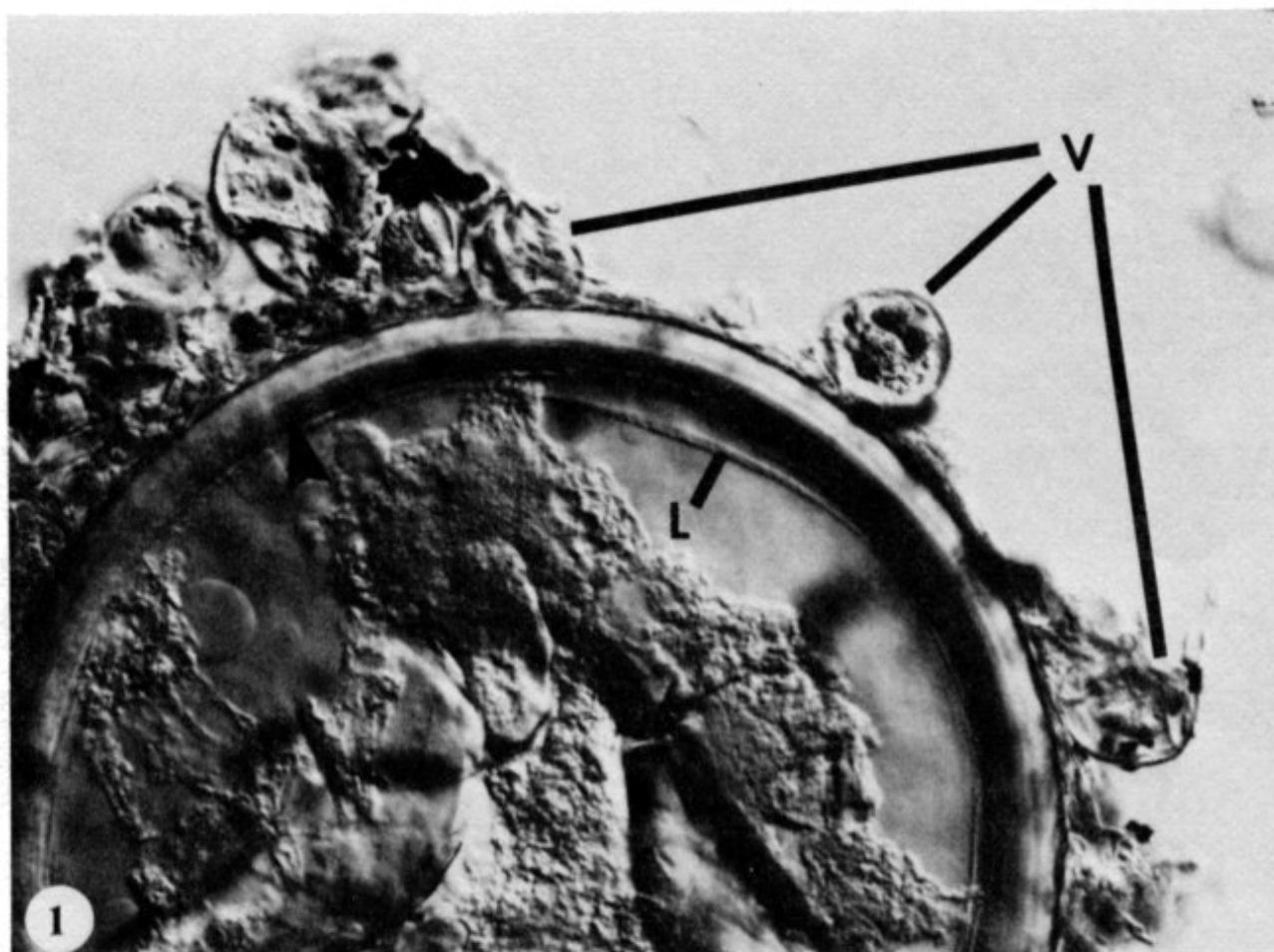
Sporocarpia ignota. Sporae singillatim, binatim, vel trinatim enatae, cinnamomeae, porphyreae, vel raro atrofuscae, globosae vel subglobosae, 150-260 x 150-270  $\mu\text{m}$ , peridium hyphae laxae et sparce septatae vel collapsae exclusum. Tunica sporae stratis tribus vel quatuor in turmis uno vel duabus. Ubi in turma una, stratis tribus vel quatuor arcte adhaerentibus: stratum extimum hyalinum vel pallide hepaticum, 0.5-3  $\mu\text{m}$  crassum, stratum duo laminatum, cinnamomeum vel porphyreum, 6-30  $\mu\text{m}$  crassum, laminis usque ad 9, subaequalibus, saepe indistinctis; strata tria et quatuor hyalina, membranacea, utrumque circa 1  $\mu\text{m}$  crassum. Ubi in turmis duabus, turma externa stratis duabus: stratum extimum hyalinum vel pallide hepaticum 0.5-3  $\mu\text{m}$  crassum, ad stratum internum, cinnamomeum vel porphyreum, 6-30  $\mu\text{m}$  crassum, laminis usque ad 9, subaequalibus, saepe indistinctis, hae-

rens. Turma interna strato uno, hyalino, membranaceo, 1  $\mu\text{m}$  crasso; vel stratis duobus, hyalinis, membranaceis, utrumque circa 1  $\mu\text{m}$  crassum; vel strato uno, coriaceo, 2-3  $\mu\text{m}$  crasso. Hyphae sustentantes, crasse tunicatae prope sporam, inferne mox tenuiter tunicatae e hyalinae, strictae vel recurvae, plerumque proximale constrictae vel interdum strictae vel infundibuliformes, 15-27  $\mu\text{m}$  crassae ad basim spora, 18-37  $\mu\text{m}$  crassae ad locum latissimum. Peridium hyphis hyalinis vel hepaticis, tenuiter tunicatis, 5-20  $\mu\text{m}$  crassis, tumoribus numerosis, terminalibus vel intercalariis, globosis vel ovoideis, vacuis vel contentu granulosis vel cinnamomeis, 12-65 x 12-75  $\mu\text{m}$  crassis. Tumorum tunicae 1-2.5  $\mu\text{m}$  crassae, stratis duobus.

Sporocarps unknown. Spores formed singly, or in pairs or triplets adhering to each other by common peridial hyphae; orange brown to rich red-brown, to (rarely) fuscous black; globose to subglobose, 150-260 x 150-270  $\mu\text{m}$ , excluding the peridium. Spore wall structure (see micrograph, Fig. 12) of an outer peridium (P) that may be of loose, sparsely septate hyphae, or of compacted, collapsed hyphae, surrounding 3 or 4 walls (walls 1-4) in 1 or 2 groups (group A or groups A & B). When in a single group, group A consisting of 3 or 4 tightly adherent walls. Wall 1 a hyaline to pale yellow-brown unit wall, 0.5-3  $\mu\text{m}$  thick. Wall 2 laminated, orange-brown to red-brown 6-30  $\mu\text{m}$  thick, with up to 9 subequal laminae that often are indistinct. Walls 3 & 4 hyaline, membranous, each approximately 1  $\mu\text{m}$  thick. When in two groups, group A consisting of a thin unit wall (wall 1) tightly adherent to a thick laminated wall (wall 2). Wall 1 hyaline to pale yellow-brown, 0.5-3  $\mu\text{m}$  thick. Wall 2 orange-brown to red-brown, 6-30  $\mu\text{m}$  thick, with up to 9 subequal laminae that often are indistinct, and that may be somewhat loose toward the interior of the spore. Group B a single, hyaline, membranous wall (wall 3) 1  $\mu\text{m}$  thick (Fig. 3), or a pair of hyaline, membranous walls (walls 3 & 4), each approximately 1  $\mu\text{m}$  thick and apparently attached to each other by a thin, amorphous cement-like layer (Fig. 7); or a single, coriaceous wall, 2-3  $\mu\text{m}$  thick.

Subtending hyphae thick-walled proximally, but with the wall thickness rapidly diminishing from the point of connection to a thin-walled, hyaline, sparsely septate, parent hypha; straight or recurved; usually constricted proximally but occasionally straight or funnel-shaped; 15-27  $\mu\text{m}$  wide at the spore base, 18-37  $\mu\text{m}$  at the widest point, with the wall 2-8  $\mu\text{m}$  thick; pore in the spore wall closed partially by ingrowth of the inner laminae of the spore wall and partially by a granular plug. At the spore base, the subtending hypha usually appears to be inserted into the spore wall. Subtending hypha typically breaking off at the constriction, or from the parent hypha, 25-85  $\mu\text{m}$  below the spore base.

Figs. 1-2. Glomus globiferum. 1. Crushed spore with vesiculate swellings (V) of peridial hyphae. Note laminations of wall 2 (arrow) and loose lamination (L), X235. 2. Crushed spores with abundant vesiculate swellings of the peridial hyphae, X145.



Peridium of loosely interwoven hyaline to yellow-brown, coenocytic or sparsely septate, thin-walled hyphae, 5-50  $\mu\text{m}$  broad, bearing numerous terminal or intercalary globose to ovoid, pale yellow-brown or hyaline vesiculate swellings that have a shape and form similar to Glomus chlamydospores, and that either are empty, or have granular, orange-brown contents. Vesiculate swellings 12-65 x 12-75  $\mu\text{m}$ , with walls 1-2.5  $\mu\text{m}$  thick, consisting of a thin, hyaline outer unit wall, and a thicker, slightly colored inner laminated wall. The vesicle contents plasmolyze when specimens are placed in a hypertonic solution, but there is no sign of an enclosing membranous wall under light microscope observation. As the spores age, the peridial hyphae lose their contents and collapse to form a tight envelope of indistinctly plectenchymatous tissue.

#### DISTRIBUTION AND HABITAT

The species is known from the root zone of A. breviligulata growing in sand dunes at Cape May, New Jersey. The sand had a pH of 6.5 and a chloride level of 8.8 ppm. It also is known from beneath plants of A. breviligulata from Seashore State Park, Virginia and from the root zone of Artemisia sp. growing in sand dunes on the shores of Lake Michigan near Grand Mere, Michigan.

#### MYCORRHIZAL ASSOCIATIONS

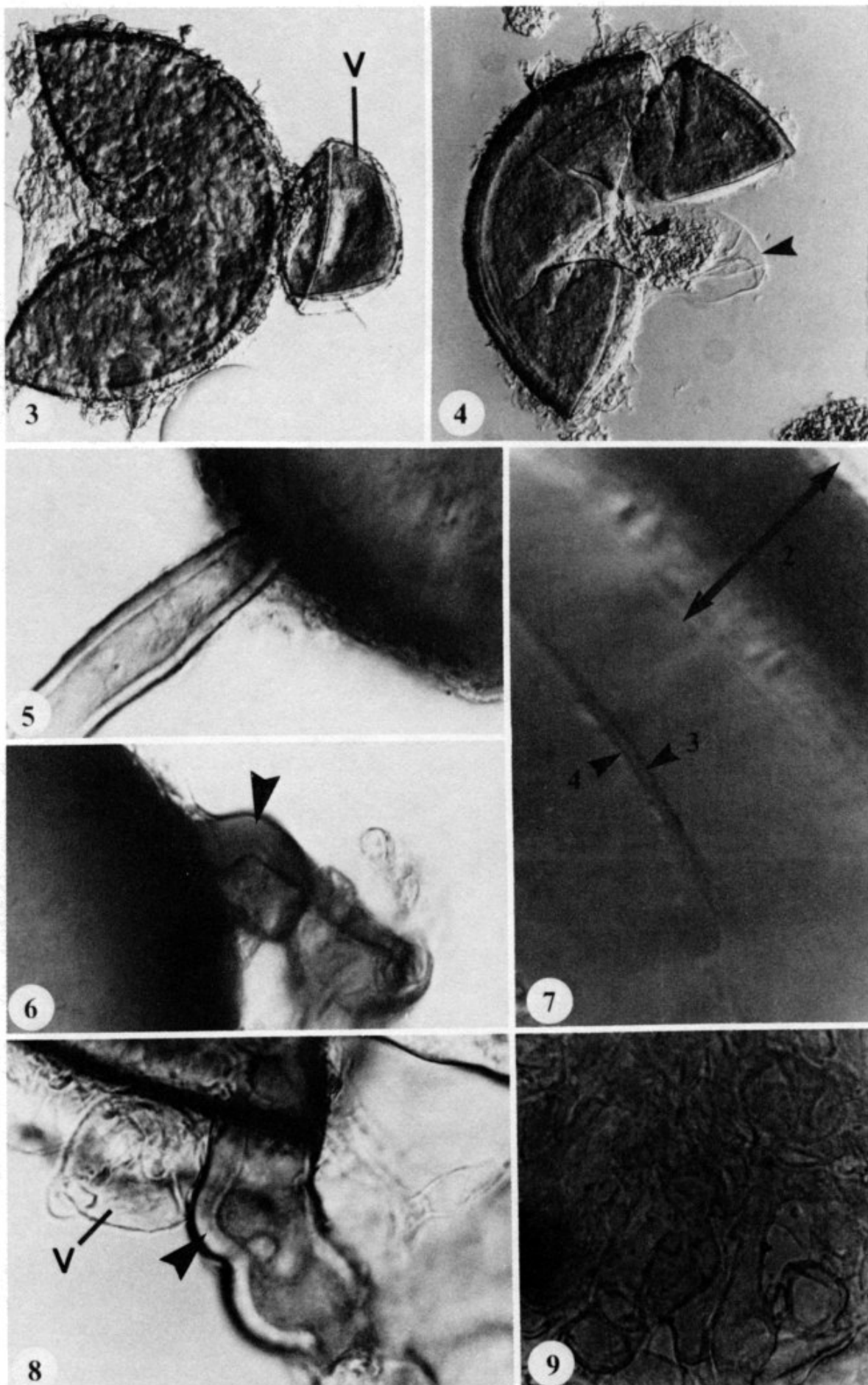
The mycorrhizal associations of Glomus globiferum are unknown. It is associated, but not proven mycorrhizal, with A. breviligulata and a species of Artemisia. Attempts to establish the species in pot culture with onion, clover, and soybean have failed.

#### ETYMOLOGY

From the Latin, globiferum ("sphere bearing"), referring to the spherical or near-spherical vesiculate swellings produced by the peridial hyphae on the outside of the spore.

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Figs. 3-9. Glomus globiferum. 3. Crushed spore with a large vesiculate swelling of peridial hypha. Rough appearance of spore is caused by the peridial hyphae, X140. 4. Crushed spore with innermost membranous wall visible (arrow), X140. 5, 6. Subtending hyphae. Note thick wall (arrow) on one side of the subtending hypha in 6, X550. 7. Spore walls. The thick no. 2 wall is shown as are the two membranous walls (walls 3 and 4) of wall group B, X1390. 8. Subtending hypha with unevenly thickened walls. Note thick wall (arrow) and vesiculate swelling of peridium, X550. 9. Peridial hyphae. Collapsed, irregular hyphae on spore surface, X550.



COLLECTIONS EXAMINED

HOLOTYPE: NEW JERSEY - Cape May County, Cape May. Among roots of A. breviligulata, 14 March 1982. Koske 400, Walker 535. (OSC; Isotypes FH, K). OTHER COLLECTIONS: VIRGINIA - Virginia Beach Township, Seashore State Park. Among roots of A. breviligulata, 23 April 1983. Koske 519: MICHIGAN - Berrien County, Grand Mere. Among roots of Artemesia sp., 23 August 1984. P. Olexia 8.

## DISCUSSION

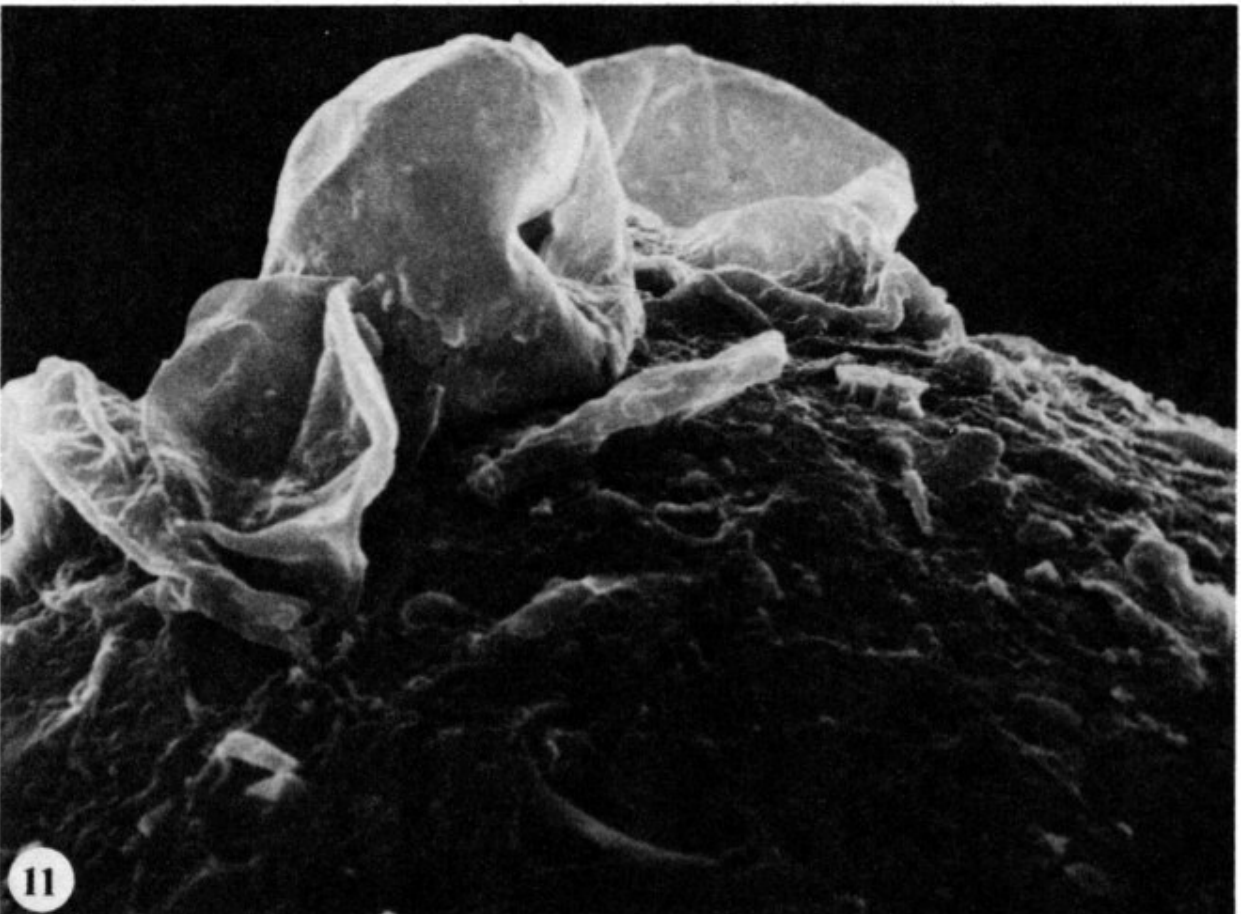
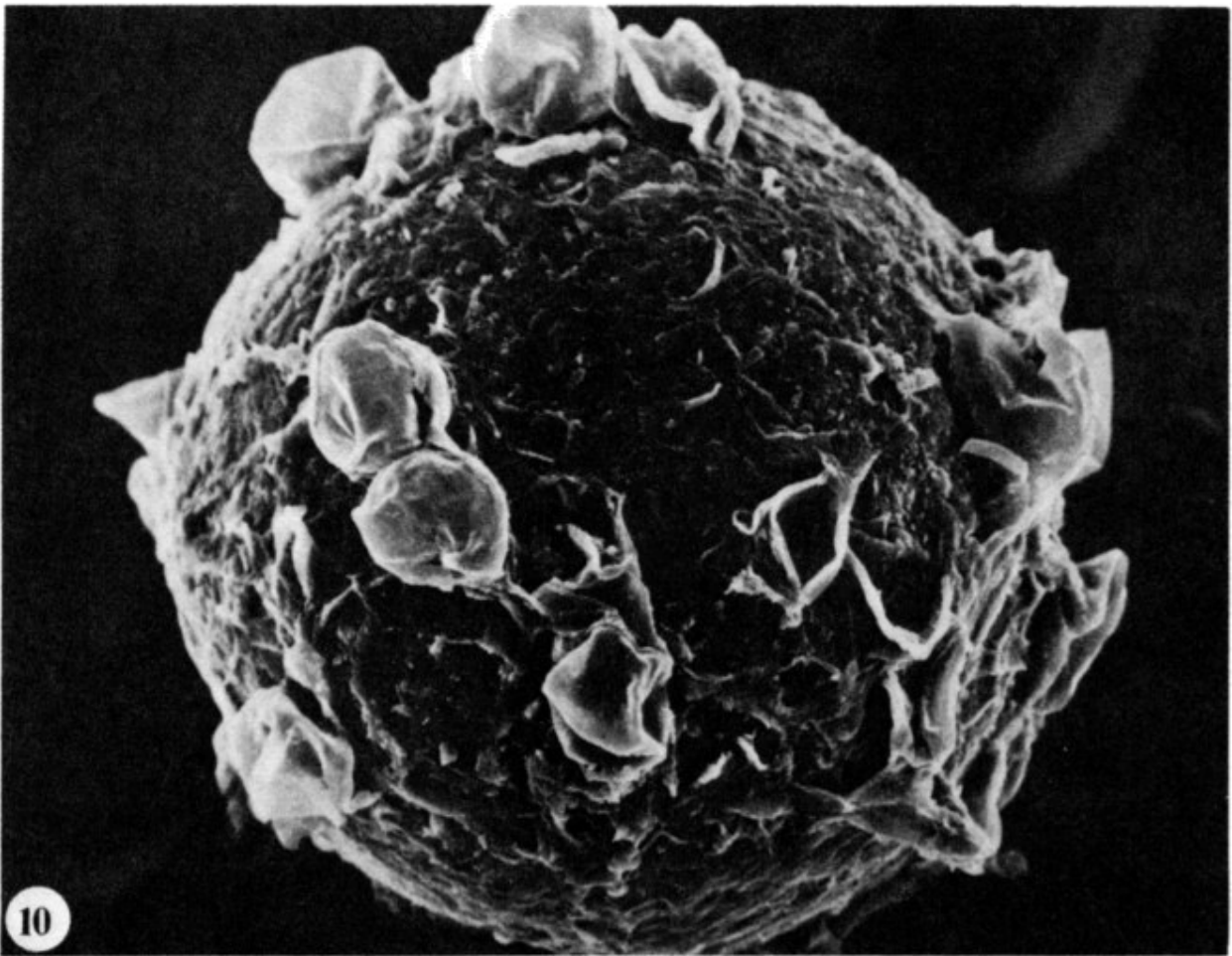
The peridial hyphae and their associated vesiculate swelling are particularly striking in this fungus (Figs. 1, 2, 3, 8-11). Although this species has not been maintained in pot culture, the color of the field-collected spores and the appearance of their contents indicate that younger specimens have a loose web of clearly distinguishable hyphae bearing the swellings, and the hyphae collapse to become plate-like as the spores age. When this collapse has occurred, it is difficult to distinguish individual hyphae in the peridium (Figs. 9, 11). The vesiculate swellings have the general appearance of small spores of a Glomus species. In common with spores, these vesiculate swellings may demonstrate wall thickening and the presence of septa occluding the contents, and under such circumstances, could perhaps be secondary chlamydospores.

The hyphal peridium was poorly developed on some spores in collections from New Jersey and Michigan. The collapsed hyphae on the spore surface were evident only at 1000X magnification, and these unusual specimens lacked the typical vesiculate swellings. The spores could be identified by their wall composition and the features of their hyphal attachment. A similar lack of peridial development can occur with some spores of Glomus tortuosum Schenck & Smith (Koske, personal observation).

The colored wall (wall 2) of G. globiferum is coarsely laminated, though the laminae are not always distinct. In some specimens, the innermost 1 or 2 laminae may separate from the rest when specimens are crushed on a microscope slide (Fig. 1), and thus give the erroneous impression of additional individual unit walls. Examination of a series of specimens will show that this is an artifact, and that this phenomenon does not occur consistently on spores of similar development.

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Figs. 10-11. Glomus globiferum. S.E.M. of spores. 10. Whole spore with peridium and vesiculate swellings, some of which have collapsed, X450. 11. Spore surface showing vesiculate swellings and collapsed peridial hyphae, X1175.



The constriction of the subtending hypha at the point of attachment to the spore is reminiscent of *G. constrictum* Trappe (1977), but, unlike that species, because of the way that the spore contents are occluded, the hypha often appears to be "inserted" into the wall of the spore. This phenomenon was originally reported for *G. epigaeum* Daniels & Trappe (= *G. versiforme* (Karsten) Berch), and is well illustrated by Daniels & Trappe (1979).

Collections in which most spores have been separated from their subtending hyphae at the point of attachment may be mistaken for an *Acaulospora* species, especially if the peridial hyphae and vesicles have collapsed. Examination of the spores at 1000X will reveal the characteristic peridium and wall structure.

*Glomus tortuosum* resembles *G. globiferum* in possessing a hyphal peridium and having spores that occasionally adhere in pairs, but the peridial hyphae of the former do not have vesiculate swellings, and are denser, and distinctly sinuate (Schenck and Smith, 1982). In addition, *G. tortuo-*

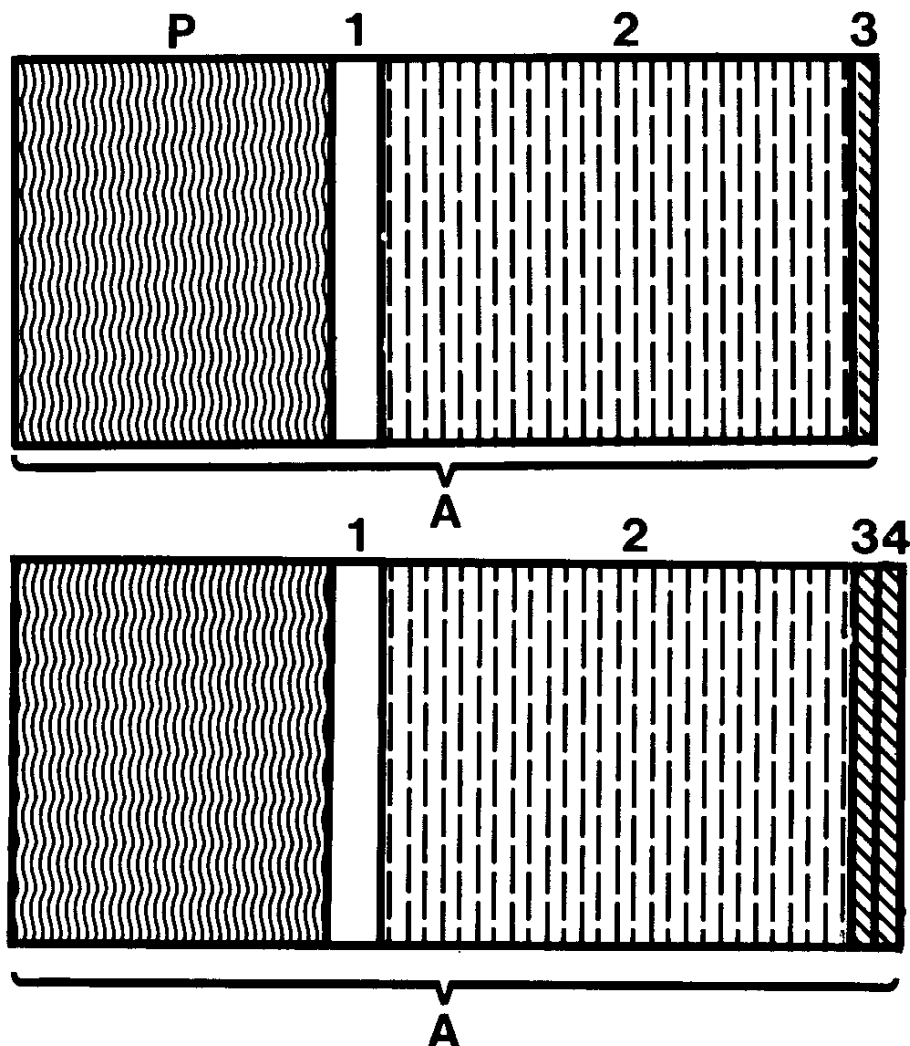
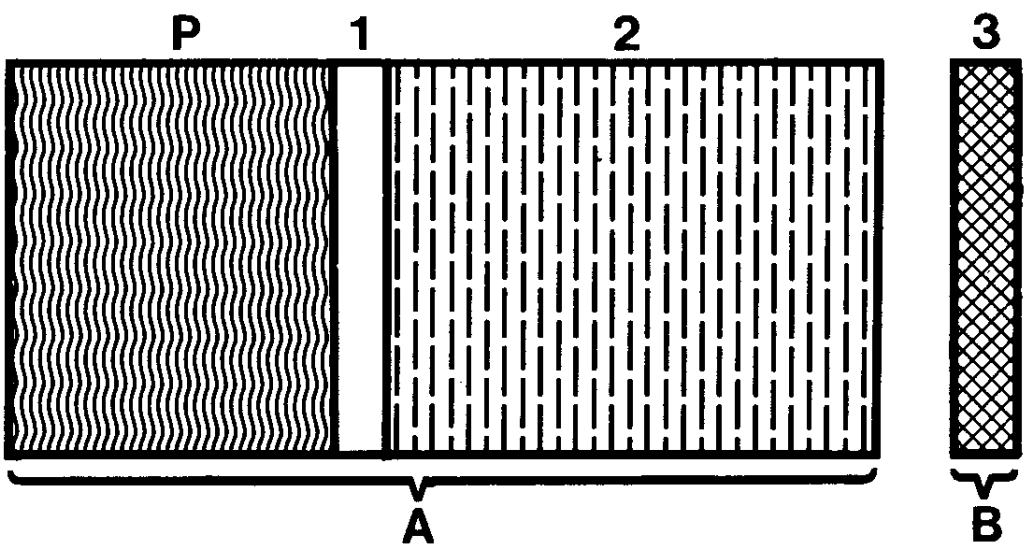
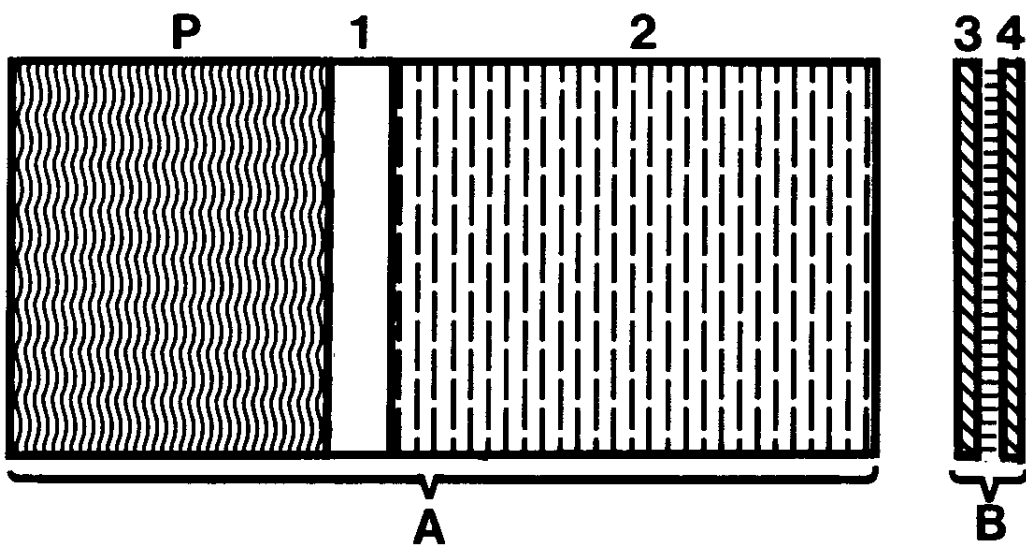
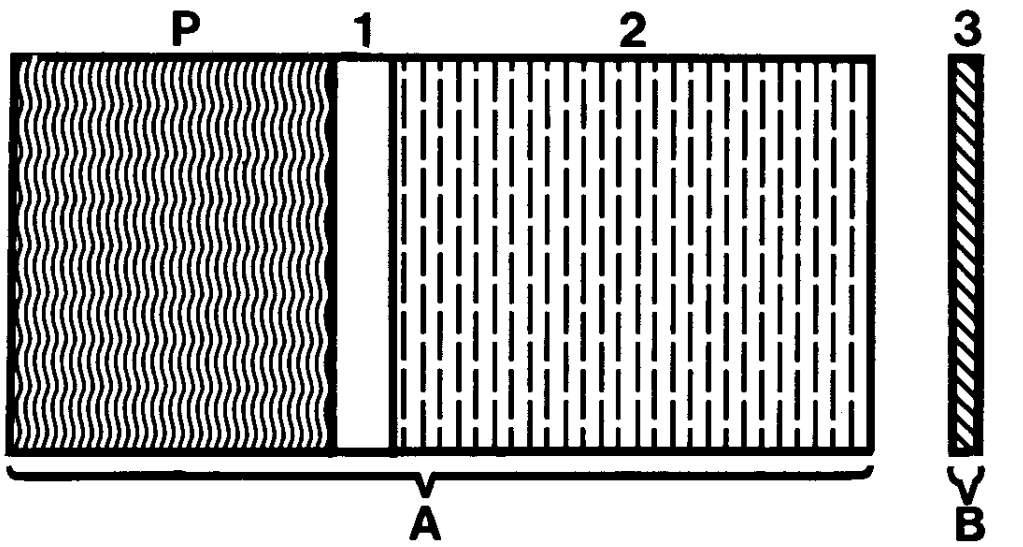


Fig. 12. Murographs of spore wall structure of *Glomus globiferum*. Five possible variations are shown above and on the facing page. See text for explanation.



sum spores are somewhat smaller than those of G. globiferum, although their size ranges do overlap. Spores of G. tortuosum are a smokey grey-brown color when viewed through a dissecting microscope, while those of G. globiferum typically are orange-brown to red-brown. Other species of Glomus that may have hyphal peridia are G. mosseae (Nicol. & Gerd.) Gerd. & Trappe, G. convolutum Gerd. & Trappe, and G. monosporum Gerd. & Trappe (Gerdemann and Trappe, 1974). None of these species has vesiculate swellings or are as dark as G. globiferum.

#### ACKNOWLEDGEMENTS

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