New and unidentified Species of Synchytrium I.

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In the preparation of a monograph of the genus *Synchytrium* the author has been studying the species deposited in herbaria in the United States and elsewhere, and these studies (1953—1956) have revealed new data about long-known species and brought to light several new ones. The present contribution concerns additional species on new hosts which have not been reported in the literature on *Synchytrium.* Most of these species were studied first from dried herbarium material after which heavily infected bits of the hosts were soaked thoroughly in water, fixed in a vacuum to remove air, embedded in paraffin, sectioned and stained. Although the host tissue in such sections was badly shrunken, the prosori, sori, sporangia and resting spores of the fungi were well enough preserved to show their characteristics. Nevertheless, these structures also were slightly shrunken, and it should be noted that the measurements given below were taken from such material. Quite probably these structures will prove to be somewhat larger in the living state. The descriptions of the galls and the measurements of them relate to separate and isolated ones on the host leaves. The species described below on *Morus, Rhus, Rubus, Solidago,* and *Populus* were collected by the author and were studied in the living condition and from prepared sections of such material. Those on *Senecio, Mertensia* and one species of *Saxifraga* were studied from Cook's herbarium specimens and slides, which he prepared from living material collected by Drs. J. N. Couch and W. G. Solheim in Wyoming.

In addition to the diagnoses of new species descriptions are given of several unidentified ones. All of these occur on new hosts and have not been reported previously, but it is not certain that they are distinct and new species. They are not fully known, and it is possible that with further study some of them may prove to be identical to long-known species. For this reason the author does not believe that it is worthwhile to give them specific names which may prove to

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be synonyms. Nevertheless a description of them here will draw attention to their occurrence and may lead to further study of them by collectors. They appear to be short-cycled, or at least only resting spores are present in the material at hand. Most collectors are inclined to name such species with colored spore content and composite galls as *S. aureum* without describing them, and in doing so they follow the lead of Schroeter (1885). Schroeter (1870) first found this species on ***Lysimachia nummularia, Cardamine pratensia*** and ***Prunella vulgaris*** and described it fully on the first of these hosts. In 1885, however, he reported it on 80 additional hosts in 30 families of flowering plants but did not study and compare the fungi on the different hosts. Most collectors have followed this precedence, which has resulted in the present-day confusion regarding *S. aureum* and the reports of its occurrence on 196 host species. As Rytz's (1932) studies suggest, probably several species are included in this binomial, and this problem will not be cleared up until all collections have been adequately described and compared with type specimens Furthermore, intensive host range studies must be made to supplement morphological and developmental data.

Synchytrium salviae sp. nov.

Prosoris subsphaericis, 102—162 μ; parietibus 2—2.8 μ crassis. Sorus subsphaericis, 110—170 μ, ovalibus, 130—160 ⇌ 148—180 μ; parietibus 1.8 μ crassis, hyalinis. Sporangiis 30—55 per soris, polyedricis, 39—52 μ; parietibus levibus, hyalinis. Sporis perdurantibus subsphaericis, 80—120 μ, ovalibus, 92—115 ⇌ 110—126 μ; parietibus levibus, 4.8 μ, crassis; germinatione ignota. Specimen typicum in herb. Univ. Calif., Berkeley, conservatum, Tracy, no. 10006.

Prosori usually solitary, subspherical, 102—162 μ; wall light-amber and up to 2.8 μ thick, usually lying in apex of infected cell when empty and partly enveloped by residue. Sori subspherical, 110—170, or oval, 130—160 ⇌ 148—180 μ, with a thin, 1.8 μ, wall; plugs between sori and prosori 14—18 μ diam. by 9—11 μ thick. Sporangia 30—55 per sorus, polyhedral, 39—52 μ in greatest diam. with a thin hyaline wall and finely-granular light-yellow content. Zoospores unknown. Resting spores subspherical, 80—120 μ, ovai, 92—115 ⇌ 110—126 μ, with a smooth, amber, 2.8 μ, exospore and a hyaline, 2 μ, endospore and yellowish granular content; enveloped by a closely adhering layer of residue which is very thick in apex of infected cell; germination unknown.

Compositely dihomeogallic, sporangial and resting-spore galls scattered or crowded and confluent, partly embedded in host tissue; sporangial galls light-tan to light-brown, almost hemispherical on surface of host, 168—204 μ high by 192—288 μ broad, sheath 2—4 cells thick; resting spore galls brilliantly lavender to lavender-violet,

almost hemispherical, 150—190 μ high × 180—260 μ broad, sheath 2—4 cells thick with cells next to the infected one thick-walled.

On leaves, petioles and stems of *Salvia sessilis,* east of Gasquet, Del Norte Co., Calif., (leg. H. E. Parks and J. P. Tracy, 5-15-1932).

The herbarium packet of this species is labeled *S. aureum,* but this is obviously incorrect because *S. aureum* is a short-cycled species. So far six species, *S. aureum, S. marrubi, S. rytzii, S. cellulare, S. holwayi* and *S. stachydis,* have been reported on members of the *Labiatae,* and among these only the last three are unquestionably long-cycled and develop a prosorus in the summer cycle like *S. salviae. Synchytrium rytzii* probably develops a prosorus and is long-cycled also but its status in this respect has not been conclusively settled. Accordingly, on the basis of hosts *S. salviae* is to be compared primarily with *S. holwayi, S. cellulare* and *S. stachydis.* Its resting spores are fairly similar in size and shape to those of these species, but its sori and particularly its sporangia are much larger. Also, it differs from *S. holwayi* and *S. cellulare* by the apical position of its empty prosorus, but is similar in this respect to *S. stachydis.* The latter species, however, may form up to 150 small sporangia whereas in *S. salviae* only 30—55 large sporangia are formed. Although *S. salviae* is similar to *S. holwayi* and *S. stachydis* in being compositely dihomeogallic it differs from *S. cellulare* which is diheterogallic. The differences which *S. salviae* exhibit appear to be quite significant at present, and for this reason the author regards it as a different and distinct species.

Synchytrium eremocarpae sp. nov.

Soris subsphaericis, 60—110, ovalibus, 78—85 ⇌ 98—124 μ; parietibus hyalinis. Sporangiis 25—36 per sorus, polyedricis, 18—44 μ. Sporis perdurantibus sphaericis, 52—90, ovalibus, 58—65 ⇌ 62—78 μ; parietibus levibus, 3—3.8 μ crassis; germinatione ignota. Specimen typicum in herb. Univ. Calif., Berkeley, conservatum, Clemens no. 10800.

Sori solitary, subspherical, 60—110 μ, or oval, 78—85 ⇌ 98—124 μ, with a thin hyaline wall. Sporangia 25—36 per sorus, polyhedral, 18—44 μ in greatest diam. with finely granular content and a thin hyaline wall. Resting spores up to 5 in a cell, 2 and 3 fairly common, spherical, 52—90 μ, oval, 58—65 ⇌ 62—78 μ, with an amber to light-brown, 3—3.8 μ thick, smooth wall and coarsely garnular content; enveloped by a sparse or rather abundant amount of residue; germination unknown.

Simply dihomeogallic, sporangial and resting-spore galls usually crowded, broadly obpyriform, 156—234 μ high by 144—186 μ in broadest diam., occasionally almost spherical, 150—170 μ, wall hyaline and up to 4 μ thick; galls appearing dark amber-brown from

included residue, invaginating at apex after drying out to become broadly cup-shaped, or collapsing and looking like empty insect eggs.

On lower leaves, petioles and stems of *Eremocarpus* sp., Griffiths Park, Los Angeles, Calif., causing stunting and distortion of young leaves. (Leg. M. S. Clemens, 3-4-1922).

No evidence of a prosorus was found in fixed and stained sections of the sporangial galls, but this species is, nevertheless, long-cycled and may belong in either *Eusynchytrium* or *Exosynchytrium* depending on whether the resting spores function as sporangia or prosori during germination. *Eusynchytrium* includes two other simply dihomeogallic species, *S. papillatum* and *S. trichophilum,* but so far no species with this type of galls are known to occur in *Exosynchytrium.* Although *S. eremocarpae* is generally similar to the above species by the type of galls which it causes, its galls nonetheless, do not become papillate and develop an „abscission" ring at the base as reported in *S. papillatum.* Furthermore, its sporangia are considerably larger than those of *S. trichophilum* and *S. papillatum,* and its sorus is usually smaller than that of the latter species. Its resting spores, on the other hand, are fairly similar in size and shape to those of these two species. It differs, also, from them by its host. *Synchytrium papillatum* and *S. trichophilum* occur on species of the families Geraniaceae and Boraginaceae, respectively, while *S. eremocarpae* occurs on a member of the Euphorbiaceae. However, until host range studies on *S. eremocarpae* have been made it is not certain how significant this difference may be. So far only two other species, *S. mercuriales* and *S. phyllanthicolum* have been reported on the Euphorbiaceae, but these species are short-cycled and quite unlike *S. eremocarpae.*

In connection with these two long-cycled species it may be noted that the author found evidence of a prosorus in the so-called summer cycle of *S. andinum* on *Ranunculus californicus* from California (leg. McMurphy, 1913). The prosorus was overlooked by Patouillard and Lagerheim (1895) and McMurphy (1913), and *S. andinum* was, accordingly, regarded as a member of the subgenus *Eusynchytrium.* In sections of sporangial galls the prosorus is subspherical, 98—140 μ, with a thin amber wall and lies in the base of the infected cell below the sorus when empty. Its presence indicates that *S. andinum* may belong in *Microsynchytrium*, and it is accordingly placed temporarily in this subgenus.

Synchytrium lithophragmae sp. nov.

Sporus perdurantibus subsphaericis, 56—74, ovalibus, 50—60 ⇌ 72—96 μ; parietibus levibus, fuscis, 3.5—4 μ, crassis; germinatione

ignota. Specimen typicum in herb. State Coll. Wash. conservatum, nos. 21287, 36926 and 23732.

Resting spores usually solitary, subspherical, 56—74 μ, or oval, 50—60 ⇌ 72—96 μ, with a smooth brown wall, 3.5—4 μ thick; enveloped by a crumbly and irregular globular, or dense and compact layer of residue which may fill remainder of cell; germination unknown.

Compositely monogallic, resting-spore galls usually separate and scattered, occasionally crowded and confluent, small, 120—167 μ high by 144—205 μ broad at base; oval to oblong infected cell protruding conspicuously and largely exposed; sheath occasionally reduced to a basal fringe of cells so that galls may be almost simple.

On the upper surface of leaves of *Lithophragma bulbifera,* Sawtooth Natl. Park, Custer Co., Idaho (leg. C. L. Hitchcock and C. U. Mulick, 8-1-1944) and Eagle Lake, Headwall, Okanogan Co., Wash. (leg. C. G. Shaw, 6-19-1950), and *L. parviflora,* Bartlett, Wallowa Co., Ore. (leg. C. G. Shaw, 4-21-1951).

This is the first species to be described on *Lithophragma,* but five other short-cycled species, *S. chrysosplenii, S. aureum, S. groenlandicum, S. rubrocinctum* and *Synchytrium* sp. have been reported on other genera of the *Saxifragaceae.* The present species usually induces galls which are markedly different in appearance from those caused by the other species. In the dried herbarium species the galls were almost black but when soaked in water they become lavender-red to dubonnet. In most of the galls the sheath is usually reduced to a few greatly enlarged epidermal cells, so that a great part or most of the infected cell is exposed. Sometimes the sheath consists only of a few slightly raised epidermal cells around the base of the host cell, and in such cases the galls appear to be almost simple and unicellular. However, a few galls were found in which the sheath extended almost to the apex of the infected cell, but here also it was composed of a single layer of greatly enlarged cells. In rare cases the galls were embedded almost completely in the leaf tissue. Accordingly, they may vary markedly, but the majority of the galls are not very complex in structure. Another conspicuous difference is that the wall of the infected cell is usually greatly thickened, up to 7 μ, and had several scalariform perforations like tracheary elements. Also, the resting spores of *S. lithophragmae* are usually smaller than those of other species reported on members of the Saxifragaceae.

Synchytrium sp. on *Erythronium americanum.*

Resting spores solitary, or up to 8 in a cell and usually occurring in linear series, filling host cell almost completely, spherical, 40—50 μ, ovoid, 42—60 ⇌ 60—66 μ, oblong with truncate ends, 20—30 ⇌ 50—74 μ, or almost polyhedral from mutual contact and pressure, with a

smooth, reddish-brown wall, 4—5 μ thick, and coarsely granular content; enveloped by a layer of reddish-brown residue which adheres tightly to spore wall; germination unknown.

Simply monogallic (?), resting-spore galls separate or crowded on both surfaces of leaves, protruding only sligthly and consisting of a subpherical, or elongate, fusiform, 60—78 ⇌ 250—312 μ, or oval, 115—132 ⇌ 160—180 μ, epidermal cell.

On *Erythronium americanum,* Franklin Co., Calif. (Leg. W. A. Setchel, 1-2-1888; specimen no. 49626 in herb. Univ. Calif., Berkeley).

Only part of an infected leaf was available for study and the tissue in the sections was so badly shrunken that it was impossible to determine whether or not sheath cells are present. However, the galls appear to be simple in structure. The resting spores may occur in linear series when several are present in a cell, and in this respect they frequently resemble those of *S. lateum, S. punctatum* and *S. niesslii,* which also are simply monogallic species. However, the spores of the fungus on *Erythronium* are usually smaller than those of these species. It is quite possible that all of these species may be related. It may be noted that *Synchytrium niesslii,* like the species on *Erythronium,* occurs on a member of the family *Liliaceae* also.

Synchytrium sp. on *Thalictrum occidentale.*

Resting spores solitary, light-yellow, spherical, 66—86 μ, or oval, 60—72 ⇌ 80—90 μ, with a smooth wall, 2.5—3.2 μ thick; enveloped by a sparse to fair amount of residue; germination unknown.

Compositely monogallic, resting-spore galls usually single and scattered, occasionally aggregated and confluent, greenish with the light-yellow spores showing through the sheath, broadly cushion-shaped, dome-shaped or hemispherical with a slight depression in the center, 92—210 μ high by 192—320 μ broad; sheath 4—6 cells thick; often occupying center of leaf and causing it to bulge out on both surfaces.

On the leaves of *Thalictrum occidentale,* Neals, Garfield Co., Wash. (leg. C. G. Shaw, 5-21-1951; specimens in herb. State Coll. Wash., no. 31288).

The majority of resting spores in the material seem to be immature with relatively thin walls. Several attempts to germinate them were unsuccessful. This fungus may be identical to the one Schroeter (1885) and others have been reported as *S. aureum* on *Thalictrium alpinum, T. augustifolium* and *T. flavum.* It is to be noted also that another species, *S. anemones,* has been reported on *T. purpurascens.*

Synchytrium sp. on *Boykinia ranunculifolia.*

Resting spores usually solitary, partly filling host cell, spherical, 108—162 μ, oval, 106—140 ⇌ 120—160 μ, with a smooth amber wall,

3.5—4.2 μ thick; enveloping residue scarce or lacking entirely; germination unknown.

Compositely monogallic, resting-spore galls usually separate and scattered, occasionally crowded and confluent, blackish-brown in dried herbarium material, but becoming brown when soaked in water, protruding conspicuously with base often slightly constricted, occasionally asymmetrical with pore subapical, 96—360 μ high by 168—480 μ broad; sheath 4—6 cells thick, consisting of markedly enlarged and fairly thick-walled cells.

On leaves and petioles of *Boykinia ranunculifolia,* north of Dedrick, Trinity Co., Calif. (leg. C. L. Hitchcock and J. S. Martin, 7-11-1939; specimens in herb. State Coll. Wash. no. 37501).

This fungus was discovered by C. G. Shaw in examining herbarium specimens of the host from California. Its identity is uncertain from the information at hand, but it may be related to one of the several fungi reported as *S. aureum* on several genera of the Saxifragaceae. The galls, however, are much larger and conspicuous than those caused by *S. aureum,* as reported by Schroeter (1870, 1885) and Rytz (1907).

Synchytrium sp. on *Gilia gracilis.*

Resting spores up to 3 in a cell, subspherical, 72—132 μ, oval, 42—84 ⇌ 72—132 μ, with a smooth wall, 3.5 μ thick, endospore hyaline, content light-yellow to almost hyaline and coarsely granular; enveloping residue sparse, usually lacking; germination unknown.

Compositely monogallic, resting-spore galls usually crowded and confluent at tip of leaves, greenish with light-yellow to almost hyaline spores showing through sheath, protruding conspicuously and largely superficial, often asymmetrical with constricted base, 192—244 μ high by 190—372 μ broad; sheath 5—6 cells thick.

On leaves of *Gilia gracilis,* Teal Springs N-Garfield Co., Wash., causing stunting and thickening of leaves, (leg. C. G. Shaw and W. D. Yerkes, Jr., 6-8-1949; specimens in herb. State Coll. Wash., no. 31972).

This species resembles *S. polemoni* which occurs on *Polemonium occidentale,* another member of the *Polemoniaceae* in Washington, and may be identical to it. Its resting spores are generally smaller than those of *S. polemoni,* but in the size, shape and structure of the induced galls, lack of residue around the spores, and the presence of a well-defined endospore the two species are similar. However, the author (1956 b) reported that *S. polemoni* is similar in many respects to *S. aureum,* and it is possible it and the fungus on *G. gracilis* may prove to be identical to *S. aureum.*

Synchytrium sp. on *Hesperochiron pumulus.*

Resting spores usually solitary, occasionally, 2—3 in a cell and partly filling it, spherical, 132—156 μ, oval, 120—150 ⇌ 156—180 μ,

with a smooth, light-yellow to almost hyaline wall, 2.8—3 μ thick, and yellow to almost hyaline content; enveloped by a thin layer of residue; germination unknown.

Compositely monogallic, resting-spore galls usually separate and scattered, occasionally crowded and confluent, greenish-yellow with spores showing through the sheath as light-yellow, protruding, broadly crateriform at apex and appearing almost cupulate, 240—300 μ high by 350—444 μ broad; sheath 6—8 cells thick.

On leaves, petioles, stems and flower bracts of *Hesperochiron pumulus,* Teal Springs, Umatilla Natl. Forest, Garfield Co., Wash. (leg. C. G. Shaw and W. D. Yerkes, Jr., 6-8-1949; specimens in herb. State Coll. Wash., no. 32484).

Most of the resting spores in Shaw's material have thin walls and look somewhat like incipient sori, but these might be immature spores. Their wall and content are almost hyaline, and from the data at hand this color appears to be characteristic of the fungus. In this respect it is somewhat similar to the species on *Gilia gracilis* described above which was collected at Teal Springs also. Its spores, however, are generally much larger, and its host belongs in a different family. The latter difference, however, may not be significant.

In this connection it may be noted that Shaw and Yerkes also collected another fungus at Teal Springs, 6-8-1949, on *Lithophragma bulbifera* which they tentatively called *S. aureum.* The resting-spore galls are separate and scattered, or sometimes crowded and confluent, composite, and light- to dark-lavender. The resting spores are spherical, 50—90 μ, or oval, 52—102 ⇌ 60—120 μ, with a smooth, brown wall, 3.5—4 μ thick, and enveloped by a layer of reddish-brown, compact and fairly homogeneous residue which adheres closely to the spore wall and fills the remainder of the host cell. In these respects it resembles the descriptions of *S. aureum* and may be identical to this species. However, it is different from *S. lithophragmae* which occurs on the same host.

Another short-cycled species was collected by Shaw and Yerkes, 6-8-1949, on *Sedum douglasii* at Teal Springs, N-Garfield Co., Wash., which they labeled *S. aureum.* This fungus appears to be identical to one Calder and Savile, 6-20-1953, collected on the same host southwest of Rossland, British Columbia at an altitude of 4000, which the author (1956 C) described briefly. The galls and resting spores are similar in appearance, size and structure, and it is quite likely that the two fungi are identical.

Thus, with the species on *Saxifraga arguta* to be described below, Shaw and Yerkes collected five short-cycled species in the same locality at Teal Springs on members of the *Polemoniaceae, Crassulaceae, Saxifragaceae* and *Hydrophyllaceae.* These are all compositely monogallic, and apparently from the material at hand develop

only resting spores which are generally similar, and it is possible that they may be identical.

Synchytrium spp. on species of *Saxifraga.*

A large number of collections of *Synchytrium* have been made on species of *Saxifraga* in Wyoming, Idaho, Washington and California. Inasmuch as these hosts and parasites have not been recorded a brief description of the fungi and host reaction is presented herewith.

Synchytrium sp. on *Saxifraga arguta,* Teals Springs, Umatilla Natl. Forest, Garfield Co., Wash. (Leg. C. G. Shaw and W. D. Yerkes, Jr., 6-8-1949) and Mirror Lake, Medicine Bow Mts., Wyoming (Leg. W. G. Solheim, 8-28-1950; specimen in herb. State Coll. Wash., no. 31274).

Resting spores solitary, spherical, 110—134 μ, or ovoid, 76—106 ⇌ 92—140 μ, with a smooth amber wall, 3—4 μ thick, and yellow, coarsely granular content; enveloping residue sparse; germination unknown. Compositely monogallic, resting spore galls separate and scattered, or crowded and confluent, lavender-red, embedded ½ to ⅔ s in leaf and forming subhemispherical protuberances, 192—240 μ high by 180—324 μ broad, sheath 3—4 cells thick.

The galls caused by the species in Wyoming are embedded ½ to ⅔ s in the leaf tissue, do not protrude conspicuously, and have sheaths which are made up of fairly compact and relatively small cells derived from the epidermis, mesophyll and palisade layers. In this connection it should be noted that Rytz (1907) reported *S. aureum* on *Saxifraga aizoides, S. androsace, S. bryoides, S. moschata, S. stellaris* and *S. varians* in Switzerland. Previously, (1906), he believed that it might be different from *S. aureum* and named it *S. saxifragae* n. sp. ad int. on the grounds that its galls are smaller. Also, the sori and sporangia produced from the germinated resting spores are smaller than those of the typical *S. aureum.* In 1907, however, the listed it as a form of *S. aureum.* Occasionally, it may cause simple galls, and the composite galls are usually small with a sheath only 1 to 2 cells thick, which is composed of greatly enlarged epidermal cells. Also, its resting spores are enveloped by a dense layer of residue that fills the remainder of the host cell. In these respects the galls are different from those caused by the Washington and Wyoming species. Nevertheless, the resting spores of these species are similar in size and shape to those of Rytz's fungus, but their walls are much thinner.

Synchytrium sp. on *Saxifraga* sp., Valley-Custer County Line, Idaho. (Leg. C. L. Hitchcock and C. V. Mahlick, 7-7-1944; specimens in herb. State Coll. Wash., no. 36996).

Resting spores solitary, occasionally 2 in a cell, spherical, 50—60 μ, with a smooth amber wall, 3—6 μ thick, and yellow, granular content; enveloping residue sparse; germination unknown. Compositely monogallic, resting spore galls scattered and sparse, not protruding conspicuously, brilliantly dark lavender-red, subhemispherical, 190—220 μ high by 280—300 μ broad; sheath 4—7 cells thick.

Synchytrium sp. on *Saxifraga californica,* Howell Mts.,Napa Co., Calif. (Leg. L. Constance, 3-27-1938; specimens in herb. State Coll. Wash., no. 36949).

Resting spores usually solitary, spherical, 120—192 μ, with a smooth amber wall, 4—5 μ thick, and yellow granular content; enveloping residue sparse or lacking; germination unknown. Compositely monogallic, resting-spore galls abundant, separate and scattered or crowded and confluent, brilliantly lavender-red, protruding and almost hemispherical on surface of leaf, 290—312 μ high by 370—414 μ broad; sheath 4—6 cells thick.

Synchytrium sp. on *Saxifraga fragosa,* Wenatchee Mts. (elevation 7000'), Chelan Co., Wash. (Leg. A. R. Kruckeberg, 8-9-1953) and War Eagle Mt., Owyhee Co., Idaho (Leg. B. Maguire and A. H. Holmgren, 7-3-1946); specimens in herb. State Coll. Wash., nos. 37516 and 37504, respectively.

Resting spores solitary, or up to 3 in a cell, spherical, 66—150 μ, or ovoid, 96—104 ⇌ 112—130 μ, with a smooth, amber-brown wall, 3—5 μ thick, and light-orange coarsely granular content; enveloping residue sparse; germination unknown. Compositely monogallic, resting-spore galls scattered or crowded and confluent, lavender-red, protruding rather prominently, 270—290 μ high by 300—350 μ broad; sheath 4—6 cells thick.

Synchytrium sp. on *Saxifraga nidifica,* Sequoia Natl. Forest, Tulare Co., Calif. (Leg. Roxana S. Ferris and Laura Lorraine, 6-15-1942) and Humboldt Co., Calif., elevation 6000 ft. (Leg. J. P. Tracy, 7-18-1932; specimen in herb. State Coll. Wash., no. 37513).

Resting spores solitary, spherical, 90—120 μ, with a smooth amber-brown wall 3.5—5 μ thick, and yellow, coarsely granular content; enveloping residue sparse; germination unknown.

Compositely monogallic, resting-spore galls scattered and sparse, not brilliantly colored, almost hemispherical on surface of leaf and protruding fairly conspicuously, 290—300 μ high by 320—344 μ broad; sheath 4—6 cells thick.

The package of material collected by J. P. Tracy in Humboldt Co., Calif. is labeled *S. groenlandicum.* The autor (1956b) has shown that *S. groenlandicum* is not a valid species of *Synchytrium.* Tracy's material, however, relates to *Synchytrium* and the fungus present

appears to be the one collected on the same host in Tulare Co., Calif.

Synchytrium sp. on *Senecio cymbalarioides.*

Resting spores usually solitary but sometimes 2 in a cell, filling cell almost completely or partly, spherical, 108—126 μ, or ovoid, 78—115 ⇌ 108—134 μ, with a smooth wall, 3 μ thick, and densely alveolar content; enveloping residue sparse or lacking; germination unknown.

Compositely monogallic,, resting,spore galls on both surfaces of leaf, scattered or crowded and confluent, embedded largely in host tissue and appearing as subhemispherical protuberances on surface of leaf, 198—246 μ high by 240—342 μ broad, with a small shallow apical crater; sheath 3—5 cells thick, consisting of fairly compact and relatively small derivatives of the epidermal, palisade and mesophyll cells.

On leaves of *Senecio cymbalarioides,* Medicine Bow Mts., Albany Co., Wyoming. (Leg. W. G. Solheim, 8-9-1950).

As noted above the galls caused by this species are embedded largely in the leaf and usually protrude only moderately on the surface. Apparently, following infection the host cell grows and expands largely inward, and as it does so the neighboring epidermal, palisade and mesophyll cells are stimulated to enlarge and divide. The sheath is thusly formed and made up of fairly compact cells which are more nearly isodiametric and sometimes smaller than the adjacent palisade and mesophyll cells. As a result the galls stand out sharply as denser areas in cross sections of leaves, like those described above for the species on *Saxifraga arguta* from Wyoming. In these respects the galls appear to differ from those usually caused by *S. aureum* and *S. globosum,* which were reported on *Senecio vulgaris* by Schroeter (1885) and Lind (1913), respectively in Europe. Neither of these workers described their fungi, and it is thus impossible to compare them with the Wyoming species.

Synchytrium sp. on *Mertensia ciliata.*

Resting spores solitary, partly filling host cell, spherical, 130—140 μ, or ovoid, 85—98 ⇌ 126—138 μ, with a smooth wall, 4—5 μ thick, and coarsely granular content; residue usually lacking or very sparse when present; germination unknown.

Compositely monogallic, resting-spore galls on both surfaces of leaves and on petioles, embedded in leaf and usually protruding almost equally on both sides, broadly pyriform to subspherical with shallow apical crater, 300—348 μ high by 312—450 μ broad; sheath 4—5 cells thick, cells greatly enlarged, oval to oblong or almost globular in shape with dark staining walls.

On *Mertensia ciliata,* Medicine Bow Mts., Albany Co., Wyoming (Leg. W. G. Solheim, 8-28-1950); specimens in herb. Univ. Wyoming.

The galls induced by this species differ from those caused by the species on *Saxifraga arguta* and *Senecio cymbalarioides,* which were collected in the same locality and described above, in that they usually protrude almost equally on both sides of the leaf. Furthermore, the sheath cells are greatly enlarged, globular to oval and oblong in shape and differ markedly in appearance from the normal epidermal, palisade and mesophyll cells. As a result the galls stand out sharply in cross sections of the leaf. The basal and lateral sheath cells appear to be derived principally from the palisade or the mesophyll layers, depending on which surface of the leaf infection occurs, and the apical cells apparently are derived from the epidermis.

Synchytrium spp. on *Penstemon* species.

Except for a report by Raper and Cooke (1954) of the collection of an unidentified species on *Penstemon* sp. in Wyoming, no species of *Synchytrium* has been recorded on this host. However, prior to 1954 Parks and Tracy collected a species on *P. ovatus* in California, and later Shaw found that herbarium specimens of *P. globosus* and *P. glaber* from Idaho and Colorado were infected by *Synchytrium.* These specimens were loaned to the author for study, and the following descriptions are given of the fungi.

Synchytrium sp. on *Penstemon ovatus.*

Resting spores solitary or up to 3 in a cell and partly filling it, spherical, 92—168 μ, or ovoid, 104—132 ⇌ 126—144 μ, with an amber-brown smooth wall, 4—5 μ thick, and dark-yellow to yellowish-orange content; enveloping residue sparse and thin, or lacking; germination unknown.

Compositely monogallic, resting-spore galls usually crowded and confluent, embedded largely in the leaf tissue and protruding usually on both surfaces, narrowly crateriform with a well-circumscribed apical pore or opening, 230—288 μ high by 250—276 μ broad; sheath 3—5 cells thick.

On *Penstemon ovatus,* Trinity Co., Calif. (Leg. H. E. Parks and J. P. Tracy, 6-1947; specimen no. 288881, herb. Univ. Calif., Berkeley).

Synchytrium sp. on *Penstemon glaber.*

Resting spores solitary or up to 3 in a cell, spherical, 72—168 μ, or oval, 54—68 ⇌ 140—156 μ, with a smooth, amber-brown wall, 3—4 μ thick, and dark-yellow content; enveloping residue usually abundant; germination unknown.

Compositely monogallic, resting spore galls separate and scattered or crowded and confluent on both surfaces of leaf and along midrib, not protruding conspicuously, hemispherical or broadly cushion-shaped, 150—210 μ high by 250—280 μ broad, sheath 2—4 cells thick.

On leaves and petioles of *Penstemon glaber,* Rabbit's Ears Pass, Vivian Allottments, Colorado (leg. A. A. Beetle, 9-5-1949; specimens in herb. State Coll. Wash. no. 38042).

Synchytrium sp. on *Penstemon* sp.

Resting spores solitary or up to 3 in a cell, spherical, 120—158 μ, ovoid, 110—125 ⇌ 120—174 μ, occasionally oblong, 90—108 ⇌ 160—180 μ, with a smooth, amber to amber-brown wall, 3—4.2 μ thick, and yellow content; enveloping residue usually sparse, amber to brown; germination unknown.

Compositely monogallic, resting-spore galls scattered or commonly crowded and confluent, reddish-brown to reddish-lavender, embedded largely in leaf, 200—260 μ high by 220—270 μ broad; sheath 3—5 cells thick.

On *Penstemon* sp., Mirror Lake, Albany Co., Wyoming. (Leg. C. G. Shaw, 7-9-1950; specimen in herb. State Coll. Wash., no. 32349).

This is the species which Raper and Cook (1954) reported from the Mycological Foray in Wyoming. It resembles the species *P. ovatus* and *P. glaber* described above, and it is possibly identical to one of them.

Synchytrium sp. on *Penstemon globosus.*

Resting spores usually solitary, sometimes 2 in a cell, and only partly filling it, spherical, 140—176 μ, oval, 135—150 ⇌ 160—173 μ, with a smooth amber wall, 4—5 μ thick, and light-yellow, coarsely granular content; enveloping residue sparse or lacking; germination unknown.

Compositely monogallic, resting-spore galls separate and scattered, or sometimes crowded and confluent, dark ruby-red or lavender-red, protruding conspicuously on leaves, broadly crateriform at apex and dome-shaped or hemispherical, 252—324 μ high by 330—428 μ broad; sheath 4—7 cells thick, sheath cell walls greatly thickened.

On leaves and petioles of *Penstemon globosus,* Burgdorf, Idaho Co., Idaho (leg. R. J. Davis; specimen in herb. State Coll. Wash., no. 37900).

In size, shape, color, and general appearance the galls induced by this species resemble those caused by *S. rugulosum* (Karling, 1956 a) on *Godetia albescens.* The sheath is quite thick, and consists usually of a layer of enlarged thin-walled cells next to the infected one and then a layer of thick-walled cells. These walls may be up to 8 μ thick and have numerous pitted ducts and scalariform perforations. In this respect the cells are similar also to those in the sheath of *S. geranii* and the short-cycled species described by the author (1956 a, fig. 10) on *Boisduvalia glabella* from Elmore Co., Utah.

The resting spores also fall within the size range of those of the Utah fungus, but they are not enveloped by a thick layer of residue.

In connection with these species it should be noted that the leaves of *Penstemon* species frequently have raised, subhemispherical, lavender-red protuberances which may resemble the galls caused by *Synchytrium.* Such protuberances were found on 22 species of *Penstemon* recently received from Dr. C. G. Shaw, but a study of them showed that they contain one to several large, thick-walled hyaline bodies which resemble cysts of insects or endophytic algae.

Synchytrium sp. on *Limnanthes rosea.*

Resting spores usually solitary, subspherical, 110—132 μ, oval, 130—168 ⇌ 172—204 μ, with a smooth, reddish-brown wall, 3—3.8 μ thick, and light-yellow coarsely granular content; enveloped by a dense, thick layer of reddish-lavender residue which adheres closely to spore wall, fills remainder of host cell and forms a cap over the apex of the spore; germination unknown.

Compositely monogallic, resting-spore galls separate and scattered or crowded and confluent, reddish-brown, protruding conspicuously, narrowly crateriform at apex, base embedded in host tissue, almost hemisperical, 245—384 μ high by 280—408 μ broad at base; sheath 3—4 cells thick, sheath cells greatly enlarged, inner ones with deeply-stainable walls, 3.5—5 μ thick, and filled with brown residue.

On leaves, petioles, stems, sepals and petals of *Limnanthes rosea,* near Rio Vista, Solano Co., Calif. (Leg. A. M. Alexander and L. Kellog, 4-24-1943; specimens in herb. Univ. Calif., Berkeley, no. 695805, and herb. State Coll. Wash., no. 36326), causing marked distortion and thickening of young leaves when infection is abundant.

This species was identified as *S. papillatum* by Lee Bonar, but this is incorrect because *S. papillatum* is simply dihomeogallic. It is not certain from the information at hand that this fungus is *S. aureum,* but the size of its resting spores fall within ranges of the latter species given by Schroeter (1870, 1885) and Rytz (1907). Also, the spores are embedded in a dense layer of residue which may be very thick and peaked in the apex of the host cell. This material adheres very tightly to the spore wall so that it is almost impossible to separate the two by dissection. The principal difference between this fungus and *S. aureum* noted so far is a thickening of the walls of the inner sheath cells, but this may not be taxonomically significant. Only two other species, *S. papillatum* and *S. geranii,* have been reported on genera of the Geraniaceae, but these two are long-cycled.

Synchytrium sp. on *Baeria chrysostoma.*

Resting spores solitary or up to 3 in a cell, oval, 132—150 ⇌ 144—204 μ, or subspherical, 135—180 μ, with a smooth wall, 3.9—4.8 μ

thick, and lemon-yellow granular content; enveloped by a crumbly layer of residue which may be very thick, almost fills the remainder of the host cell, and forms a peaked cap over the upper surface of the spore; germination unknown.

Compositely monogallic, resting spore galls separate and scattered but usually crowded and confluent, forming large outgrowths, dark ruby-red to lavender-red, narrowly to broadly crateriform and depressed at apex, protruding conspicuously, unusually large, 384—600 μ high by 450—844 μ broad at base; sheath 6—18 cells thick, frequently containing vascular elements.

On leaves, petioles, stems and flower bracts of *Baeria chrysostoma* var. *gracilis,* south of Perris, Riverside Co., Calif. (Leg. H. S. Fawcett, 6-1935; specimen no. 538843 in herb. Univ. Calif. Berkeley), causing marked thickening and distortion of infected organs.

This species was determined as *S. aureum* by L. J. Klotz, according to the label on the herbarium material. Its resting spores are usually larger than those reported for *S. aureum,* and the galls which it induces are many times larger than those caused by the latter species. These galls are highly colored and except for their larger size resemble those caused by *S. rugulosum* (Karling, 1956 a). Also, its resting spores resemble those of the latter species, and it is possible that the two species might be identical although they occur on widely different hosts. The most striking difference is the reaction of the host. The fungus on *Baeria* causes conspicuous outgrowths on the host where galls are confluent, and in such regions the leaf may be up to 900 μ thick in comparison with its 50 to 63 μ normal thickness. Also, the sheath may be up to 18 cells thick with some of its cells 120 μ long by 6—10 μ broad. It is among such cells that clearly differentiated scalariform and scalariform-reticulate vascular elements occur. Such elements extend halfway up the sides of the gall, but it is not certain that they are continuous with the vascular elements of the veins and midrib of the leaves. In most sections they appear to be isolated. Galls with clearly differentiated vascular elements are rare in *Synchytrium,* and as far as the author knows they have been reported only in *S. endobioticum* (Kohler, 1925; Bally, 1911), *S. vulcanicum (Raciborski,* 1898), and the species on *Morus* which is described below. However, the author (1956 a and c) has found sheath cells with greatly thickened walls and scalariform perforations in *S. geranii* and *Synchytrium* sp. on *Boisduvalia glabella.* Whether this is a new species or identical to *S. rugulosum* or *S. aureum* remains to be determined from further developmental and host range studies, and for this reason the author is reluctant to give it a specific name.

Synchytrium sp. on *Morus alba.*

Resting spores solitary, partly filling host cell, spherical, 126—246 μ, or ovoid, 144—186 ⇌ 180—222 μ, with a smooth wall, 8—11 μ thick, and coarsely granular content; residue sparse, usually in the form of globules; germination unknown.

Compositely monogallic, resting-spore galls usually scattered, occasionally confluent, quite variable in size and shape, often causing a pit or depression in leaf around them and protruding conspicuously on both sides of leaf, oval, oblong to elongate transversely to leaf, 360—720 μ high by 380—456 μ broad, with a narrow canal or cone-shaped crater leading to infected cell; cushion-or somewhat dome-shaped and protruding only from one surface of leaf, 198—582 μ high by 350—384 μ broad; or almost spherical and largely superficial on leaf, 380—408 ⇌ 395—416 μ; sheath 4—8 cells thick.

On leaves and petioles of *Morus alba,* Baton Rouge, La., U.S.A. (Leg. M. T. Cook, 3-4-1947; specimens in herb. Purdue Univ.).

As noted in the above diagnosis the galls induced by this species vary markedly, but the majority of them are large and protrude on both surfaces of the leaf. In this respect they are similar to some of the galls caused by *S. parthenocissi, S. corni, S. asterum, S. gonolobi, S. carpini, S. erechitis,* and *S. callicarpae* which were described by Cook (1953) from Baton Rouge, La. Also, they may cause a pit or depression in the leaf immediately surrounding them as in *S. corni, S. carpini, S. erectis,* and *S. callicarpae* which were described by Cook. The upper and lower epidermal as well as palisade and mesophyll are extensively proliferated. Occasionally, vascular elements may occur among the sheath cells as in the species described above on *Baeria.* The resting spores may be quite large and have an unusually thick wall like those of *S. tecomae.* In light of these similarities the author believes the fungus on *Morus* may be identical to one of the short-cycled, compositely monogallic species described by Cook (1953) from Baton Rouge. Nevertheless, it is the first species of *Synchytrium* found so far on a member of the Moraceae.

Synchytrium sp. on *Rhus radicans.*

Resting spores solitary, partly filling host cell, spherical, 120—174 μ, or ovoid, 98—178 ⇌ 120—198 μ, rarely oblong, 60—72 ⇌ 150—168 μ, with a smooth wall, 5—7 μ thick, and coarsely granular yellow content; enveloped by a thick, dense and homogenous layer of residue which fills remainder of host cell; germination unknown.

Compositely monogallic, resting spore galls abundant on both surfaces of leaves, scattered or crowded and confluent, sometimes lavender-red, frequently bearing a tuft of trichomes, highly variable in size and shape, large, and causing a pit or depression in the leaf around them and protruding almost equally on both sides of leaf, 420—672 μ high by 528—600 μ broad, with a deep broadly cone-shaped

apical crater or a long narrow canal which leads to the deeply-buried infected cell, sheath 7—9 cells thick; or broadly cushion-shaped 210—230 μ high by 300—480 μ broad and protruding only on one side of leaf, sheath 5—7 cells thick; or small, and largely superficial, 144—240 μ high by 228—360 μ broad, with constricted base, sheath 3—4 cells thick.

On leaves and petioles of *Rhus radicans,* Baton Rouge, La., U.S.A. (Leg. J. S. Karling, 3-24-1954; specimens in herb. Purdue Univ.).

This host is commonly attacked by mites which cause galls and malforations on the leaves, and the galls induced by *Synchytrium* may be superficially similar to them. However, the latter are distinguishable by the presence of the yellow incipient spore within the sheath. Like the insect galls, those caused by the fungus usually bear a tuft of trichomes which are usually more numerous than on a corresponding healthy area of the leaf. Other galls may lack trichomes. As noted in the diagnosis above the galls may vary markedly in size and appearance. The large galls with a surrounding pit or depression in the leaf are strikingly similar to the large ones caused by *S. corni, S. liquidambaris, S. carpini, S. bignoniae, S. callicarpae,* and *S. tecomae* as illustrated by Cook (1953). Other galls may be broadly mound-, or dome-shaped and protrude only on one side of the leaf. In rare cases almost simple galls are formed, and consist mostly of a greatly enlarged cell embedded in the leaf tissue.

The identity of this species is uncertain, but it is probably identical to one of the species noted above. It was collected in the locality where Cook discovered *S. liquidambaris, S. carpini, S. tecomae,* and other similar species.

Synchytrium sp. on *Rubus* sp. and *R. trivialis.*

Resting spores usually solitary, partly filling host cell, spherical, 80—110 μ, ovoid, 84—110 ⇌ 120—132 μ, with a smooth wall, 3.5—4 μ thick, and yellow coarsely granular content; enveloping residue sparse; germination unknown.

Compositely monogallic, resting spore galls scattered, principally on lower surface of leaf, usually covered with trichomes, lavender-red, usually large, and protruding, 300—360 μ high by 250—300 μ broad, with a broadly cone-shaped apical crater leading to infected cell; occasionally protruding equally on both sides of leaf, or only on one side, 240—432 μ high by 420—582 μ broad; sheath 5—10 cells thick.

On leaves and petioles of *Rubus* sp. and *R. trivialis,* Baton Rouge, La., U.S.A. (Leg. J. S. Karling, 3-28-1954; specimens in herb. Purdue Univ.)

This fungus was collected in the same ditch as the one on *Rhus radicans* as well as *S. lythrii* and other unidentified species on

Solidago sp. and *Populus deltoides,* and it is not improbable that all of these fungi may be one species. It may be noted here that *Synchytrium aureum* also has been reported on *Rubus caesius* (Schroeter, 1885), *R. dumetorum* (?) (Rytz, 1907), *R. hispidus, R. triflorus* and *R. villosus* (Davis, 1924), and it is equally plausible that the fungus on *Rubus* from Louisiana may be *S. aureum.* However, none of the above collectors described their fungi on *Rubus,* and they apparently assumed them to be *S. aureum* because only resting spores were present.

Synchytrium sp. on *Populus deltoides.*

Resting spores solitary, partly filling host cell, subspherical, 90—120 μ, or ovoid, 102—110 ⇌ 114—120 μ, with a smooth wall, 4—5 μ thick, and yellow, granular content; reddish-brown residue around spore usually sparse and crumbly; germination unknown.

Compositely monogallic, resting-spore galls, sparse, scattered and separate, dark reddish-lavender, protruding conspicuously and largely superficial on leaf, usually constricted at base 360—410 μ high by 444—560 μ broad, with a shallow apical depression; sheath 5—7 cells thick, sheath cells greatly enlarged.

On leaves and petioles of *Populus deltoides,* Baton Rouge, La., U.S.A. (Leg. J. S. Karling, 3-28-1954; specimens in herb. Purdue Univ.).

This fungus occurred on seedlings 8″ to 24″ high in a ditch where somewhat similar, short-cycled, compositely monogallic *Synchytrium* species were found on *Lythrum, Rhus, Rubus* and *Solidago,* and it is possible that all of these fungi may be identical as noted previously. Schroeter (1885) reported *S. aureum* on *Populus alba* in Germany but did not describe it, and it is equally possible that the Louisiana fungus in the same as Schroeter's species. The galls induced by the species on *Populus deltoides* are quite large and, except for the base which extends down into the palisade or mesophyll layers, they are largely superficial on the host. In this respect they are unlike those caused by the species on *Rhus* and *Rubus* which may protrude on both surfaces of the leaves. Numerous infected seedlings were dug up and transferred to the greenhouse at Purdue where they grew to large size. The fungus on these plants was studied over a period of 10 months but only resting spores developed. Several attempts were made to germinate these without success.

Synchytrium sp. on *Solidago* sp.

Resting spores usually solitary, spherical, 144—198 μ or ovoid, 150—174 ⇌ 165—186 μ, with a smooth dusky greenish-amber or light olive colored wall, 3.8—4.6 μ thick, and yellow, granular content; residue around spore dusky, usually sparse; functioning as a prosorus in germination.

Compositely monogallic, resting-spore galls separate and scattered, or crowded and confluent on both surfaces of leaf, greenish-yellow at first, becoming reddish-lavender, almost hemisperical on surface of host, 180—220 μ high by 210—280 μ broad with a shallow apical depression; sheath 3—5 cells thick.

This species was described briefly by the author (1956 c) in relation to the germination of its resting spores. It was assumed to be *S. aureum* which Juel (1893) reported on *Solidago vignarea* in Sweden.

Summary.

Three new species, *Synchytrium salviae* on *Salvia sessilis, S. eremocarpae* on *Eremocarpus* sp. and *S. lithophragmae* on *Lithophragma bulbifera* and *L. parviflora,* are described from California, Idaho, Oregon and Washington. The first two species are long-cycled, and the third one is short-cycled and forms only resting spores. *Synchytrium andinum* from California was found to develop a prosorus in its so-called summer cycle. In addition 25 unidentified species are described on new hosts. These are short-cycled, develop only resting spores, and appear to be members of the subgenus *Pycnochytrium.*

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