Some Zoosporic Fungi of New Zealand.

II. Synchytriaceae.

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With Plate VI & VII.

This study of the New Zealand species of *Synchytrium* was conducted largely at the Plant Disease Division, DSIR, Mt. Albert, Auckland, and the author is grateful to Dr. E. E. Chamberlain, Director of the Division, for providing laboratory facilities for this investigation. Particular thanks are expressed herewith to Miss Joan M. Dingley, Dr. Ross McNabb and Sue Davison for their help, hospitality, and friendly cooperation. Miss Dingley furnished the author with daily transporation to the laboratory, and she and Dr. McNabb took him on weekly field trips to various parts of the North Island.

The genus *Synchytrium* is the largest of the chytrid genera and includes at present more than 200 species; yet, so far as published records go, it is unknown in New Zealand except for a species on *Melicope simplex* which Cooke (1892) identified as *S. melicopidis*. However, a study of Cooke's type material by the author (1961) showed that this organism is not a species of *Synchytrium*. Nevertheless, it is evident from herbarium specimens at the Plant Disease Division, DSIR, Mt. Albert, Auckland, that species of *Synchytrium* had been known and collected for a long time in New Zealand. According to these specimens, the first valid species was collected and identified by G. A. Cunningham in 1928. Since that time several other species were collected by V. D. Zotov, A. J. Healy, S. D. Baker, F. J. Newhook, J. M. Dingley, D. W. McKenzie, and Ross McNabb.

The present study was conducted by the author during the late spring, summer, and fall of 1965—66 under the auspicies and support of a Fulbright Research Grant, and it is based on the herbarium specimens noted above as well as on living and fixed material collected in the field. Up to the present time ten species have been identified. These include the following:

Synchytrium hypochoeridis sp. nov.

Prosori globosi vel subglobosi, 60—150 μ diam., interdum ovoidei, 54—102 × 82—156 μ, pariete 2—3.2 μ crasso et plasmate pallide aureo farctae; sori plerumque supra prosoros, raro in matricis cellulis orti,

globosi vel subglobosi, 70—160 μ diam.; interdum etiam ovoidei, 58—90 × 110—165 μ, pariete hyalino, 2—3.2 μ crasso praediti, plasmate aureo-aurantiaco farcti, sporangia 32—110 gignentia; sporangia polyedrica, 16—34 μ diam., pariete hyalino, crassiusculo praedita, plasmate aureo-aurantiaco farcta; zoosporae late ovoideae, 3 × 3.4 μ, globulo aurantiaco splendidissimo refringenti 1.5—1.8 μ diam. metiente ornatae; flagellum 28—32 μ longum; sporae perdurantes plerumque globosae vel subglobosae, 98—200 μ diam., interdum ovoideae, 85—120 × 115—160 μ, subinde etiam oblongae, plasmate flavidulo vel hyalino farctae et pariete succineo vel obscure brunneo, 3.6—4.2 μ crasso praeditae, post quietem ut prosori proficientes.

Specimen typicum in herb. Plant Disease Division, D. S. I. R. et Purdue University conservatum.

Prosori spherical, subspherical, 60—150 μ diam., or ovoid, 54—102 × 82—156 μ, with a fairly thick, 2—3.2 μ, wall and bright-golden content. Sori ususally formed above the prosori outside of the infected cell on the surface of the host, rarely within the host cell, spherical, subspherical 70—160 μ diam., or ovoid, 58—90 × 110—165 μ, with a hyaline, 2—3.2 μ thick, wall and golden-orange content; forming 32—110 sporangia. Sporangia polyhedral, 16—34 μ in greatest diameter, with hyaline, fairly thick walls and golden-orange content. Zoospore broadly ovoid, 3 × 3.4 μ, with a brilliantly refractive, 1.5—1.8 μ diam., orange globule; flagellum 28—32 μ long. Resting spores predominantly spherical, 98 μ diam., ovoid, 85—120 × 115—160 μ, or oblong with slightly yellowish to hyaline content and amber to dark-brown walls, 3.6—4.2 μ thick, enveloped by a layer of blackish-brown residue; functioning as prosori in germination.

Predominantly compositely dihomeogallic; galls greatly variable in size and shape. Composite sporangial galls relatively small, crowded or separate, hemispherical to lowly mound-shaped, 102—144 μ highly 120—192 μ broad at base and enveloped by 1—3 sheath cells except at the broad apex. Resting spore galls crowded or separate occasionally confluent and compound, protruding separate galls highly or lowly mound-shape to hemispherical, 140—240 μ high by 180—450 μ broad at base with a sheath of 1—4 cells; frequently embedded in leaf and protruding only slightly. Simple unicellular sporangial and resting spore galls fairly common on midrib of leaf.

Type locality, Sharp's Bush, Auckland.

Type spec. in PDD, Mt. Albert, Auckland and PU.

Parasitic on *Hypochoeris radicata* in many localities in New Zealand and on *H. glabra* in Australia.

This species is widely distributed on the North Island and has been collected frequently and identified as *S. taraxaci*. The author collected it on *H. radicata* at the type locality as well as at Mt. Albert, Atkinson's Bay, Cornwallis Wharf, Waipou Kauri Forest, Auckland, and the Hutt

Valley, Wellington. In 1961 the author examined specimens (no. 74, ADW) of a species labeled *S. taraxaci* on *Hypochoeris glabra* from the Waite Agricultural Research Institute at Adelaide, South Australia, and inasmuch as only resting spores were present he noted (p. 104) that they and the galls produced fall within the range of those produced by *S. aureum*. However, on a visit to the Institute in 1966 he had the opportunity to study additional specimens in which prosori and superficial sori of sporangia were present in addition to resting spores. These conformed in size and shape to those of *S. hypochoeridis* in New Zealand, and the author was, thus, able to determine that they relate to the New Zealand fungus instead of to *S. aureum* or *S. taraxaci*.

As noted in the diagnosis and shown in figs. 2, 5, 6, 7 and 12, *S. hypochoeridis* induces galls or warts which are predominantly composite and multicellular, but on the midrib of the leaf principally simple unicellular galls (fig. 4) are frequently formed. In the development of composite galls the host epidermal cell begins to expand largely inward shortly after infection, and within a short time the adjacent healthy cells usually enlarge markedly and sometimes divide so that the parasitized cell becomes enveloped, except for the broad apex, by a sheath of 1 (fig. 2, 5) to 4 non-infected cells. In the development of simple galls the host cell merely enlarges and crowds the adjacent cells aside. Unlike in the case of *S. taraxaci* the composite sporangial galls small in comparison to the resting spore galls. The latter galls are usually quite large when they protrude conspicously, but quite often they are embedded or submerged (fig. 11) in the leaf tissue and protrude only slightly. In some instances the parasitized cell may occupy $^3/_4$'s of the cross section of the leaf. In addition to differences in size, the resting-spore galls may be readily distinguished by the thickness of the infected cell wall. In sporangial galls (fig. 2, 4, 5, 6, 7, 8) the host cell wall remains thin, but infections leading to the development of resting spores cause the wall to thicken and become lignified (figs. 12—14), and in most resting-spore galls the wall may become up to 7 μ thick.

Infection and the early developmental stages of the parasite in the host cell are basically similar to those of other *Synchytrium* species. Therefore, the present description will begin with the mature evanescent prosorus or initial cell. The most conspicuous structure in fixed and stained sections of this cell is the large primary nucleus which usually occurs near the base (figs. 2, 3, 4). The apex of the prosorus is occupied by a dense area of differentially stainable cytoplasm which is free of dark-staining bodies or granules (fig. 2, 3, 4). This area varies markedly in size and may extend down to the center of the prosorus as a projection (fig. 3). In addition to the structures noted above, the cytoplasm is filled with dark-staining granules or bodies. Such granules are commonly present in the resting spores of most *Synchytrium* species, but *S. hypochoeridis* is the only species the author has observed so far in which

they occur in the evanscent prosorus. The wall of the prosorus is comparatively thick, 2—3.2 μ, and consists of the thicker exospore and a very thin hyaline endospore (fig. 3).

The evanescent initial cell functions as a prosorus and forms a superficial sorus of sporangia. The first step in this process is the formation of a pore up to 4 μ in diameter, in its wall as well as in the wall of the host cell. The protoplasm then flows or grows out through this pore. The first protoplasm to emerge is that of the dense area or zone in the apex, as described previously (fig. 4). As more of the content flows out the primary nucleus moves upward and through the pore (fig. 5) into the superficial vesicle. At the same time the granules or bodies in the protoplasm become less densely strainable and appear to be used up as storage food in the process of sorus formation. After entering the superficial vesicle of protoplasm the primary nucleus divides, and by subsequent divisions of its daughter nuclei the incipient sorus becomes multinucleate (fig. 6). After all of the protoplasm has emerged, the exit pore in the prosorus wall is closed up by the development of a plug of densely stainable material which may extend in a radial direction and become 9—12 μ in diameter. Later, progressive cleavage of the protoplasm occurs whereby multinucleate segments are delimited, which develop walls and become sporangia (fig. 7). By this process, then, a sorus of sporangia is developed usually on the surface of the host cell. Rarely, however, the sorus fails to emerge from infected cell and develops within it (fig. 8).

The development of the dormant prosori or resting spores is similar to that of the evanescent prosorus described above, but it stimulates greater enlargement of the host cell and a thickening of its wall, as noted above. As a result probably of the increased enlargement of the infected cell, the spore rarely fills it completely, and as the spore attains maturity it becomes enveloped by a thick, dense and crusty layer of residue (figs. 11—14). After a period of dormancy and in favorable moisture conditions, the resting spore germinates, and in this process it functions as a prosorus (figs. 12, 13) giving rise to a superficial sorus of sporangia in the same manner described above for the evanescent prosorus or initial cell. When leaves are kept in water for a long time and the galls begin to degenerate, the sorus may rarely occur beneath the empty prosorus whereby the latter is pushed out of the degenerating gall (fig. 14).

The type of development cycle described above is characteristic of species of the subgenus *Microsynchytrium,* as defined by the author (1958, 1964), and *S. hypochoeridis* is, accordingly, placed in this subgenus. It differs, however, from the other fully known members of this group by the usual development of the sorus of sporangia on the surface of the host instead of within the infected cell. However, as noted before, the sorus of *S. hypochoeridis* is occasionally formed within

the host cell (fig. 8), and this species may sometimes exhibit both types of development.

So far as is known *S. hypochoeridis* appears to be limited to species of *Hypochoeris* and differs in this respect from *S. taraxaci* with which it had previously been identified. The author inoculated seedlings of *Taraxacum officinale* with motile zoospores of *S. hypochoridis* at 8 periodic intervals in New Zealand but none of them became infested In a similar manner 10 seedlings of *Hypochoeris radicata* were inoculated with zoospores of *S. taraxaci,* but these, likewise, were not infected. These results confirm in part the early inoculation experiments of Ludi (1901, 1902) which indicated that *S. taraxaci* is limited in host range to a few species of *Taraxacum.*

In relation to this description of *S. hypochoeridis* it may be noted that the author (1955 f.) described an unidentified species on *Hypochoeris* sp. which had been collected by Lindquist (18-12-1939) at La Plata, Argentina. In this species, however, the evanescent initial cell is transformed directly into a sorus of sporangia as in *S. taraxaci,* and it differs markedly in this respect from *S. hypochoeridis.* The author has reexamined his sections and material of the Argentinian fungus and found that his earlier description is correct. Another specimen (30414, SP) collected by Lindquist (16-11-1961) on *H. tweediei* at La Plata and labeled *Synchytrium* sp. is not a species of this genus. The large swellings are filled with large hyaline spores which resemble those of *Protomyces.*

Synchytrium leontodontis sp. nov.

Sporae perdurantes globosae vel subglobosae, 135—190 μ diam. vel ovoideae, 120—150 × 160—175 μ, pariete obscure succineo vel pallide brunneo, 2.3—4.8 μ crasso praeditae, plasmate griseo-albido farctae, matricis cellulas partim replentes et crusta residuorum densiuscula obvolutae; germinatio ignota.

Specimen typicum in Herb. Plant Disease Division, DSIR, Auckland, conservatum, no. 24308.

Resting spores spherical to subspherical, 135—190 μ diam., ovoid 120—150 × 160—175 μ, with a dark-amber to light-brown wall, 2.3—4.8 μ thick, and greyish-white content; partly filling host cell and enveloped by a dense crusty layer of residue; germination unknown.

Compositely monogallic. Resting spore galls usually separate, sometimes compound, hemispherical to highly mound-shaped, large, 280—396 μ broad at base by 300—420 μ high, with a sheath of 3—5 non-infected cells; sometimes protruding from both surfaces of the leaf.

Parasitic on *Leontodon leysseri,* Upper Hutt, Wellington.

This species was collected by A. J. Healy (21-3-1953) on a periodically flooded plot west of Upper Hutt and subsequently identified as

S. taraxaci, presumably because of its occurrence on a cichoriaceous host. However, in none of the numerous herbarium specimens available are large, crateriform, lavender-red galls, sori and sporangia present among the resting spore galls and spores as one usually finds in *S. taraxaci*, and for this reason the author believes that the specimens relate to a short-cycled species for which he proposes the name *leontodontis*. It induces large composite galls which usually occupy the thickness of the leaf and often protrude slightly on opposite surface, also (fig. 15). More specifically it stimulates a thickening, lignification and perforation of the host cell wall which is unusual and characteristic. The wall becomes lignified and up to 12 μ thick, and is sculptured and perforated somewhat like that of *Valeriana* species infected by *S. perforatum* (Karling, 1955 d). However, in *S. leontodontis* the perforations or openings in the wall are usually narrow slits as shown in fig. 18. After long immersion in water the thin-walled sheath cells soften, decay and slough off, leaving the large infected cell with its resting spore intact (fig. 10, 17).

Although the host reaction described above is not a specific morphological character of the parasite, the fungus apparently produces a characteristic stimulus of some sort which results in this host reaction. The other two species, *S. aureum* Schroeter and *S. incrassans* Maire (see Karling, 1964), which have been reported to occur on *Leontodon hispidus* and *L. tuberosus*, respectively, do not stimulate such a reaction in their hosts, according to the author's study of herbarium material, and for this reason the author believes that the stimulus produced by *S. leontodontis* may be specific. It remains, however, to be shown whether or not other species produce the same reaction in *L. leysseri*.

Synchytrium leontodontis may prove to be related to *S. incrassans* on the grounds that its spore content is greyish-white instead of pigmented like that of *S. aureum*. However, Maire (1917) reported that *S. incrassans* is very similar to *S. aureum*. with the exception that the content of the spore is first yellow and then turns grey in color. So far as it is known, *S. leontodontis* may be classified in the section *Leucochytrium* of the subgenus *Pycnochytrium*.

Synchytrium limosellae sp. nov.

Prosori evanescentes subglobosi vel globosi, 80—132 μ diam., vel ovoidei, 90—96 × 108—123 μ; pariete obscure brunneo, 2.5—3.6 μ crasso, incrustato praediti; sori supra prosoros in matricis cellulis orti, ovoidei, 80—96 × 114—123 μ subhemisphaerici vel saepe reniformes, 90—98 × 142—168 μ, pariete pallide brunneo, 2—2.8 μ crasso praediti; sporangia usque ad 120 in quoque soro, polyedrica, 14—36 μ diam., pariete hyalino obtecti; sporae perdurantes globosae vel subglobosae, 98—132 μ diam. vel ovoideae, 115—130 × 140—156 μ, pariete levi,

obscure brunneo, 3.5—4.2 μ crasso, praeditae, plasmate griseo-albido farctae, residuis globoso-granulosis incrustatae.

Specimen typicum in Herb. Plant Disease Division, DSIR, conservatum, no. 25212.

Evanescent prosori subspherical, spherical, 80—132 μ diam., ovoid, 90—66 × 108—123 μ, with a dark-brown encrusted, 2.5—3.6 μ, thick wall. Sori formed above prosori in infected cell, ovoid, 80—96 × 114—123 μ, subhemispherical to almost reniform, 90—98 × 142—168 μ, with a light-brown, 2—2.8 μ, thick wall. Sporangia up to 120 per sorus, polyhedral, 14—36 μ in greatest diameter, with a hyaline wall. Resting spores spherical, subspherical, 98—132 μ diam., ovoid, 115—130 × 140—156 μ, with a smooth dark-brown, 3.5—4.2 μ, thick wall, encrusted with globular residue, and greyish-white content; germination unknown.

Compositely dihomeogallic. Sporangial and resting-spore galls usually crowded together, lavender-red, dome-shaped to almost hemispherical, up to 500 μ broad at base by 200—250 μ high; sheath 2—4 cells thick.

Type locality, Ranfurly central Otago.

Parasitic on *Limosella lineata.*

This species was collected by Healy (21-1-1957) in a dried up swamp near Ranfurly, Otago, and deposited in the PDD herbarium without identification. It causes marked malformation and curling of the leaves, particularly where the galls are crowded and confluent. At first, it was believed to be a short-cycled species which forms only resting spores, but a more careful study of the specimens revealed a few sporangial galls with empty prosori, sori and sporangia among the resting-spore galls and spores. The sori, which are formed above the prosori within the host cell, appear to be firmly attached to the empty and collapsed prosori by a common plug of densely-stainable material and may be readily dissected out of the galls intact, as is shown in figs. 19 and 20. The sori are comparatively small but usually bear a large number of sporangia which vary greatly in size and shape (fig. 21).

The occurrence of evanescent prosori, sori, sporangia and resting spores indicate that *S. limosellae* is a long-cycled species which probably belongs in the subgenus *Microsynchytrium,* but its final classification will depend on the manner of resting spore germination. Several species, *S. aureum, S. linariae, S. linderniae, S. globosum, S. macrosporum,* and numerous unidentified specimens (Karling, 1964, pp. 394—395) have been reported on species of the family Scrophulariaceae, but the present fungus is the only one known to occur on *Limosella.* Among the species listed above only *S. linariae* and *S. lindernae* are long-cycled; the remainder develop only resting spores so far as they are known. In *S. linderniae* the initial cell, apparently, is transformed directly into a sorus, and evanescent prosori are unknown. Accordingly, it was tentitively assigned to the subgenus *Synchytrium* (Karling, 1964, p. 202). In

S. linariae Karling (1957 c), on the other hand, the initial evanescent cell or prosorus gives rise to a sorus as in *S. limosellae,* but unlike in the latter species the sorus develops beneath the prosorus. It, also, is a smaller species than *S. limosellae,* produces only 15—35 sporangia per sorus, and causes a marked thickening, lignification, and scalariform perforations in the walls of the infected and inner sheath cells. It's resting spores, however, are only slightly smaller than those of *S. limosellae.* The two species are, nevertheless small and somewhat similar, and for the time being, at least, *S. limosellae* may be placed near *S. linariae* among the incompletely known species of *Microsynchytrium.*

Synchytrium taraxaci De Bary and Woronin, 1863. Ber. Naturforsch. Gesell. Freiburg 3: 22—61, pls. I, II.

This type species of *Synchytrium* is almost world-wide in distribution and usually occurs abundantly on *Taraxacum officinale* in New Zealand wherever this host is found. The author collected it in the provinces of Auckland, Hawke's Bay, Taranaki, Wellington, Marlborough, Canterbury and Otago. Previously, Cunningham (1930), Zotov (1930), McKenzie (1948), and Dingley (1951, 1954, 1956, 1957) had collected it in various localities in New Zealand, according to the specimens in the Plant Disease Division, DSIR, herbarium at Mt. Albert, Auckland. These labeled specimens listes its occurrence, also, on *Crepis capillaris* (spec. 10569, 11602, 12115, 24305), *C. taraxacifolia* (spec. 3698), and *Cirsium vulgare* (spec. 12867), but it is questionable that the parasites on these host relate to *S. taraxaci.* As noted above, Ludi (1901, 1902) found that *S. taraxaci* is closely limited in host range to species of *Taraxacum.* His cross inoculation experiments involved 11 genera and 19 species of non-cichoraceous plants and nine genera and 21 species, besides *Taraxacum,* of the *Cichoraceae,* all of which remained immune. Only eight of the *Taraxacum* species were susceptible in varying degrees. *Crepis biennis* and *Cirsium palustre* were found to be immune, which casts doubts about *S. taraxaci's* occurrence on other genera besides *Taraxacum.* Obviously, Ludi's experiments should be duplicated to determine if the hosts mentioned above harbor races of *S. taraxaci.*

The specimens labeled *S. taraxaci* on *Cirsium vulgare,* which was collected by Healy (1-1954) in Upper Hutt, Wellington, differs in some respects and may prove to be different from *S. taraxaci.* In fixed and stained sections of the herbarium material the initial cell appears to function directly as a sorus as in *S. taraxaci,* but the sheath cells of the sporangial galls usually contain numerous resting spores. As a result, the resting spores are heaped up on the empty sporangial galls, very much as in *S. cinnemomeum* (Karling, 1957 b), and *S. succissae.* The isolated resting spore galls were quite small as in *S. taraxaci.*

How significant and specific this infection of the sheath cells and heaping up of the resting spores on empty sporangial galls is in distinguishing species remains to be seen. It occurs occasionally in a number of species and seems to depend to some degree on the crowding of the sporangial galls, the meristematic condition of the sheath cells at the time of zoospore discharge, and the subsequent localization of some infective zoospores on the sporangial galls after discharge from the sporangia-all of which may be circumstantial occurrences rather than characteristics of a species. However, in *S. succisae* and *S. cinnemomeum* it occurs abundantly and frequently on isolated sporangial galls, according to the author's observations, and may be used to some extent as an adjunct criterion for these species.

The specimens on *Crepis capillaris* collected by H e a l y (24-11-1953) in Upper Hutt, Wellington and identified as *S. taraxaci* are very similar to the latter species in the size and shape of the large sporangial and small resting spore galls as well as the sori and sporangia, and no marked morphological differences have been observed. The author collected this parasite on the some host at Taita, Wellington which was growing in paddocks with densely infected plants of *Taraxacum officinale*. Obviously, cross inoculation tests must be made to determine whether or not *S. taraxaci* will infect species of *Crepis*.

Since K o l e (1965) disproved the many previous reports that the resting spores of *S. endobioticum* function as sporangia in germination and form zoospores directly, *S. taraxaci* is the only remaining known and authentic species in which this is reported to occur. Accordingly, the author has made repeated attempts to germinate the resting spores of the latter species to confirm or disprove DeBary and W o r o n i n's (1863) report of this process, but all attempts have been unsuccessful. None of the changes within the spores reported by these careful workers nor the formation of zoospore have been observed. Obviously, if the resting spores should be found to function as prosori, as Kole discovered in *S. endobioticum*, considerable reclassification of the species of *Synchytrium* and merging of subgenera will be necessary.

S y n c h y t r i u m a u r e u m Schroeter, 1870. Hediwia 9: 4.

This identification was made by G. H. C u n n i n g h a m of a species (spec. 3341) which he collected on *Schizeilima nitens* at the Franz Joseph Glacier, Westland. From the material available this appears to be a short-cycled species which forms only resting spores in composite galls. At least, no other developmental stages were found by the author in Cunningham's collection. The galls on the leaves are frequently crowded and form a scurf or crust when all adjacent epidermal cells are infected, or they may be heaped up and confluent. Isolated separate and protruding galls occur, also, and these may be as much as 420 μ in dia-

meter at the base by up to 480 μ high. Many of the large galls contain several resting spores. The latter are subspherical to spherical, 92—222 μ diam., or ovoid, 72—90 × 95—180 μ, with a light — to dark-brown, 2.8—3.5 μ thick, wall, and yellow content. The sizes of the resting spores depend to a large degree on the intensity of infection and crowding of the galls, and the larger ones are generally found in the large isolated galls.

The symptoms produced on the host, the crowding, sizes and structure of the galls as well as the shapes, sizes, and contents of the resting spores are very similar to *S. aureum,* and Cunningham's identification appears to be correct. If his fungus is *S. aureum, Schizeilima nitens* is a new host for this ubiquitous species.

Synchytrium globosum Schroeter, 1870. Hedwigia 9: 3.

Pycnochytrium globosum Schroeter, 1897, Engler and Prantl, Naturl. Pflanzenf. 1 (1): 73, fig. 55 A—D.

S. globosum var. *alpestre* Maire, 1910. Bull. Soc. Bot. France 57: CLXVI.

This species was cellected by Healy (23-10-1956) on *Viola lyalli* near the Hobson Monument in the Arthur Pass at an elevation of 3,000 ft. The herbarium specimens of his collection at the Plant Disease Division, DSIR, are labeled *S. aureum.* However, the color of the contents, sizes and shapes of the resting spores as well as the structure of the galls induced on the host are more characteristic of *S. globosum,* and the author is tentatively identifying Healy's collection as such. The hyaline to greyish-white color of the resting spore content is quite unlike that of *S. aureum* which is yellowish and orange, to reddish-orange. No evidence of evanescent prosori, sori and sporangia were found in Healy's collection, and on these grounds it is assumed to be a short cycled species which develops only dormant prosori or resting spores.

This parasite causes marked hypertrophy of the lower leaves and petioles. Densely infected leaves may be nothing more than contorted and fleshy masses of tissues and galls, and in such cases the galls may be confluent and compound. Cytologically, it cause a marked irregular thickening and lignification of the wall of the infected cell and part of the sheath cells. As a result, when the surrounding tissue cells degenerate and slough off after long soaking in water part of the galls, infected cell, and resting spore remain intact and "feel" like grains of sand. As shown in fig. 23, the thickening of the walls of the sheath cells may be interrupted at intervals. Also, in some of the upper sheath cells the walls are greatly thickened, while in others they appear thin and unchanged. The upper part of the pyriform host cell is filled with a light-brown, resinlike substance which is almost optically homogeneous and hard, and

this contributes to the hard "feeling" noted above. Probably, because of the thickening and lignification of the walls, the galls are remarkedly wellpreserved in the herbarium material and can be readily embedded, sectioned and stained. Even the resting spore nucleus was clearly distinguishable (fig. 23).

So far it is known this New Zealand parasite belongs in the section *Leucochytrium* of the subgenus *Pynochytrium*. The author searched the locality of Healy's collection in March, 1966, and although the host was fairly abundant no evidence of the parasite was found.

Synchytrium australe Spegazzini, 1881. Anales Soc. cient. Arg. **11**: 1—138.

S. modiolensis Cook, 1945. Mycologia 37: 288, fig. 1 B.

This species occurs commonly on *Modiola caroliniana* on lawns and fields in the Auckland Province, but the author failed to find it on on the South Island. Miss J. M. Dingley collected it on this host as well as *Malva neglecta* at Mt. Albert in 1950 and 1954, according to the specimes in the Plant Disease Division herbarium. In addition to this locality the author collected it in the Kaueranga Valley near Thames, and at the Forest Service Station in the Waipou Kauri Forest. So far he has not found any essential differences between the New Zealand specimens and those studied by him (1954 a, b, c; 1955 a, b) in the U.S.A.

Synchytrium cotulae DuPlessis, 1933. Ann. Univ. Stellenbosch. **11** (ser. A, Afl. 5): 9, figs. 1—8.

This species was collected first by DuPlessis on *Cotula coronopifolia* in South Africa, and what appears to be the same species was collected by Miss S. D. Baker on *C. australis* at the Auckland Domain in 1953 and deposited in the herbarium of the Plant Disease Division at Mt. Albert. The author searched the same locality on several occasions in November, 1965, but failled to find the parasite. A careful study of Baker's herbarium material showed that the New Zealand fungus is very similar to the one described by DuPlessis and the author (1957a), and it is identified herewith as *S. cotulae*.

Synchytrium epilobii Karling, 1955d. Bull. Torrey Bot. Club 82: 457, figs. 28—33.

This species was collected by Dr. Ross McNabb and Miss Joan M. Dingley on *Epilobium rotundifolium* among rocks in the Ferry Falls stream in Sharps Bush, Auckland, 1965. Later, in November of the same year they found it in the Kauaeranga Valley on the same host as well as on *E. peduculare;* and since then McNabb has found it on *E. erectum* at the Maruia River, Nelson Province. The author has collec-

ted it on *E. rotundifolium* in the Waipau Kauri Forest, various places in the Hutt Valley, Mt. Cook National Park, Arthur's Pass, Milford Sound and southern Otago. It usually occurs abundantly along seeping shady banks where its hosts are frequently moistened by water spray. The developmental cycle, morphology and size of the New Zealand fungus conform closely with those of *S. epilobii* studied by the author in the U.S.A. and there is no conclusive evidence to indicate that it is a different species.

Observations on living material in New Zealand has enabled the author to supplement his earlier study of this species with regard to the zoospores. These are ovoid to subspherical, 3—3.2 × 3.5 μ, and 3.5 μ diam., respectively, with a light-golden refringent globule and a 26—30 μ long flagellum (fig. 24). Attempts have been made in the course of several months to induce resting spores germination by freezing, drying, and wetting, but these were unsuccessful. Accordingly, *S. epilobii* is still to be classified as an incompletely known member of the subgenus *Microsynchytrium*.

Synchytrium erieum Karling, 1961. Sydowia 15: 100.

This species, known previously only from Ireland, was collected first on *Plantago lanceolata* on the Auckland Domain in November, 1965. Later, in the same month, the author collected it again on the same host at Mt. Albert, Auckland, the Kauaeranga Valley near Thames, and in the Waipou Kauri Forest. Apparently, it is fairly widely distributed on the North Ishand. The author failed to find it on the South Island.

The prosori, sori, sporangia and resting spores of the New Zealand specimens conform closely in size and shape with those of *S. erieum* from Ireland, and the author is identifying it as such. The zoospores (fig. 25) are ovoid, 3—3.4 × 3.6—3.8 μ, to subspherical, 3.8 μ diam., with a refractive yellowish globule and a 24—29 μ long flagellum. All attempts to induce resting spore germination by alternately drying, freezing and wetting have proven unsuccessful. Until these haven been germinated, *S. erieum* is still to be classed as an incompletely known species of the subgenus *Microsynchytrium*.

In addition to the species noted above two other collections of *Synchytrium* in New Zealand are present in the herbarium of the Plant Disease Division, DSIR. In both of these collections only resting spores are present and the content of the resting spores is hyaline to greyish-white instead of pigmented as in *S. aureum*. On these grounds the species may be assigned tentatively to the section *Leucochytrium* of the subgenus *Pycnochytrium* so far as they are known. The first of these species (spec. 3335) was collected on *Plantago spathulata* at Raikaia George, Canterbury Province, by G. H. Cunningham in January, 1928. A careful search for this fungus in the locality where Cunning-

h a m found it was made by the author in March, 1966, and although the host was abundant no infections were found. This species causes large isolated as well as confluent and compound, red galls on the underside of the leaves. The galls may be crowded when areas of adjacent epidermal cells are infected and usually form in such cases a scurf or crust on the leaf. The large isolated galls vary from 220—400 μ high by 300—600 μ in diameter at the base with a sheath of 2 to 5 uninfected cells. When the dried herbarium specimens are soaked in water for a long time part of the galls may be dissected out of the leaves, and in such cases a plaque of dark epidermal cells remains attached to the apex of the galls in much the same manner as described by the author (1960) for *S. texanum* on *Plantago rhodosperma*. In stained sections the walls of such cells are greatly thickened and the cells are filled with a hard resin-like material which shatters badly in sectioning. The resting spores are spherical, 150—240 μ daim., or ovoid, 102—209 × 120—250 μ, with a thick, up to 5 μ, light-brown wall which is enveloped by a thick layer of dark-brown residue, and hyaline to greyish-white content.

No evanescent prosori, sori, and sporangia were found in C u n n i n g h a m's collection, and so far as it is known this species is short-cycled and forms only resting-spores. As intimated above, it is striking similar in many respects to *S. texanum*, and the author would identify it as such if the content of the resting spore were yellow or otherwise pigmented. The hyaline to greyish-white color of the spore content is not due to aging and loss of color, in the author's opinion, because in many pigmented species which he has studied the pigment is retained for a great number of years. As noted by the author (1964) several short-cycled species besides *S. texanum* have been reported on *Plantago*, including *S. plantaginicola* on *Plantago* sp. in Argentina, *S. plantagineum* on *P. lanceolata* in Mississippi, U.S.A., and *S. aureum* on *P. lanceolata* and *P. virginica*, but in all of these the content of the resting spore is reported to be pigmented.

The second (spec. 11752) of the species noted above was collected by H e a l y (16-1-1953) on *Hydrocotyle* sp. near the mouth of the Whawahakiri River in the Hutt Valley, Wellington Province and identified as *S. aureum* by Miss S. D. B a k e r. It causes large up to 480 μ broad at the base by 375 μ high, dome-shaped to hemispherical and subspherical composite resting-spore galls on the leaves and petioles. These usually occur separately, but sometimes they become confluent and crowded. The resting spores in them are relatively small, spherical to subspherical, 114—180 μ diam., or ovoid with a thin, 2—2.5 μ, almost hyaline wall and hyaline content. *In toto* they look like greyish-white spheres in the galls and infected cell. They do not fill the host cell compheteley and look as if they might be immature.

However, it is doubtful that the lack of pigment in the spores is due to immaturity. In all pigmented short-cycled species, including

S. bonaerense on *Hydrocotyle bonaerensis* in Argentina, *H. umbellata* and *H. canbyi* in Massachusetts and Louisana, U.S.A. and *S. aureum* (?) on *H. callicarpa* in Australia, which the author (1964) has studied the content of the resting spores from the early stages maturity were yellowish-to reddish-orange in color. Although the present species falls within the ranges of variations exhibited by *S. aureum* the author does not regard it as such and is listing it herewith as unidentified species until more is known about it. He made a careful search it in 1966 in the same locality of H e a l y's collection, but neither host nor parasite was found. This locality has become a favorite recreational aea.

In conclusion to this study of the Synchytriaceae it is to be noted that no aquatic species nor members of the subgenera *Woroninella* and *Exosynchytrium* were observed. The identified species are representative of the subgenera *Microsynchytrium, Synchytrium* and *Pycnochytrium.*

Summary

Ten species of *Synchytrium,* including *S. hypochoeridis* sp. nov., *S. leontodontis* sp. nov., *S. limosellae* sp. nov., *S. taraxaci, S. aureum, S. globosum, S. australe, S. cotulae, S. epilobii,* and *S. erieum,* were identified from a study of living material and herbarium specimens in New Zealand. These are representative of the subgenera *Microsynchytrium, Synchytrium* (*Eusynchytrium*) and *Pycnochytrium.* Two additional short-cycled species were studied, but it was impossible to identify them from the herbarium material available. They were assigned tentatively to the section *Leucochytrium* of the subgenus *Pycnochytrium.* No representatives of the subgenera *Woroniella* and *Exosynchytrium* were observed.

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Explanation of Figures.

Figs. 1—14. *Synchytrium hypochoeridis*. Fig. 1. Amoeboid uniflagellate and rare biflagellate zoospores. Fig. 2. Mature evanescent prosorus or initial cell with a fairly thick wall, primary nucleus, dense staining bodies or granules and non-granular area at apex. Fig. 3. Similar evanescent prosorus with more extensive non-granular area. Fig. 4. Early stage in formation of external sorus. Fig. 5. Later stage with prophase nucleus about to pass into incipient sorus. Fig. 6. Multinucleate incipient sorus at apex of gall. Fig. 7. Sorus of sporangia on surface of infected cell. Fig. 8. Sorus of sporangia lying within infected cells. Fig. 9. Variations in sizes and shapes of sporangia. Fig. 10. Discharge of zoospores. Fig. 11. Low magnification of cross section of leaf with a largely submerged or barely protruding resting-spore gall. Thick-walled infected cell occupying more than ½ thickness of leaf. Fig. 12. Early stage in germination of dormant prosorus or resting spore in a protruding gall. Fig. 13. Completion of resting spore germination; sorus of sporangia superficial to infected cell and gall. Fig. 14. Similar stage; sorus of sporangia within infected cell and beneath empty resting spore which it has been pushed out of the disintegrating gall.

Figs. 15—18. *Synchytrium leontodontis*. Fig. 15. Resting-spore gall with thick-walled infected and resting spore in longitudinal section. Figs. 16, 17. Thick-walled infected cell with slit-like perforations; resting spores within. Fig. 18. Portion of infected cell wall with perforations.

Figs. 19—22. *Synchytrium limosellae*. Figs. 19, 20. Sori of sporangia with attached empty evanescent prosori beneath; dissected out of sporangial galls. Fig. 21. Variations in sizes and shapes of sporangia. Fig. 22. Longitudinal section of resting-spore gall with resting spore. Fig. 23. Upper portion of a gall caused by *S. globosum* showing resting spore, thickened infected cell wall, and interrupted thickening of sheath cells. Figs. 24, 25. Zoospores of *S. epilobii* and *S. erieum* respectively.