Art. II.—*Note on* Cordyceps sinclairii, *Berkeley.*

By Professor W. B. Benham, D.Sc., M.A., F.Z.S.

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Plate I.

The group of colourless plants referred to by the botanist as "fungi" include a number of organisms having very varied habitats and interesting life-histories. For example, the edible mushroom; the numerous toadstools, many of large size and conspicuous colouration; the minute "blue moulds" growing on jam, old boots, stale moist bread, and in various other situations; a number of still less noticeable species occurring as saprophytes or parasites in plants, and producing gall-like malformations and other diseases, such as "rusts," mildews, and so forth; and, finally, there are several genera that attack living animals, causing disease and bringing about their destruction.

Amongst these so-called parasitic fungi there is one genus, *Cordyceps*, that is confined to insects. A good number of species are known, each attacking a different insect. The general mode of attack is, as far as is known, as follows: During the resting-period of the insect, when the larva is preparing to enter the stage preceding its metamorphosis into the imago stage, or complete insect, spores of the fungus gain entrance into its tissues. Here the spores give rise to thread-like "hyphæ," which make their way in all directions through the living tissues of the insect's body, absorbing nourishment therefrom. As a consequence the fungus grows, and gradually replaces entirely the tissues of the animal, which has slowly died. Up to this period the plant has been invisible from the outside, but now it proceeds to "fructify." For this purpose some of the hyphæ push their way, as a compact bundle, through the skin of the insect, and grow upwards into the air. The purpose of this exposure is to insure scattering of the spores destined to be formed by these "aerial hyphæ." This dissemination is effected by the wind or other external agent. They thus have an opportunity of reaching another insect, or living organism, so that the life-history may be continued.

The vegetable caterpillar, which is fairly well known to New Zealand naturalists, and has been referred to by a number of observers in the pages of the Transactions, is a fungus called *Cordyceps robertsii*, Hooker, 1843 (or, as it is more correctly named according to the laws of priority, *C. hugelii*,

Corda, 1842). A large number of other species are known in other lands, and these have been recently described and figured by Mr. G. Massee in the "Annals of Botany" (vol. ix., 1895), wherein will be found an epitome of all that is known about the matter.

In New Zealand we have a second species attacking the larva of the singing locust (*Cicada*). This species, known as *Cordyceps sinclairii*, was originally named by Berkeley in his "Flora of New Zealand" (1855): it is figured by him in his "Introduction to Cryptogamic Botany" (p. 73, fig. 17), and also by Taylor in his "New Zealand and its Inhabitants" (p. 647). Both these figures are rather crude; but, except for cursory references to it by Mr. Maskell and Mr. A. Hamilton in their papers on the vegetable caterpillar in the Transactions, I can find no further account of this species.

Massee, in his monograph above referred to, merely quotes Berkeley's description, who gave as its habitat, "Northern Island (New Zealand); in the larva of some orthopterous insect; amongst loose gravelly soil." Hooker records it from a coleopterous larva.

Last month (August) I received two well-preserved specimens of this vegetable *Cicada* from the lightkeeper at Farewell Spit, who had been good enough to comply with a request of mine to preserve in a bottle of formol that I had forwarded to him, any animals of interest that he met with. My thanks are due to him for these specimens, as well as for some very fine large *Scalpellum*, which appear to be new to science.

The two specimens of *C. sinclairii* are at different stages of development, and are so different in appearance from *C. hugelii* (= *robertsii*) that I looked into the literature of the subject, and, as a result, proceeded to investigate the matter.

The fungus, in this stage, makes its way out of the insect near the anterior end, as in all normal cases of *Cordyceps* hitherto recorded. It issues between the head and pronotum. The main branch grows straight forward for some distance and gives off branches right and left in a very characteristic fashion. At first the fungus is cylindrical, white in colour, with a certain amount of pink in places.* In one specimen the branches are few and short (figs. 1, 2); in the other (fig. 3) they are more numerous, and the whole aspect is much more elaborate, and resembles a deer's antlers. The branches lose their cylindrical shape and become irregular; some others broaden out, become more or less flattened, and are very

* Berkeley states that *C. sinclairii* is yellowish. It must be borne in mind that the above description refers to specimens preserved in formol, but the colour of the dried fungus is practically the same, though the pink tint is less pronounced. Possibly "yellowish"-brown might apply to a dried specimen.

irregularly arranged. The pink colour is now more extensively developed and shades into a brown, the white being limited to the axils of the branches. These changes are connected with the maturity of the fungus. In addition to the main post-cephalic bundle of hyphæ, other smaller ones, in the older specimens, issue from the joints of the legs and from the sides of some of the segments.

A still further stage in maturity was represented by a dried specimen given to me by Mr. Hamilton. Here several long main stems issue behind the head, and one behind the pronotum, and run side by side directly forward. These are less branched than in my specimen.

A comparison of the mature condition of *C. sinclairii* with that of *C. hugelii* shows very remarkable and easily recognisable differences (quite apart from the absence of branching in the latter), illustrating two distinct methods of spore-formation.

If an aerial fructifying branch of *C. hugelii* be examined even with the naked eye, it is seen to terminate in a long, velvety, thickened region, sharply marked off from the more woody base or stalk. This upper region owes its velvety appearance to a vast number of closely set yellowish vesicles (or perithecia), each of which, on further examination, may be found to contain eight long filamentous spores packed side by side. But the closest and most careful superficial examination of *C. sinclairii* shows nothing of the kind; there are no perithecia, the surface of the brown-pink region is quite smooth. If, however, this fungus be submitted to microscopical examination, either by the simple method of teasing up with needles, or, better, by cutting sections across it with a razor, it will be found that below this smooth surface, formed of closely arranged fungal hyphæ, innumerable spores occur, but of quite a different size and shape and arrangement. These spores are short and oval, quite irregularly arranged amongst the hyphæ. Further, they are produced in a manner quite different from that exhibited by *C. hugelii*. In fact, these two species of New Zealand *Cordyceps* illustrate the two chief modes of reproduction by spore-formation recognised by botanists as occurring in the group of fungi, and which generally occur in two different stages in the life-history of one and the same species of fungus.

The two different modes of spore-formation yield different kinds of spores—(1) *Ascospores*, formed by subdivision of the protoplasm inside a single cell or "ascus"; (2) *Conidiospores*, formed by constriction of a hypha, so as to form a row of spores arranged more or less like a string of pearls or beads.

Without entering into further details, it must suffice to state that the fructification of most of the species of *Cordyceps* with which we are acquainted is known only in the

ascospore stage (as in the vegetable caterpillar of New Zealand, *C. hugelii*), while nothing is known of the other stage—the conidiospore stage—of the life-history; but in a few European species, such as *C. militaris* and *C. entomorhiza*, both stages in the life-history of the fungus are known, and the relation of one to the other has been worked out. From experimental researches on these species we know that the conidial stage is a saprophytic form, which may grow on leaves, bark, wood, &c., and not necessarily on insects, and has been hitherto regarded as a distinct genus of fungus, to which the name *Isaria* had been given, while the ascospore stage is, of course, that condition known as infesting the insect. Thus *C. militaris* is the ascospore stage of a fungus of which the conidial stage has been known as *Isaria farinosa;* and *C. entomorhiza*,* infesting the larvæ of various insects, has as its conidial stage *I. densa*, which normally occurs on the larva of the cockchafer (*Melolontha*). These two stages do not occur at the same period of the year, but it appears that a resting-stage, known technically as "sclerotium," intervenes.

From these and other facts botanists consider it likely that each of the species of *Cordyceps* has its own "isarial" stage, though this can only be ascertained by experiments similar to those that have enabled the facts above mentioned to be determined.

Now, the chief interest in my own observations on *C. sinclairii* lies in the fact that it is the conidial stage of a fungus—a fact already noted, I may state, by Berkeley. We do not know its ascospore stage, and one is inclined to suggest that possibly the two fungi known as *C. sinclairii* and *C. hugelii* may be merely links in the chain of events in the life-history of one species of *Cordyceps*. But this can only be determined by direct experiments with living organisms—by sowing the spores of *C. sinclairii* (from the *Cicada*) in the tissues of the caterpillar, and ascertaining whether they give rise to *C. hugelii*. It is manifestly a difficult experiment to perform, and a considerable number of living fungi and insects would be required; and since we do not know with certainty what species of caterpillar (and whether more than one) is attacked by *C. hugelii*, it will be necessary to make a further investigation into the whole subject.†

* Massee records *C. entomorhiza* as occurring in New Zealand as well as in Europe. He does not state its host in New Zealand; the only detail given is "(Coll. Colenso)."

† In looking at Taylor's book I note that on page 641 he refers to "*Mumutawa*, the largest beetle of New Zealand," living on sandhills, as being infested by a "fungus, which entirely occupies its body, without sending up any shoot." It is desirable to look into this matter, and I should be very grateful for specimens—preferably fresh; otherwise, preserved in alcohol or formol.

Postscript (December).—I have throughout spoken of this parasite of *Cicada* larva as *C. sinclairii*, though I am by no means certain that this identification is correct. Berkeley states that his specimen is "yellowish," inclining to "lemon-coloured" at the edges. Now, neither the dried specimens nor carefully preserved ones are yellow: if the terms "brownish" or "pinkish" be used, either is true. Moreover, while Berkeley's figure is very similar to Mr. Hamilton's specimen, it differs from my own specimens from Farewell Point. However, the latter difference is not one that has any importance; and, with regard to the colour, it may be that when fully mature, when all the spores that can be formed are formed, the fungus turns yellow. For the present it is less confusing to retain Berkeley's name for the fungal destroyer of our *Cicada* larva, especially as only one other case of a similar insect being attacked by *Cordyceps* is known—viz., *C. cicadæ*, Miquel, from Brazil—and it is improbable that there is any connection between the two species. I have been unable to find an account of the Brazilian species, which appears to be very imperfectly described.

EXPLANATION OF PLATE I.

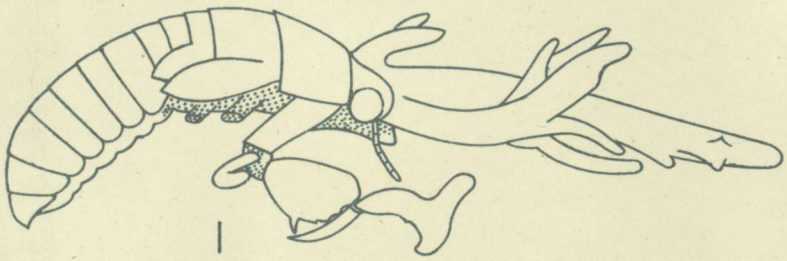
[The figures are mere outlines, tracings from more elaborate sketches carefully drawn to scale. The magnification of the figures is about twice the natural size.]

Fig. 1. Side view of *Cicada* larva, with a young fructification of *Cordyceps sinclairii* issuing from its neck, and a small one from the base of the right fore leg (the other legs are represented as being cut short). The greater part of the main aerial bundle is white, but the tips are pink.

Fig. 2. Dorsal view of fore part of same larva, showing the three main branches of the aerial bundle and a small vertical branch.

Fig. 3. A *Cicada* larva with a very well developed *Cordyceps*. The single main axis branches almost at once into a number of more or less bifurcated lobes, flattened, and brown-pink in colour; the bases only are now white, though here and there white patches persist.

Bundles of white hyphæ of the fungus are seen issuing from all the thinner parts of the body-wall, between the abdominal and thoracic segments, and from various parts of the fore leg and second leg (which is bent up against the body); the third leg is removed.



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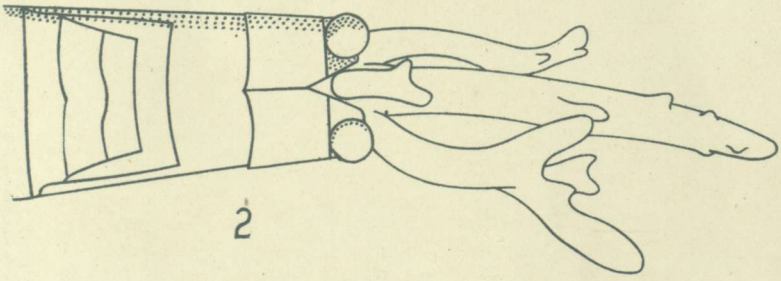

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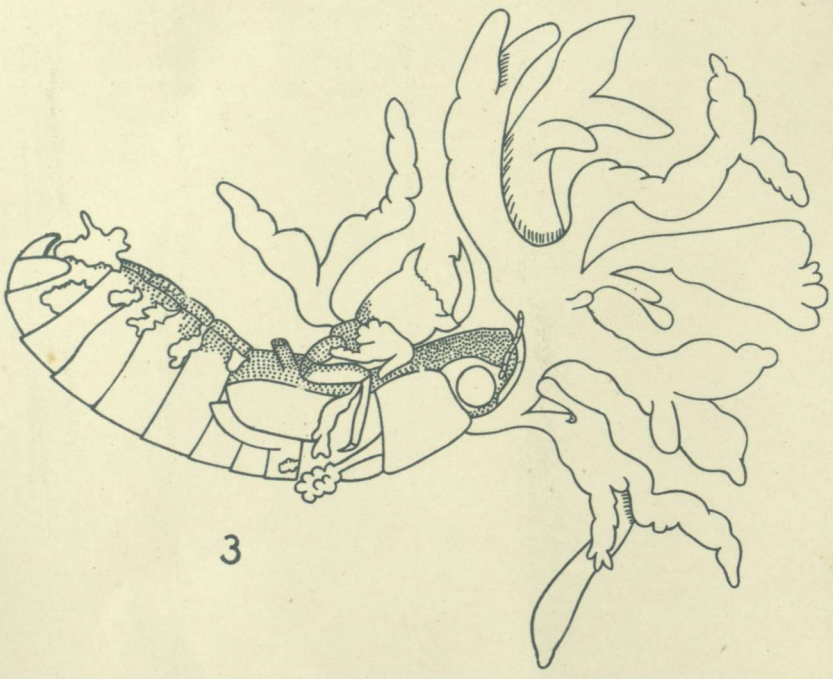

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CORDYCEPS SINCLAIRII
(Benham)