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TWO NEW MEMBERS OF THE MUCORALES

R. K. BENJAMIN

During the first and last years of the decade just past, two very unusual monotypic genera of thamnidiaceous mucors were described. Early in 1950, Poitras characterized *Cokeromyces recurvatus* and assigned the species to the family Choanephoraceae (Shanor, Poitras, and Benjamin, 1950). It soon was recognized that this fungus does not belong in the above family but, rather, is a member of the Thamnidiaceae (Poitras, 1950; Hesseltine, 1952). *Cokeromyces recurvatus* first was encountered on rabbit dung collected near Urbana, Illinois, in March, 1949. The species since has been collected in Iowa by R. W. Lichtwardt and several times in California by G. F. Orr and the writer.

In January of last year, Embree (1959) described *Radiomyces spectabilis* which had been isolated from lizard dung collected near Bishop, California, in September, 1957. *Radiomyces* also has been assigned to the Thamnidiaceae.

Both *Cokeromyces recurvatus* and *Radiomyces spectabilis* are strongly homothallic and lack multisporeous columellate sporangia. The former species develops rather restricted colonies in which the closely crowded sporophores arise directly from the substrate mycelia and reach heights of only 0.5-1 mm., whereas the latter species gives rise to abundant aerial mycelia forming sporophores near the ends of elongate stolons. Sporangio-phores of these species develop fertile vesicular enlargements terminally. In *Cokeromyces recurvatus*, pedicellate sporangiola arise directly from the vesicles, whereas in *Radiomyces spectabilis* these enlargements give rise to pedicellate secondary vesicles each bearing numerous nearly sessile sporangiola. The sporangiola of both species contain several sporangiospores.

The above species differ quite markedly in the character of their sexual structures. In both species, the zygospore is formed between opposed progametangia arising from aerial hyphae. The zygospores of *Cokeromyces recurvatus* are formed near the substrate and have dark colored, coarsely roughened walls as in *Thamnidium*, *Helicostylum*, and *Chaetocladium*; the suspensors lack appendages. The zygospores of *Radiomyces spectabilis* are formed at various levels above the substrate, have light brown or nearly colorless smooth walls, and their suspensors possess elongate, branched, acuminate appendages.

Among fungi isolated by the writer from rodent dung collected last fall in southern California a new representative of both *Cokeromyces* and *Radiomyces* was obtained. These new species compare in all essential characters with their respective genera, but they are characterized by unisporeous rather than multisporeous sporangiola.

Cokeromyces poitrasii sp. nov.

(Plates 1 and 2)

Coloniae in agaro YpSs "Deep Mouse Gray," restrictae, 1-2 mm. altae. Hyphis vegetantibus hyalinis, ramosis, nonseptatis, in aetate septatis, 2-25 μ diam. Sporangio-phoris rectis, simplicibus vel ramosis, in aetate pallido-fumosis, 1-2 mm. altis, 5-10 μ diam.; apicibus vesiculis globosas fertiles gerentibus. Vesiculis 25-75 μ diam., sporangiolas numerosas in pediculis brevibus vel longis gerentibus. Pediculis deciduis, 3-150 μ longis, 0.5-1 μ diam., rectis vel valide curvatis, vesiculas basales 1-1.5 $\mu \times$ 1-1.5 μ diam. gerentibus. Sporangiolis deciduis, de 1 spora, ovoideis, 8-14(-19) $\mu \times$ 6-9 μ , pallido-fumosis. Sporangii et sporangioli de sporis numerosis absentibus. Homothallicis. Zygosporis numerosis, globosis, nigris, (30-) 35-60(-70) μ diam. (med. 48 μ); episporio scabro; hyphis sexualibus hyalinis vel pallido-memnoniis, levibus, approximate aequalibus, oppositis.

Colonies on YpSs agar near Deep Mouse Gray (Ridgway, 1912, Pl. LI), restricted, forming compact turfs 1-2 mm. high, reaching 4-5 cm. in diameter in 14 days at 21°C. Vegetative hyphae hyaline, branched, becoming septate, 2-25 μ in diameter. Sporangio-phores arising from the substrate hyphae, more or less erect, usually unbranched, at first colorless, becoming light gray in age, 1-2 mm. high, 5-10 μ in diameter, forming globose fertile enlargements terminally. Apical enlargements 25-75 μ in diameter, giving rise, over their entire surfaces, to large numbers of pedicellate unisporous sporangia. Pedicels deciduous, of variable lengths, 3-150 μ long, uniformly 0.5-1 μ in diameter, nearly straight to strongly recurved, with slight basal enlargements about 1-1.5 $\mu \times$ 1-1.5 μ . Sporangia separating readily from their pedicels, ovoid, 8-14(-19) $\mu \times$ 6-9 μ , the pale gray sporangi-

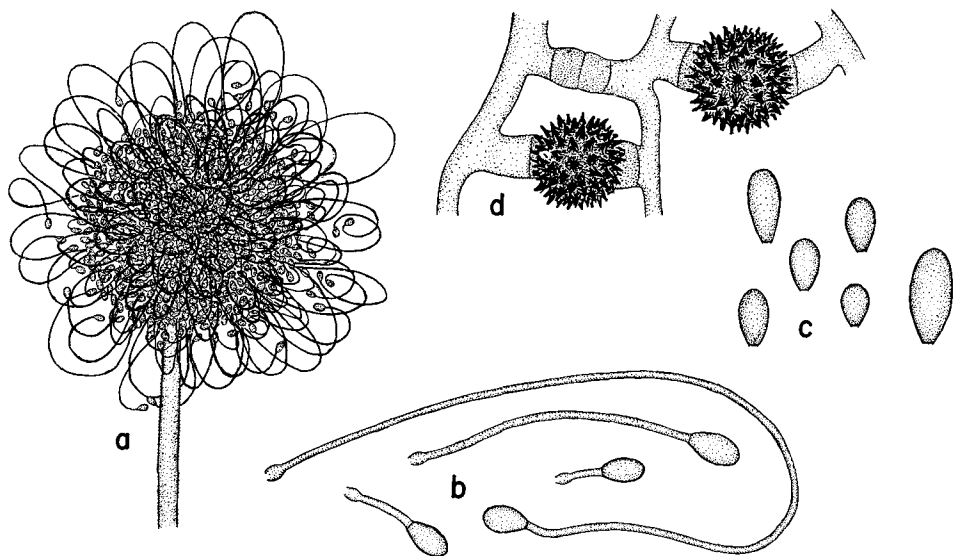


PLATE 1. *Cokeromyces poitrasii* Benjamin.—a. Apical portion of mature sporophore showing dense aggregate of sporangia around terminal vesicle and numerous sharply recurved pedicels of sporangia. \times 400. b. Four sporangia showing pedicels of varying lengths; note basal enlargements of pedicels. \times 1360. c. Six sporangia showing size range. \times 1360. d. Two mature and one immature zygospores showing conformation of suspensors. \times 360.

olar membranes separating readily from the sporangiospores. Multisporous sporangia and sporangia absent. Homothallic. Zygospores formed in great numbers between opposed progametangia arising from aerial hyphae near the surface of the substrate; zygospores globose, black, coarsely roughened with conical, blunt, rounded, or pointed projections 5-10 μ high, (30-)35-60(-70) μ in diameter (aver. 48 μ) including projections. Suspensors hyaline to pale brownish-black, nearly equal, smooth.

Holotype.—CALIFORNIA. Riverside County: San Jacinto Mts., about 15 miles southwest of Palm Desert, September 2, 1959, isolated from rat dung (RSA Culture 903). Dried specimens have been placed in the Mycological Collections of the Rancho Santa Ana Botanic Garden, and transfers of the type culture have been deposited in the American Type Culture Collection, Washington, D. C., Centraalbureau voor Schimmelcultures, Baarn, Netherlands, and Commonwealth Mycological Institute, Kew, Surrey, England.

Like *Cokeromyces recurvatus*, *C. poitrasii* grows well, if rather slowly, on Emerson's

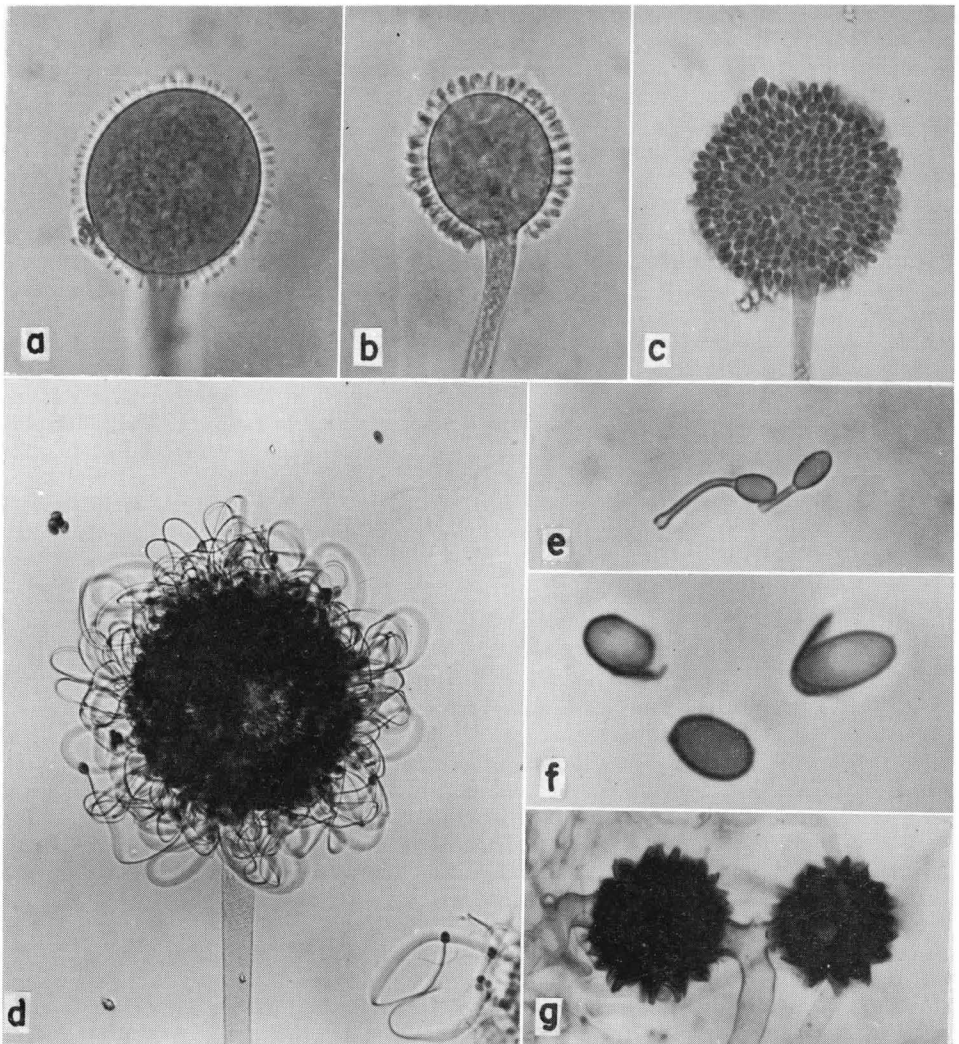


PLATE 2. *Cokeromyces poitrasii* Benjamin.—a-c. Three immature terminal vesicles of sporangiophores showing successive stages in the development of sporangiola. $\times 560$. d. Apical portion of mature sporophore. $\times 340$. e. Two detached sporangiola with relatively short pedicels. $\times 1300$. f. Three sporangiola; two of these show the sporangial membranes beginning to slough away. $\times 2330$. g. Two mature zygospores. $\times 310$. (Specimens shown in Fig. f living; others mounted in KOH-Phloxine.)

YpSs agar and forms colonies consisting almost entirely of densely crowded sporophores and hyphae forming zygospores near the surface of the substrate. There is little or no sterile aerial growth in vigorously sporulating cultures. The turfs of *C. poitrasii* usually are 1-2 mm. deep, whereas those of *C. recurvatus* rarely exceed 0.5 mm. In color, the colony of *C. poitrasii* approaches Deep Mouse Gray of Ridgway; the colony of *C. recurvatus* often appears nearly black, being close to Blackish Brown (2) of Ridgway (1912, Pl. XLV). General characteristics of the vegetative mycelia and the manner of formation of sexual

and asexual reproductive structures are very similar in both species of *Cokeromyces*.

The erect, usually somewhat curved, sporophores of *C. poitrasii* are terminated by subglobose to slightly ovoid vesicles giving rise over their entire surfaces to numerous slender outgrowths (Pl. 2a) which immediately become enlarged distally and form ovoid sporangiola initials (Pl. 2b). Each initial reaches nearly definitive size prior to elongation of the pedicel which elevates the sporangiolum above the surface of the fertile vesicle (Pl. 2c). The lengths of the pedicels vary greatly so that the sporangiola are borne at varying levels above the surface of the vesicle with many of the more elongate pedicels strongly arched beyond the mass of sporangiola (Pl. 1a; Pl. 2d).

Sporangiola with their attached pedicels are readily detached from the subtending vesicles. Each pedicel is slightly enlarged immediately above the fertile vesicle and separates from the latter near the base of this swelling (Pl. 1b; Pl. 2e). The sporangiola, likewise, are easily separated from their pedicels and appear truncate at their bases as a result of the slightly projecting sporangial membranes (Pl. 1c; Pl. 2f). Sporangiola are pale gray in color; most of the pigment imparting this color is located in the sporangial membrane which readily separates from the nearly colorless sporangiospore (Pl. 2f). The latter phenomenon can easily be demonstrated in slide mounts of sporangiola—especially when the sporangiola are supported by thin films of agar.

Sexual reproductive structures of *C. poitrasii* (Pl. 1d; Pl. 2g) are similar in all respects to those of the type species, except that the zygospores are nearly black rather than dark brown as in *C. recurvatus*.

Radiomyces embreei sp. nov.

(Plates 3, 4, and 5)

Coloniae in agaro YpSs albae, in aetate "Light Buff," expansae, effusae, mucoroideae, 1-2 cm. altae. Hyphis vegetantibus hyalinis, ramosis, 8-20 μ diam., nonseptatis, in aetate septatis, hyphas aerias numerosas simplices vel ramosas gerentibus. Hyphis aeriis 5-15 μ diam. sporangiophora praelonga simplices vel ramosa pallido-brunnea 0.5-3.5 cm. longa \times 4-15 μ diam. et stolones numerosos gerentibus. Stolonibus prope hyalinis, sporangiophora 1 vel 2 subterminalia rhizoideis subtensa gerentibus. Sporangiophoris stoloniferis (0.6-) 0.8-1.4(-2) mm. longis \times 6-17 μ diam., levibus, de muris crassis, pallido-brunneis. Stipitibus sporangiophororum vesiculas terminales subglobasas vel nonnihil clavatas 10-60 μ diam. gerentibus. Vesiculis 3-80 ramos fertiles gerentibus. Ramis fertilibus praelongis simplicibus, 20-120 μ longis, in pediculis cylindricis, 3-40 μ longis \times 3.5-6 μ diam., et in vesiculis fertilibus clavatis terminalibus consistentibus. Vesiculis fertilibus 10-18 μ diam. sporangiolas in spinis brevibus 0.5-2 μ altis gerentibus. Sporangiolis deciduis, de 1 spora, 5.7-10.9 μ \times 3.9-7 μ . Sporangii et sporangiolis de sporis numerosis absentibus. Homothallicis. Zygosporis numerosis, globosis, levibus, pallido-brunneis, (35-)40-62(-68) μ diam. (med. 51 μ); hyphis sexualibus pallido-brunneis, levibus, approximate aequalibus, oppositis, 5-7 appendices ramosas gerentibus.

Colonies on YpSs agar at first white, near Light Buff (Ridgway, 1912, Pl. XV) in age, widespreading, forming lax, mucoroid turfs 1-2 cm. high in 14 days at 21°C. Vegetative hyphae hyaline, branched, 8-20 μ in diameter, becoming septate, giving rise to abundant simple or branched aerial hyphae 5-15 μ in diameter. Aerial hyphae forming elongate, simple or branched, dark brown sporangiophores, 0.5-3.5 cm. long by 4-15 μ wide, bearing fertile heads terminally; numerous sporangiophores also borne, usually singly, near the ends of stolons terminating in rhizoids. Stolons nearly colorless, up to 2 cm. or more long, 5-15 μ wide. Rhizoids dark brown, consisting of 1-7 main branches with few laterals. Portions of stolons between rhizoids and sporangiophores smooth, thick-walled, dark brown, 60-150 μ long. Main stalks of stoloniferous sporangiophores (0.6-)0.8-1.4(-2) mm. long \times 6-17 μ wide, smooth, thick-walled, dark brown. Stalks of sporangiophores terminating

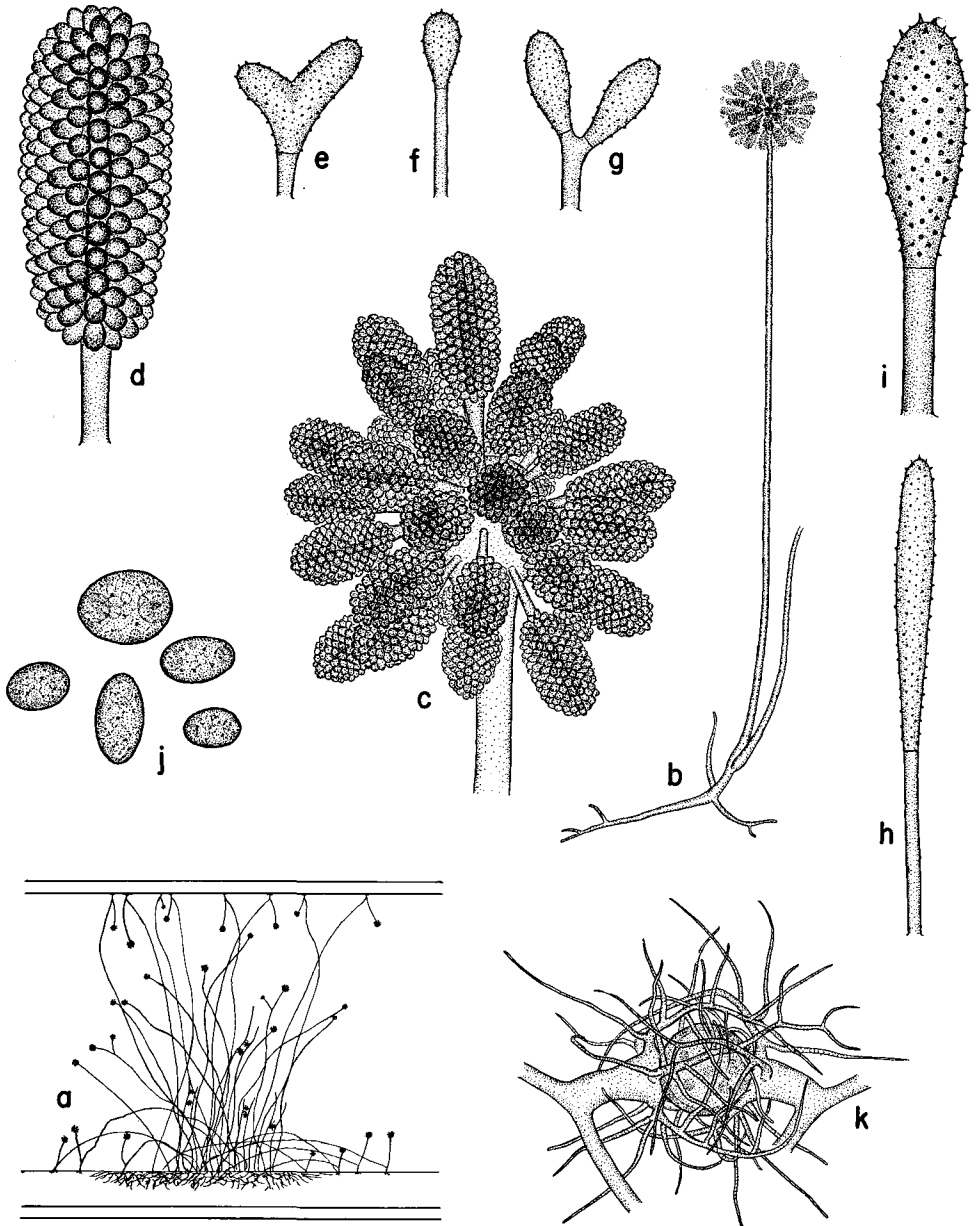


PLATE 3. *Radiomyces embreei* Benjamin.—a. Semidiagrammatic habit sketch of colony growing on agar in Petri dish showing stoloniferous and nonstoloniferous sporangiohores. $\times 5$ (Sporangiohores.) b. Stoloniferous sporangiohore. $\times 60$. c. Apical portion of mature sporophore showing conformation of fertile branches arising from terminal vesicle. $\times 290$. d. Fertile branch before sporangia have fallen away. $\times 780$. e-h. Fertile branches after sporangia have fallen away; these show typical variations from the usual type branch shown in the next figure. $\times 360$. i. Typical fertile branch after sporangia have fallen away; note septum separating pedicel from clavate fertile portion and the spine-like prominences on which the sporangia were borne. $\times 780$. j. Five sporangia showing size range. $\times 1360$. k. Mature zygospore showing suspensor appendages. $\times 240$.

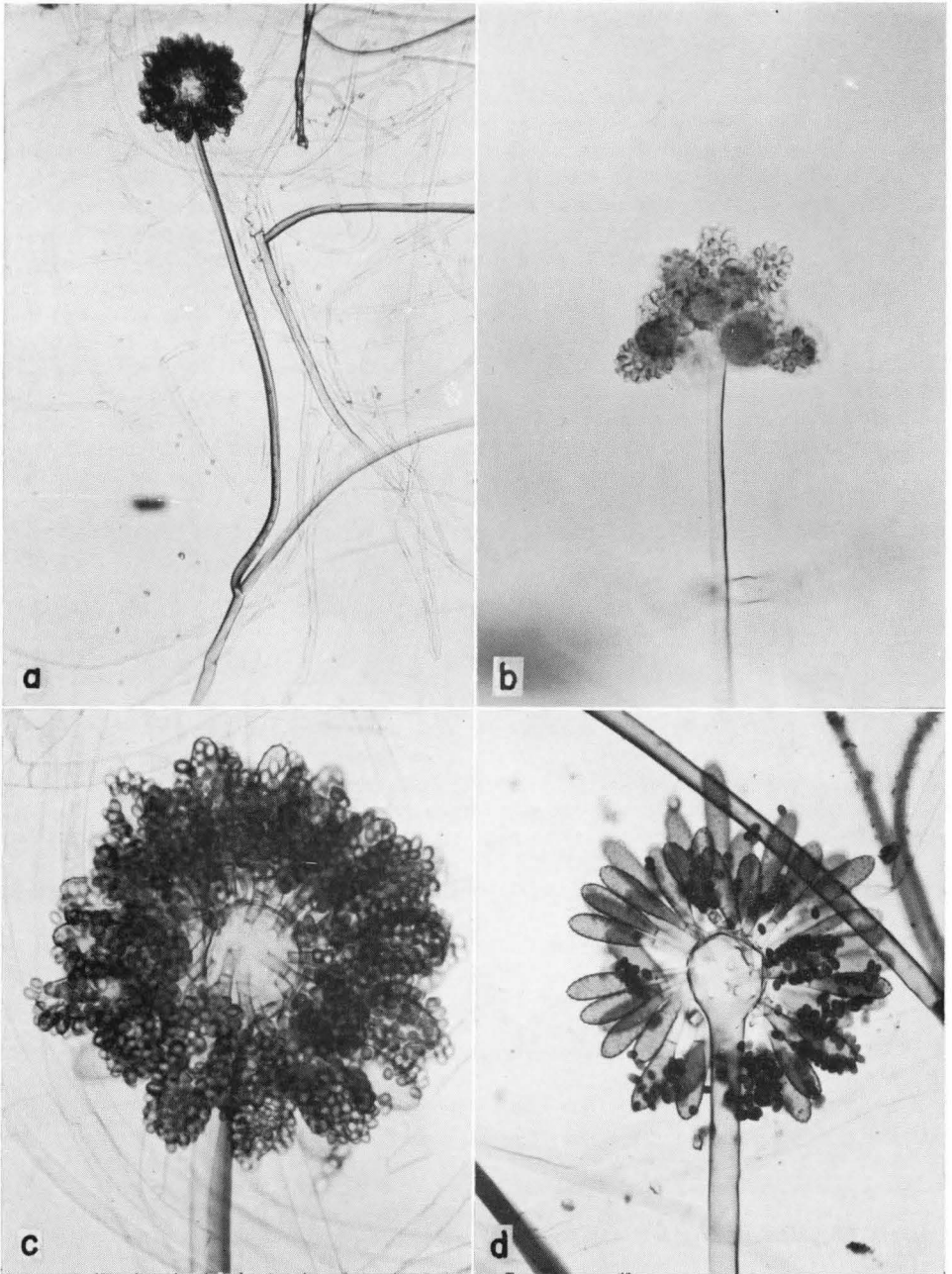


PLATE 4. *Radiomyces embreei* Benjamin.—a. Stoloniferous sporangiophore. $\times 80$. b. Apical portion of nearly mature sporophore showing conformation of fertile branches. $\times 220$. c. Apical portion of mature sporophore showing numerous fertile branches with most of the sporangia still attached. $\times 310$. d. Apical portion of sporophore showing terminal vesicle with attached fertile branches from which most of the sporangia have fallen. $\times 220$. (Specimens mounted in KOH-Phloxine.)

in subglobose or slightly clavate vesicles 10-60 μ in diameter, bearing 3-80 fertile branches. Fertile branches elongate, usually simple, 20-120 μ long, consisting of cylindrical pedicels, 3-40 μ long \times 3.5-6 μ wide, subtending clavate vesicular enlargements, 10-18 μ in diameter, bearing sporangia on short spine-like prominences, 0.5-2 μ high, over their entire surfaces. Fertile vesicles usually separated from their pedicels by cross walls at maturity. Sporangia deciduous, containing single spores, 5.7-10.9 μ \times 3.9-7 μ ; the sporangial walls not readily distinguishable from the spore walls. Multisporous sporangia and sporangia absent. Homothallic. Zygosporangia formed in large numbers between opposed progametangia arising from aerial hyphae at all levels above the substrate. Suspensors becoming appendiculate; appendages 5-7 on each suspensor, branched, loosely investing the zygosporangia, light brown, slender, acuminate, the longest main axes reaching as much as 225 μ long. Zygosporangia

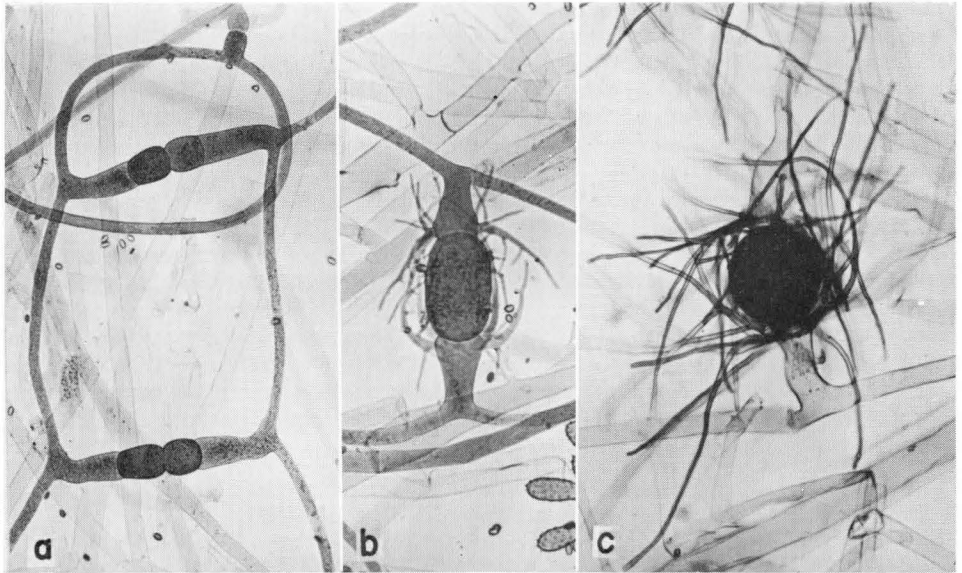


PLATE 5. *Radiomyces embreei* Benjamin.—a. Two immature sexual structures showing opposed suspensors bearing terminal gametangia which have fused. \times 170. b. Immature sexual structure showing enlarging zygosporangium and early stages of development of suspensor appendages. \times 220. c. Mature zygosporangium showing conformation of suspensor appendages. \times 220. (Specimens mounted in KOH-Phloxine.)

smooth, light brown, (35-)40-62(-68) μ in diameter (aver. 51 μ); the walls 2-5 μ thick.

Holotype.—CALIFORNIA. San Bernardino County: Northeast slope of Coxcomb Mts., about 40 miles east of Twentynine Palms, October 12, 1959, isolated from mouse dung (RSA Culture 914). Specimens and cultures distributed as for *Cokeromyces poitrasii*.

Growth and development of the vegetative and aerial mycelia of *Radiomyces embreei* and the type species, *R. spectabilis*, are nearly identical. Certain minor differences in fruiting characters do exist, however, between the single strains of each of the above species available for study. On ordinary media such as YpSs, CM, and ME-YE (Benjamin, 1959, p. 322), *R. embreei* typically gives rise to very large numbers of sporangiophores relative to the number produced by *R. spectabilis*. Also, nonstoloniferous sporophores are common in *R. embreei*, whereas they are rather rare in *R. spectabilis*. Conversely, on the above media, zygosporangium production is much greater in *R. spectabilis* than in *R. embreei*; on ME-YE, *R. spectabilis* forms zygosporangia in such abundance that cultures grown in test-tubes become

nearly black in color after about a week—a beautiful violet color after only three or four days. The sexual structures of both species of *Radiomyces* are, however, quite similar; it is in the nature of the fertile heads of the sporangiophores, and especially the character of the sporangia, that the species differ most conspicuously.

The sporophores of both species of *Radiomyces* form terminal vesicular enlargements which give rise to pedicellate fertile branches. In *R. spectabilis*, these branches consist of slender, elongate pedicels terminated by nearly globose vesicles over the surfaces of which numerous sporangia containing about 5-12 smallish, reniform to oblong elliptical, sporangiospores are borne on slender projections 1-2 μ high. The walls of the sporangia are ornamented with spine-like prominences, 1-2 μ long, terminating in swollen tips. Single septa are delimited in the pedicels of the fertile branches at an average distance of 11.5 μ below the vesicles.

Like those of *R. spectabilis*, the fertile branches of *R. embreei* consist of slender pedicels terminating in vesicles bearing sporangia on spinose prominences. In *R. embreei*, the vesicles usually are long-clavate rather than globose and septa are delimited in the pedicels immediately below the fertile regions (Pl. 3c-i; Pl. 4c-d); also, the ovoid sporangia contain single spores. The walls of the sporangia of *R. embreei* are unadorned and are distinguishable from the walls of the sporangiospores with difficulty only at the time of spore germination (Pl. 3j).

Early stages of zygospore formation in *R. embreei*, as in *R. spectabilis*, are *Mucor*-like and resemble those found in other known sexual species of the Thamniaceae (Pl. 5a). As the young zygospore enlarges, appendages develop adjacent to the zygospore at apparently the same rate on each suspensor (Pl. 5b) and, when mature, are similar to those formed on the suspensors of the type species (Pl. 3k; Pl. 5c). Mature zygospores are nearly globose, smooth-walled, and light brown in color. The zygosporangial membrane is thin, about 1 μ thick. The average diameter of the zygospores of *R. embreei* is about 15 μ less than that of *R. spectabilis*, and the numerous oil-like droplets within the maturing zygospores of the former species do not regularly coalesce to form single large droplets as in the latter.

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