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THE

# JOURNAL OF ECONOMIC BIOLOGY.

## NOTES ON SOME NEW AND RARE THYSANOPTERA *(TEREBRANTIA)*, WITH A PRELIMINARY LIST OF THE KNOWN BRITISH SPECIES.

By

RICHARD S. BAGNALL, F.L.S., F.E.S., Etc.

Since my last contribution to this Journal (1909, vol. iv, No. 2), I have recorded[1] *Cryptothrips latus*, Uzel, *Trichothrips longisetis*, Bagnall, *T. propinquus*, Bagnall, *Acanthothrips nodicornis* (Reuter), and *Liothrips hradacensis*, Uzel, from the British Isles, whilst in the following pages *Frankliniella breviceps*, sp. nov., *Euthrips pallipennis*, Uzel, *Amblythrips ericae*, gen. et sp. nov., *Oxythrips brevistylis* (Trybom), *O. brevicollis*, sp. nov., *Thrips validus*, Uzel, *T. albopilosus*, Uzel, *Bagnallia agnessae*, sp. nov., and *B. halidayi*, sp. nov., are for the first time recorded as British.

At the end a list of the 74 species now recognized as belonging to our fauna will be found, those marked with an asterisk having been recorded since Haliday's papers were published, and with but one exception during the past three years. A hundred species are known from Bohemia, and I feel confident that as many or more will be found in this country, if diligently and systematically worked.

Prof. O. M. Reuter, in his monograph of the Finnish Thysanoptera, recognizes 59 species, but since that date other forms have been discovered, so that the list includes more than 60 species. In Dr. Buffa's last note on Italian Thysanoptera he gives a list of 42 species. With the exception of the Scandinavian countries and Belgium, and of course those referred to above, very few thrips indeed are recorded from the European countries.[2]

[1] Entom. Mon. Mag., Nov., 1910, and Trans. Nat. Hist. Soc. of Northumberland, Durham, and Newcastle-on-Tyne, December, 1910.

[2] Dr. Trybom has added considerably to our knowledge of the Swedish Thysanoptera, whilst I hope to publish notes shortly on collections recently made by myself in Norway, Denmark, Sweden and Belgium.

I should especially welcome material from the South of England, where, I am convinced, many new forms await discovery.

Genus **Frankliniella,** Karny (*Physapus*, Serv.).

**Frankliniella breviceps,** sp. nov.

Length about 1.0 mm. Dark chestnut-brown, head yellowish-brown, fore femora greyish-yellow, lighter apically, fore tibiae yellow, lightly tinged with grey; hind and intermediate femora light greyish-brown, yellowish at extreme tips, tibiae greyish-brown, yellowish apically and at knees; all tarsi yellowish.

Head short, only slightly more than three-fifths the length of prothorax and two-fifths as long as broad. Prothorax one half as long as broad; anterior-marginal spines almost as long as those at posterior angles. Pterothorax broader than, and two and one-half times as long as the prothorax. Wings long, over-reaching the tip of the abdomen; white, lightly tinged with grey; spines long and strong, black; lower cilia of fore-wings wavy.

Abdomen ovate, a little broader than the pterothorax; tip sharply narrowed and furnished with long and rather slender bristles, which are nearly one and one-half times as long as the length of the prothorax.

*Hab.*—One female taken by Mr. C. O. Waterhouse at Acton, August 22nd, 1906.

The antennae are unfortunately broken in the type specimen, but it may be readily separated from *vulgatissimus* (Hal.), *tenuicornis* (Uzel), and *pallidus* (Uzel), by the form of the head, which is not contracted behind. *Breviceps* comes in the group containing *robustus* (Uzel), *nervosus* (Uzel), and *nigriventris* (Uzel), and differs from each of these species by the shortness of its head; from *robustus* by the type of coloration, smaller size, the light-coloured wings and apparent absence of the fore-tarsal tooth; from *nervosus* by the much shorter head and coloration, and from the macropterous form of *nigriventris* by the dark colour of the thorax, the long strong wings and the colour of the hind and intermediate tibiae.

Genus **Euthrips,** Targ.-Tozz.

**Euthrips pallipennis,** Uzel.

Uzel, Monographie der Ordnung Thysanoptera, 1895, p. 110, pl. v, fig. 57.

This species is recognised from its allies by the form of the antenna which has the third joint considerably longer than the second, the third and fourth long and spindle-formed, and the sixth shorter than the third. The wings are light, from which feature the species gets its name.

I have a specimen taken in the flower of the field scabious (*Scabiosa arvensis*) at Hart, Co. Durham, July, 1907.

Distribution.—Bohemia, Heligoland, Sweden and Finland, England.

### Genus **Amblythrips,** nov.

Near *Euthrips*. Ocelli and wings absent, head shorter than prothorax, antennae about twice as long as the head with the style two-jointed and less than one-half as long as the sixth joint; maxillary palpi three-segmented. Prothorax slightly and evenly narrowed anteriorly with two long bristles at each posterior margin.

Last abdominal segment in the female broadly rounded and ovipositor rather short, apparently almost straight laterally and protruding slightly beyond the end of the abdomen; bristles on the two apical segments long, all others short.

Type *Amblythrips ericae,* mihi.

In 1907 Mr. H. Karny, in his paper "Die Orthoperenfauna des Kustengebietes von Osterreich-Ungarn" suggested dividing the genus *Physopus* or *Euthrips* into five genera, representing five of the main divisions, tabulated by Uzel, namely *Physapus,*[1] Serv. (type *vulgatissimus* (Hal.)); *Odontothrips,* Serv. (type *O. phalerata* (Hal.)); *Taeniothrips,* Serv. (type *T. primulae* (Hal.)); *Euthrips,* Targ.-Tozz. (type *E. ulmifoliorum* (Hal.)); and *Pezothrips,* Karny (type *P. frontalis* (Uzel)). This arrangement is a very helpful one and I believe perfectly sound, as the characters relating to the chaetotaxy are apparently considerably more valuable than has hitherto been acknowledged. The genus *Pezothrips,* Karny, contains the two species *frontalis* (Uzel) and *pilosus* (Uzel), and a new form in my possession from Norway, whilst recently Karny describes *Pezothrips* (?) *pedestris,* which it will be seen he doubtfully refers to that genus.

This latter species apparently belongs to the genus above diagnosed, which would appear to be a well-defined one, differing from *Pezothrips* by the entire absence of ocelli and wings, the shorter antennal style, the form of prothorax and the rounded tip of abdomen, this latter character suggesting the generic name.

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[1] *Frankliniella,* Karny.

### **Amblythrips ericae**, sp. nov.

Female, length 0.6 mm.

Colour reddish-yellow, prothorax very slightly, margins of abdomen and head (more noticeably distally) greyish-brown; two basal joints of the antennae yellow and the others dark grey, with a slight brownish tinge; all legs light yellow.

Head broader than long, widening posteriorly, with mouth-cone reaching across the prosternum. Antennae separated at base, first joint broader than long, cylindrical; second broadly cyathiform, broad; third faintly claviform; fourth oviform, as wide as third, but slightly longer; fifth constricted at base and truncate at apex, narrower than the eighth and preceding joints. Relative lengths of joints, 5, 9.5, 9, 11, 8, 12.5, 2, 3.5.

Prothorax transverse, not quite three-fifths as long as broad across hind angles, where it is widest; narrowed evenly from base to fore-margin; two long bristles at each posterior angle. Pterothorax slightly broader than prothorax, transverse. Legs rather stout, spine at tip of hind tibia within.

Abdomen rather long and sub-linear, only a little broader than the pterothorax.[1] Bristles moderately long, those on ninth segment exceptionally long, about half as long again as those on the tenth segment and more slender. Tenth segment broader than long and broadly rounded.

*Hab.*—Five specimens on heather (*Calluna*) in an old fir plantation at the edge of the moors near Ravenscar, Yorkshire, at about 800 feet. There is also a single example in my tube of *Oxythrips parviceps* and *Euthrips ericae* taken at Colintraive in the Kyles of Bute, July, 1907.

*A. pedestris* (Karny) differs from *ericae* by the form, relative lengths and coloration of the antennae, and by the extremely long prothorax, the mouth-cone in that form only reaching about half-way across the prosternum.

### Genus **Oxythrips**, Uzel.

The following table of the known species may be useful. *O. firmus* has not yet occurred in this country, but is apparently not uncommon in Bohemia.

I. Colour generally yellowish. Hind angles of prothorax with a single bristle. Prothorax slightly longer than head:

[1] In one specimen the abdomen is shrunken and apparently oviform and broader than in the others.

(*a*) Tenth abdominal segment in the female very long, almost tubular. The upper vein of the fore-wing set with five bristles in the apical half. (Habitat usually in flowers of pine trees). . . . *brevistylis* (Trybom).

(*b*) Tenth abdominal segment normally long. The upper vein of the fore-wing set with three bristles in the apical half. End of fore-tarsus with a small needle-like bristle. (Habitat usually in flowers of *Ajuga reptans*). . . . *ajugae,* Uzel.

II. Colour generally darker. Hind angles of prothorax each with two bristles. Prothorax considerably longer than the head:

(*a*) Head longer and slightly widened posteriorly:

(i.) Body wholly black or blackish-brown; end of second and the whole of third antennal joint yellowish, fourth greyish-yellow. Prothorax longer and less strongly transverse. (Habitat usually on grass). . . . *firmus,* Uzel.

(ii.) Colour lighter, abdomen yellowish-brown and black at apex; antennal joints three to eight uniform dark grey or greyish-black. Prothorax shorter in comparison to length of head, and strongly transverse. (Habitat apparently in sphagnum). . . . *brevicollis,* Bagnall.

(*b*) Head very small and slightly narrowed or contracted posteriorly. Resembling brevicollis in general form and coloration, but having the head narrower, shorter, and contracted posteriorly, and the prothorax narrower and longer and roundly narrowed anteriorly. (Habitat usually in flowers of *Calluna* and *Erica*). . . . *parviceps,* Uzel.

### **Oxythrips brevistylis** (Trybom).

*Belothrips bicolor*, Reuter, Ofv. Finsk. Vetens.-Soc. Förh., 1878-9, xxi.
*Belothrips brevistylis* Trybom, Ent. Tidskr., 1895, xv, p. 185.
*Oxythrips hastata*, Uzel, Monographie der Ordnung Thysanoptera, 1895, p. 135, pl. v, fig. 66.

By beating the flowers of pine; in numbers, Prestwich Carr, Northumberland, June, 1910; in a wood above Westgate in Weardale, Co. Durham, June, 1910; and between Riding Mill and Minsteracres, and on the road from Minsteracres to Slaley, and Slaley to Hexham, Northumberland, July, 1910.

### **Oxythrips brevicollis,** sp. nov.

Closely resembling *O. parviceps* in size and structure, differing chiefly in the type of coloration and in the form of the prothorax, which is strongly transverse, two and one-third times as broad as long, and has the lateral margins only very slightly converging anteriorly.

The head, which widens posteriorly, with the prothorax is dark grey-brown in colour, whilst the pterothorax is more of a yellowish-brown tinged with grey. The abdomen is yellow, or light yellowish-brown shaded with grey, from the fifth segment to the tip of the eighth being almost entirely grey, and the ninth and tenth uniform grey-black. Antennae uniform dark grey or grey-black, with the two basal joints lighter and tinged with brown. All femora greyish-yellow and tibia lighter and shaded to a light yellow at tips; all tarsi yellow. Wings light grey.

Head basally and fore-margin of prothorax distinctly broader than in *parviceps,* prothorax broader and shorter, with the sides only slightly narrowing towards head; spines on hind-tibia excepting the distal pair comparatively shorter and the abdominal bristles, especially the lateral and sublateral pairs from the third to the eighth segment comparatively longer.

*Hab.*—One female taken in sphagnum on the moors near Ravenscar, Yorkshire, at about 700 feet, September, 1910. Owing to the stormy weather I was unable to search for further material.

## Genus **Thrips,** L

### **Thrips validus,** Uzel.

Uzel, Monographie der Ordnung Thysanoptera, 1895, p. 183.

A single male taken in the flower of a dandelion at Gibside in June, 1907, is referable to this species. *T. validus* belongs to the group wherein the species have fifth antennal joint decidedly shorter than the fourth, and is separated from the allied form *linaria,* Uzel, by its larger size and in having the third and fourth and the basal part of the fifth joints light in colour.

Distribution.—Bohemia (Uzel), England.

### **Thrips albopilosus,** Uzel.

Uzel, Monographie der Ordnung Thysanoptera, 1895, p. 190.

A female and two males taken on juniper with *T. juniperina* at Nethy Bridge, Inverness-shire, July, 1908, differs from *T. flavus* var. *obsoletus* in having the fifth antennal joint almost if not quite as long as the fourth, the fifth and sixth segments broadly united, and the style comparatively longer. The female specimen agrees well with Uzel's description of *albopilosus,* but before describing the male or writing further on this species, I shall make every endeavour to obtain more material.

Distribution.—*T. albopilosus* has only been recorded from Bohemia (Uzel), and the male is not described.

### Genus **Bagnallia,** Karny.

### **Bagnallia agnessae,** sp.n.

*Forma macroptera.*

Female: length 1.45 mm.

Dark blackish-brown, pterothorax slightly lighter; second and fourth antennal joints brownish and the third clear yellow; all tibiae shaded to yellowish and all tarsi yellow-brown apically; fore-wings greyish-brown, darkest at tips, light patch at base, lower wings white, greyish towards tip.

Head practically as long as broad, and about seven-eighths the length of the prothorax; frons rounded between eyes. Eyes not quite so prominent as in *klapaleki,* but distinctly bulging, coarsely facetted; ocelli rather widely separated and the anterior ocellus smaller than the others.

Cheeks slightly constricted behind eyes and thence parallel to base, surface towards base mildly striate. Mouth-cone reaching across prosternum. Antennae one and four-fifths as long as the head, inserted below vertex with the joints sub-contiguous. First joint short and broad, second only slightly constricted at base and truncate at apex; third and fourth narrower than the preceding or succeeding joints (style excepted), each mildly constricted at base and faintly narrowed distally (the third with a short distinct stem), truncate at apex; fifth broader, widened roundly from base, apex truncate and broadly jointed to base of sixth which, including style, is narrowed evenly from basal third to extreme tip. Relative lengths of joints excluding stem of the third joint: 7, 14, 15, 14, 13, 17, 8.

Prothorax transverse, two-thirds or a little more than two-thirds as long as wide across basal third; sides evenly and gently narrowed anteriorly, hind margin arcuate, hind-angles broadly rounded; fore-margin and angles obtuse. Two long bristles at each hind angle; other marginal bristles short, a lateral bristle below the mid-line being a little longer than any of the others.

Pterothorax broader than the prothorax and longer than broad. Legs rather stout, especially the anterior pair, hind tibiae armed with a series of short spines from the middle to the tip within. Wings short, reaching to the hind-margin of the fifth abdominal segment.

Fore-wing broadest at base, apparently narrowed slightly near middle and pointed at tip; only seventeen to twenty spines along the fore-margin, which are long and widely spaced, and one or two spines at tip; veins obsolete, fore-vein with two spines distally, one near middle and three basally; hind vein with as a rule seven unevenly spaced spines; hind cilia long. Hind-wing narrower than fore-wing, pointed at tip; median vein running for almost the length of wing; hairs on fore-margin few and widely spaced, cilia on hind-margin long.

Abdomen elongate-ovate; wider than pterothorax, widened to fourth segment, and very sharply narrower from fore-margin of seventh segment to tip; tenth segment four-fifths as long as the ninth. Bristles on ninth and tenth segments long, longer than the segments bearing them; a short curved lateral bristle on eighth segment; other lateral bristles shorter and not so noticeable.

*Hab.*—Several females on grass by the side of a ditch, Gibside, Co. Durham, October, 1910.

Allied to *klapaleki* (Uzel), *calcarata* (Uzel), *discolor* (Hal.), *angusticaps* (Uzel), *viminalis* (Uzel), *longicollis* (Uzel), *palustris* (Reut.) and *capito,* Karny.

Separated readily from *calcarata* by absence of fore-tarsal tooth and colour; from *klapaleki, palustris* and *angusticeps* by the shape and relative lengths of antennal joints; from *longicollis* and *viminalis* by the colour of the antennae and from *discolor* and *capito* by the shape of head and colour. So far as I can gather *agnessae* differs from all the above-named species with the exception of *calcarata* and *klapaleki,* in having the eyes distinctly bulging or laterally prominent, and as it is readily separated from these forms I have little hesitation in naming it as new.

### **Bagnallia halidayi,** sp. nov.

*Forma brachyptera.*

Male: length, 0.85 mm.

Colour, dark blackish-brown, head and prothorax black, pterothorax lighter; antennal joints two, three and four clear yellow, tinged lightly with grey apically; basal joints brown, and five to seven grey, with base of fifth light. Fore-tibiae and end of fore-femora yellow, hind and intermediate-tibiae yellow, tinged with grey at knees. Wing-pads white.

Head about as long as broad, and a little longer than the prothorax; like *agnessae,* but with the eyes less prominent. Antennae as in *agnessae*; relative lengths of joints, excluding the short stem of the third segment, as follows: 5, 9.5, 10.5, 11, 10, 13, 6.

Prothorax transverse, seven-eighths as long as the head and one and five-eighths as broad as long; two long bristles at each posterior angle, three-sevenths the length of the prothorax. Pterothorax a little broader than the prothorax and about as long as broad; sides of metathorax gently converging to base of abdomen. Wings reduced to a pad. Fore-legs short and stout; intermediate pair short, but not so stout; hind pair long, spines on the inner side of hind-tibiae with the exception of the apical one, weak.

Abdomen about as broad as the prothorax, gently narrowing apically from the seventh segment. Apex bluntly rounded; eighth segment with moderately long bristles at hind-angles, ninth and tenth with several longer and apparently more slender bristles. Each of the sternites three to seven with a strongly transverse depression, relative lengths across each depression as follows: 15, 17.5, 20, 15, 9. In one specimen the third depression is only the same breadth as the second.

*Hab.*—Four males from coarse grass growing by the side of a rivulet in Epping Forest, near Chingford, September, 1910.

Easily separated from *agnessae* by colour of antennae and legs, and by the less prominent eyes. Comes nearest *angusticeps, viminalis* and *longicollis*. The male of the first two of these species is known; *angusticeps* has an elliptical depression on each of the sternites 3, 5, 6, and 7, and a minute circular depression on the fourth, whilst *viminalis* has a circular depression on each of the sternites three to six. Only the female of *longicollis* is known, from which *halidayi* may be recognized and easily separated by having the fifth antennal joint only very slightly shorter than the fourth, and by the coloration of the antennae. The female of *longicollis* is smaller than the male of *halidayi*.

# A PRELIMINARY LIST OF THE THYSANOPTERA KNOWN TO OCCUR IN THE BRITISH ISLES.

ORDER THYSANOPTERA.

Sub-order TEREBRANTIA.

Aeolothripidae, Hal.

AEOLOTHRIPS, Hal.

† 1. A. melaleucus, Hal.
2. A. vittatus, Hal.
3. A. fasciatus (L).
4. A. albocinctus, Hal.

MELANOTHRIPS, Hal.

5. M. fuscus (Sulz.).

Thripidae, Hal.

CHIROTHRIPS, Hal.

6. C. manicatus, Hal.
* 7. C. similis, Bagnall.

LIMOTHRIPS, Hal.

8. L. denticornis, Hal.
9. L. cerealium, Hal.

SERICOTHRIPS, Hal.

10. S. staphylinus, Hal.

FRANKLINIELLA, Karny (Physapus, Serv.).

11. F. vulgatissimus (Hal.).
*12. F. robustus (Uzel).
*13. F. breviceps, Bagnall.

ODONTOTHRIPS, Serv.

14. O. phaleratus (Hal.).
15. O. ulicis (Hal.).

EUTHRIPS, Targ.-Tozz.

†16. E. asperus (Hal.).
17. E. atratus (Hal.).
*18. E. inconsequens (Uzel).
19. E. primulae, (Hal.).
20. E. ericae (Hal.).
*21. E. pyri, Dan.
*22. E. pallipennis (Uzel).
23. E. ulmifoliorum (Hal.).
*24. E. orchidii, Moulton.
*25. E. longipennis, Bagnall.

AMBLYTHRIPS, Bagnall.

*26. A. ericae, Bagnall.

OXYTHRIPS, Uzel.

*27. O. brevistylis (Trybom).
*28. O. ajugae, Uzel.
*29. O. parviceps, Uzel.
*30. O. brevicollis, Bagnall.

PACHYTHRIPS, Uzel.

†31. P. subapterus (Hal.).

ANAPHOTHRIPS, Uzel.

32. A. obscurus (Mull.).
*33. A. orchidaceus, Bagnall.

UZELIELLA, Bagnall.

*34. U. lubbocki, Bagnall.

APTINOTHRIPS, Hal.

35. A. rufus (Gmel.).
36. A. nitidulus, Hal.

BELOTHRIPS, Hal.

†37. B. acuminatus, Hal.

HELIOTHRIPS, Hal.

38. H. haemorrhoidalis (Bouche).
*39. H. femoralis, Reut.

PARTHENOTHRIPS, Uzel.

*40. P. dracaenae (Heeger).

LEUCOTHRIPS, Reut.

*41. L. nigripennis, Reut.

THRIPS, L.

42. T. physopus, L.
*43. T. tabaci, Lind.
*44. T. major, Uzel.
*45. T. salicarius, Uzel.
*46. T. validus, Uzal.
47. T. flavus, Sch.
†48. T. fuscipennis, Hal.
*49. T. juniperina L., Bagnall.
50. T. minutissimus, L.
*51. T. albopilosus, Uzel.

BAGNALLIA, Karny.

†52. B. discolor (Hal.).
*53. B. agnessae, Bagnall.
*54. B. halidayi, Bagnall.

BALIOTHRIPS, Uzel.

†55. B. dispar (Hal.).

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* Recorded since the publication of Haliday's papers.

† Species of which I have not yet had the opportunity of examining British examples.

**PLATYTHRIPS**, Uzel.

56. P. **tunicatus** (Hal.).

Sub-order **TUBULIFERA**.

**Phloeothripidae**, Hal.

**MEGATHRIPS**, Targ.-Tozz.

*57. M. **lativentris** (Heeger).
*58. M. **nobilis**, Bagnall.

**CRYPTOTHRIPS**, Uzel.

*59. C. **latus**, Uzel.
*60. C. **dentipes** (Reut.).

**ANTHOTHRIPS**, Uzel.

61. A. **statices** (Hal.).
62. A. **aculeatus** (Fab.).
63. A. **subtilissimus** (Hal.).

**TRICHOTHRIPS**, Uzel.

*64. T. **longisetis**, Bagnall.
65. T. **pedicularius** (Hal.).
*66. T. **propinquus**, Bagnall.
*67. T. **semicaecus**, Uzel.
68. T. **ulmi** (Fab.).
69. T. **pini** (Hal.).
*70. T. **copiosus**, Uzel.

**PHLOEOTHRIPS**, Hal.

71. P. **coriaceus**, Hal.

**ACANTHOTHRIPS**, Hal.

*72. A. **nodicornis** (Reut.).

**LIOTHRIPS**, Uzel.

*73. L. **hradecensis**, Uzel.
*74. L. **setinodis** (Reut.).

# RAT FLEAS.*

By

A. E. SHIPLEY, F.R.S.

"*In 'x' finita tria sunt animalia dira:*
*Sunt pulices fortes, cimices, culicumque cohortes;*
*Sed pulices saltu fugiunt, culicesque volatu*
*Et cimices pravi nequeunt foetore necari.*"

It used to be the custom to classify the fleas with the *Diptera,* but in recent years there has been an increasing tendency to split into smaller groups the larger Orders of Insects which satisfied our forefathers, and fleas have now been promoted to the rank of an Order of Insects under the name of the *Siphonaptera,* a term proposed

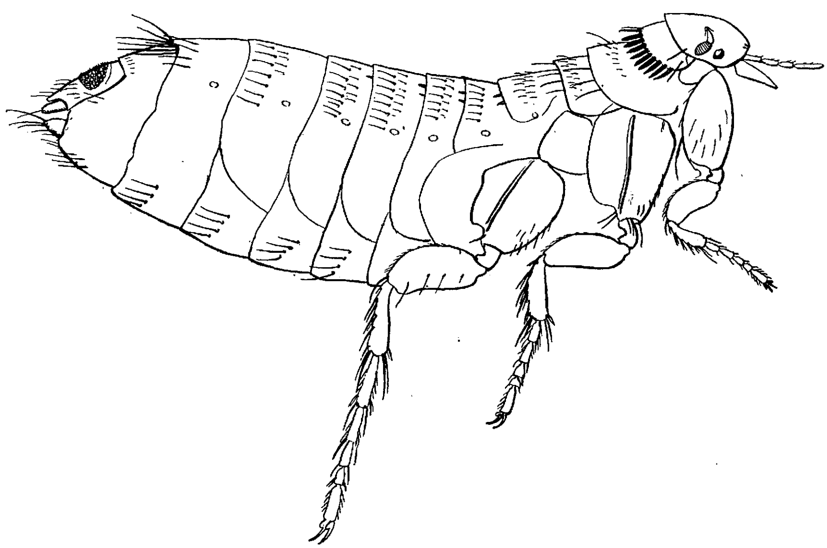

Fig. 1.—*Ceratophyllus fasciatus* (female). Magnified thirty times.

by Latreille some years before Kirby suggested the name *Aphaniptera.*

The head of a flea is small, and the antennæ are short and in rather an unusual position, sunk in a groove and of three joints only, the terminal one being very sensory (Figs. 1 and 2). The mandibles

* Reprinted from "Country Life," by the kind permission of the Editor.

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take the form of long styles with saw-like edges (Fig. 3). The organ with which the insect injects the secretion which sets up the irritation in the bitten is conveyed by a median unpaired hypopharynx.

The first maxillæ have long palps, or sensory organs, which project forward and look like and appear to act as antennæ. The labial or second maxillary palps are also very large, and form a sheath in which the biting styles play (Fig. 3).

The male flea is generally not more than half the size of the female, and the dorsal surface of its abdomen is concave (Fig. 2). In both sexes the three thoracic segments are distinct, and the anterior legs have an extra articulation which throws them forward and gives them almost the appearance of arising from the head (Fig. 2). The legs are unusually powerful, and well adapted for leaping, especially the third pair. So great are their powers of jumping that could a

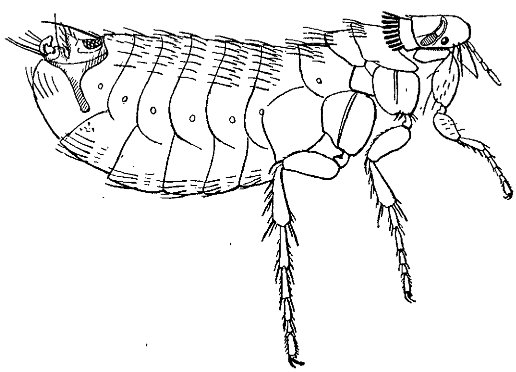

Fig. 2.—*Ceratophyllus fasciatus* (male). Magnified thirty times.

flea be enlarged to the size of a lion without loss of strength, it could spring two-thirds of a mile. The abdomen has nine segments, and the structures at the posterior end are used for the purposes of separating the species.

Fleas undergo a very complete metamorphosis. The eggs are laid some twelve at a time among the hair of the host, or in crannies or cracks in wainscoting, among dirty linen or in crevices in the floor (Fig. 4). They are oval, white, porcelain-like, beautiful ova, not affixed to the hair of their host, for they readily fall on to the ground, and are commonly found where the host sleeps, in kennels and in lairs. The young larva when it emerges is seen to be provided with a process on the head for breaking the egg-shell.

The larva itself is small (Fig. 5), with the mouth-parts of a mandibulate insect. It is provided with a head and thirteen segments, very uniform in appearance, and is, as a rule, of a whitish colour. In spite of having no legs, these little creatures are very active and move quickly about, aided by the wriggling of the body and by numerous bristles. The larvæ live upon any organic refuse found in the dust of the place where they are born and they can be reared upon the sweepings of living-rooms. After a varying number of days, and after casting their skin once, twice or thrice, they pass into the pupa stage, in which the limbs are free. The larva when changing into the pupa spins for itself a little white silken cocoon (Fig. 6), which is frequently covered with dust. After a time the pupa (Fig. 7), which is white, becomes gradually darker, and in a week or two the imago, or perfect insect, emerges. The whole metamorphosis does not last long; the entire development of the generation of a cat flea occupies but little more than a fortnight.

Eight or nine years ago Mr. L. O. Howard, Government Entomologist at Washington, made a series of experiments with *Pulex serraticeps,* a common dog or cat flea. He collected a number of eggs and placed them in two glass vessels; one was kept dry and the other moist with damp blotting-paper. The eggs hatched out as a rule in about twenty-four hours after having been placed in position, and the young larvæ soon showed a brown tinge to their alimentary canal, indicating that they had been feeding on some dried blood which had been given them for food. The larvæ were very active, crawling about, wriggling their bodies and moving their heads and their numerous bristles. They were difficult to rear, an excess of moisture or too much dryness being equally fatal. They cast their first skin in from two to seven days after hatching, and they cast a second skin two or three days later. The length of the larval life varied considerably, from a week to fourteen days, probably being dependent partly on the food supplied and partly on external conditions. The larvæ vary also in the number of skins they cast before they curl themselves up and begin to spin their cocoon, some apparently having cast three skins, others only one. The cocoon is a flattened structure, adherent to some surface, on the lower side, but it soon becomes inconspicuous from the dust which collects and adheres to it. If disturbed while building the cocoon the larva leaves the incomplete structure and transforms into the pupa outside it. On an average the larvæ commence spinning between the seventh and fourteenth day after hatching from the egg, and the imago emerges five days later. It thus appears that in summer-time, at Washington, the whole metamorphosis, from egg to imago, takes from a fortnight to three weeks. This confirms some similar observations made by Mr. W. J. Simmons in Calcutta.

It is not difficult to destroy fleas in the larval stage. They are delicate organisms, and do not develop well in situations where they are likely to be disturbed; but if undisturbed they flourish in the sweepings of floors or where dust collects in the crevices and cracks between boards. This accounts for the great accumulation of fleas that sometimes takes place in unoccupied houses during the summer months.

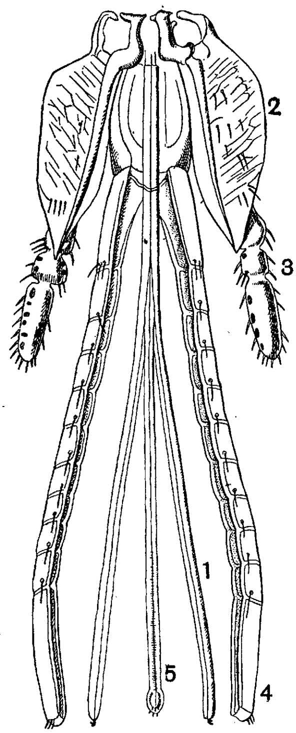


Fig. 3.—Mandibles of a flea. Highly magnified. From Wagner.

1.—Mandibles. 2.—First Maxillæ. 3.—Palp of first Maxillæ. 4.—Second Maxillæ. 5.—Hypopharynx.

The destruction of the adult flea is a much more difficult problem. Various powders and the using of the Californian Buhach and Pyrethrum have at times been unsuccessfully tried, and even a free sprinkling with benzine of the place where dirt had collected was ineffective in one case of extreme infection. One method of getting rid of fleas was successfully practised by Professor Gage of Cornell University. He draped the legs of the "janitor" of the building with fly-papers, with the sticky side outwards. The "janitor" then proceeded to walk up and down the floor of the infected room, with the result that nearly all the fleas jumping at his ankles, as they always do, were caught on the fly-papers.

Fleas are sometimes found in uninhabited rooms in numbers which seem incredible. The floor seems covered with a dense, moving haze of minute insects leaping in the air. These hungering fleas will readily attack any unhappy person or animal that enters the room. Although certain species of flea are usually associated with but one host, many species pass readily from one animal to another. Rabbit fleas will pass on to cats, and fleas from many mammals undoubtedly do bite man. One of the largest, of the one hundred and fifty odd species of fleas, is the *Hystrichopsylla talpæ,*

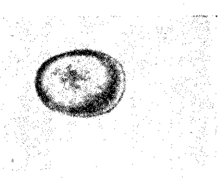

Fig. 4.—Egg of a flea. Very highly magnified. From Howard.

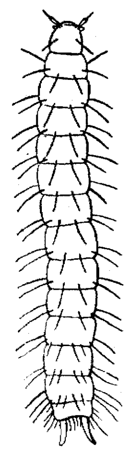

Fig. 5.—Larva of a flea. Magnified ten times. After Laboulbene.

which occurs on moles, voles and field-mice. It is also found in the nests of the humble bee, *Bombus subterraneus*, where it is probably carried by the voles which burrow into their nests. *Pulex serraticeps*, a common dog flea already mentioned, apparently acts as the intermediate host of one of the *Tænias* which infest the alimentary canal of the dog.

The following list of fleas found on *M. decumanus* and *M. rattus* and their allies is compiled from the Hon. N. Charles Rothschild's Synopsis (Bulletin of Entomological Research, Vol. I, 1910, page 89). In this valuable paper he has enlarged and corrected the list which he kindly helped me to draw up, as a part of my paper on the Parasites of the Rat (Journal of Economic Biology, Vol. III, 1908, page 61) some two years ago.

## FAMILY I.—SARCOPSYLLIDÆ.

This family is that of the Chigoes or Jiggers, whose females burrow in the skin of the feet of man in South America.

I. Genus *DERMATOPHILUS*, Gueér.

1. *D. caecata*, Enderl.—Male unknown; this species has been taken in Brazil on and behind the ears of *M. rattus*.

II. Genus *ECHIDNOPHAGA*, Olliff.—The genus belongs to warm countries in the Eastern Hemisphere. Numerous species are known, four of which have been found on rats.

2. *E. gallinaceus*, Westw.—A common species, particularly on the heads of fowls in tropical Asia and Africa; introduced into the United States; also found on rats in Africa.

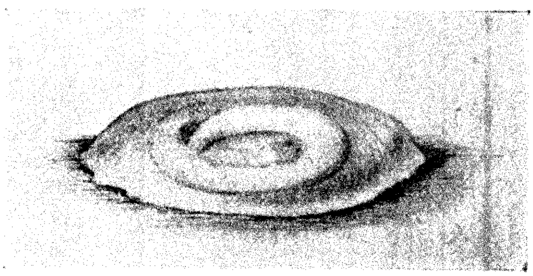

Fig. 6—Larva of a flea. Spinning silk cocoon. Magnified about ten times. After Howard.

3. *E. myrmecobii*, Rothsch.—A species peculiar to Australia, where it has been taken on several indigenous animals and also on rats.

4. *E. murina*, Tirab.—A native of Southern and South-Eastern Europe, where it occurs on the heads of rats; it is apparently rare.

5. *E. liopus*, Rothsch.—Found on rats in India; originally described from Western Australia, where it is plentiful on *Echidna*.

## FAMILY II.—*PULICIDÆ* (TRUE FLEAS).

III. Genus *PULEX*, L.

6. *Pulex irritans*, Linn.—The human flea; practically cosmopolitan. It has been found on *M. rattus* and *M. decumanus* and many other animals which come in contact with man.

IV. Genus *XENOPSYLLA*, Glink.—This genus includes numerous species from Africa: one of them *X. cheopis*, Rothsch., is now practically cosmopolitan, and another, *X. brasiliensis*, Baker, has been introduced into South America.

7. *X. cheopis*, Rothsch.—Originally discovered in Egypt; this is the common flea of rats in the tropics. Although apparently cosmopolitan, it does not flourish in temperate and cold climates. It is the chief agent in conveying plague from rats to man in the East.

This flea was described by Rothchild from specimens taken from numerous small rodents in Egypt. Tiraboschi found it commonly in Italy, and in forty per cent. of the ship rats in Genoa. It occurs on from eighty per cent. to ninety per cent. of the rat population of Sydney and Brisbane, where it was

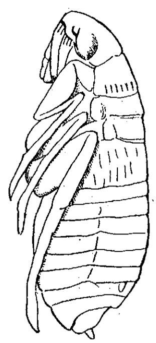

Fig. 7.—Pupa of a flea. Magnified ten times. After Howard.

described by Tidswell under the name of *Pulex pallidus*, and on twenty-five per cent. of the rats in Marseilles, where Gauthier and Raybaud record that the numbers decrease as the distance from the water-front increases. Herzog took forty-two fleas of this species from one hundred and fifty-three rats of both species in Manila, and it also occurs commonly in South America. It has been found at Plymouth and at Pretoria. It is by far the commonest of the rat fleas of warmer countries, and the Plague Commission consider that it forms ninety-nine per cent. of the fleas found on *M. rattus* and *M. decumanus* in India.

8. *X. brasiliensis*, Baker (= *vigetus*, Rothsch.).—This species occurs on rats in West Africa, and has been introduced into Brazil.

V. Genus *HOPLOPSYLLUS,* Baker.—These are North American fleas; one species has been found on rats, but only once.

9. *H. anomalus,* Baker.—This species is recorded from Colorado and California.

VI. Genus *CTENOCEPHALUS,* Kolen.—There are two species, which, although confounded by many authors, are easily distinguished by the shape of the head.

10. *Ct. canis,* Dugès.—This is the flea commonly found on the dog, but it also occurs on rats. It is practically cosmopolitan, but more abundant in temperate countries than in the tropics.

11. *Ct. felis,* Bouché.—This again is a widely distributed and very common flea all over the world on rats as well as many other animals.

VII.—Genus *CERATOPHYLLUS,* Curtis.—The number of species is very large; many of them are found on birds, but five only have been recorded from rats or house-mice.

12. *G. fasciatus,* Bosc.—This is the flea most commonly found on *M. rattus* and on *M. decumanus* in Great Britain, and, indeed, throughout Central and Northern Europe. It also occurs on the house-mouse, *M. musculus.* Rats from Cape Town also harbour this species, and it is occasionally found on rats from India. Should the epizootic in Suffolk become an epidemic, this flea will be in all probability the intermediary between rat and man.

13. *C. londiniensis,* Rothsch.—This species is widely distributed on both the British species of rat and of mice. It is apparently rare in England, but a large number of specimens were once taken in South Kensington. Apparently this species does not bite man.

14. *C. anisus,* Rothsch.—Originally described from Japan, where a male was obtained off *Felis* sp. Another specimen was found at San Francisco, California, taken off *M. decumanus.*

15. *C. penicilliger,* Grube.—This flea, like *Ctenophthalmus agyrtes,* is common on the field-mouse (*M. sylvaticus*) in England, and occurs on rats and small Carnivora in Europe and North Asia. One specimen was taken off *M. decumanus* at Rannoch, Scotland.

16. *C. niger,* Fox.—A bird-flea from California, but also occurring on rats.

VIII. Genus *PYGIOPSYLLA*, Rothsch.—A number of species are known from the tropical countries of the Eastern Hemisphere, two being recorded from rats. Specimens of both these fleas have been sent from Australia labelled "from *M. rattus*"; but subsequent examinations of large numbers of this animal in the same locality have not yielded any more. As both fleas are common on *M. assimilis*, a purely Australian rat, it is probable that the hosts called *M. rattus* were really *M. assimilis*.

17. *P. hilli*, Rothsch.

18. *P. rainbowi*, Rothsch.

IX. Genus *CHIASTOPSYLLA*, Rothsch.—The genus includes a few species from South Africa, one of which has been obtained from a rat.

19. *Ch. rossi*, Waterst.—Only one female known, which was taken off a rat in South Africa. Probably a common flea.

X. Genus *NEOPSYLLA*, Wagn.—A small number of Palæartic species, one of which was obtained from a rat.

20. *N. bidentatiformis*, Wagn.—Russia.

XI. Genus *CTENOPHTHALMUS*, Kolen.—There are many species of this genus: two species have been recorded from rats.

21. *Ct. agyrtes*, Heller.—This is a European species, common in England on field-mice and bank-voles, and occurs also on *M. decumanus* when captured in the open.

22. *Ct. assimilis*, Tasch.—This species is found in Central Europe on field-mice; it is common in Germany on *Arvicola arvalis*, and has also been recorded from rats; it is apparently not found in England.

XII. Genus *CTENOPSYLLA*, Kolen.—One of the species has been obtained from rats.

23. *Ct. musculi*, Dugès.—This is a widely distributed species, very common on rats and mice, especially on *M. musculus*, with which it has spread.

XIII. Genus *HYSTRICHOPSYLLA*, Tasch.—One species has been found on rats.

24. *H. tripectinata*, Tirab.—This is a Mediterranean species which occurs on mice and rats. It has also been found in the Azores.

## REVIEWS.

**Doane, R. W.**—Insects and Disease. Pp. xiv + 227, 112 figs. London: Constable and Co., Ltd., 1910. Price 8s. net.

The sub-title of this work explains that it is a popular account of the way in which insects may spread or cause some of our common diseases. The author has attempted to bring together in a non-technical form the more important facts connected with his subject. In spite of a number of minor errors, he has succeeded in presenting a very interesting and readable book, which we commend to the notice of the general public.

The illustrations, of which there are a large number, are good, and there is a useful bibliography for those who desire to extend their reading in more technical channels.

**Marshall, Francis H. A.**—The Physiology of Reproduction. With Preface by E. A. Schäfer, and contributions by William Cramer and James Lockhead. Pp. xvii + 706, 154 figs. London: Longmans, Green and Co., 1910. Price 21s. net.

Dr. Marshall has written a remarkable work, which cannot fail to command the attention of many classes of investigators. As Dr. Schäfer remarks, in a short preface, it is the first time that the physiology of the organs of reproduction has been presented in a complete form. Incidentally the work furnishes a much needed introduction to the science of Eugenics, whilst the multiplicity of facts which are set forth, and the manner in which questions of difficulty are discussed, will not only satisfy but also stimulate inquiry in a most important branch of physiology.

It seems strange that hitherto we have had no comprehensive work dealing with this subject, one of paramount importance to the gynaecologist, physiologist, veterinarian, and breeder of live-stock.

No side of the subject has been left unnoticed, and special mention must be made of the chapters dealing with foetal nutrition, fertility, the factors which determine sex, and that on the biochemistry of the sexual organs.

The work is well illustrated and reflects the greatest credit on the author, all who have rendered him assistance, and the publishers.

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THE
# JOURNAL OF ECONOMIC BIOLOGY.

## ON SOME COCCIDAE AFFECTING RUBBER TREES IN CEYLON, WITH DESCRIPTIONS OF NEW SPECIES.

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WITH PLATES I AND II.

THE various species of rubber-yielding trees appear to be self-protected from most biting insects by the action of the viscid latex that exudes from the slightest wound. The secretion is not present in any large quantity in the foliage, and consequently we find the leaves occasionally attacked by caterpillars. The larvae of a Pyralid moth (*Caprinia conchylalis*) have given considerable trouble by repeatedly defoliating our trees of *Funtumia elastica*. But no serious caterpillar pests have yet been recorded from our more important rubber plants (*Hevea brasiliensis* and *Manihot glaziovii*).

Sucking insects, such as *Coccidae*, on the other hand, are able to obtain nourishment from any part of the tree without becoming involved in the exudation of viscid latex. Their sucking tubes (haustella) are so fine and hair-like and are, moreover, introduced so gently and gradually, that they do not cause any wound. They are probably able to avoid the latticiferous vessels and to extract the sap alone.

In a previous number of this Journal, 1910 (vol. v, part i), I have described a species of *Asterolecanium* that infests Hevea rubber trees in the Seychelle Islands. The following species of *Coccidae* have been observed upon rubber-bearing trees in Ceylon.

On *Hevea brasiliensis*:—

*Lecanium nigrum*, Nietner: affecting the leaves and young stems. Although sometimes fairly abundant, this species does little or no harm to well established trees. When present on the green stems of young plants and saplings, the insect checks the growth to a certain extent; but on such small plants the pest may be easily removed, either by hand, or by the application of one of the standard soapy insecticides.

*Aspidiotus cyanophylli*, Sign.

*Mytilaspis fasciata*, Green.

These two Diaspid scales may be found upon the foliage; but they do not occur in sufficient abundance to appreciably affect the health of the plant.

On *Manihot glaziovii*:—

*Lecanium nigrum*, Nietner: affecting the foliage of older trees, but doing little damage.

*Dactylopius virgatus*, Cockerell. This omnivorous species is sometimes present in considerable numbers on the young foliage and tender stems of the plants. It is fortunately kept in check by several small Coccinellid beetles.

On *Castilloa elastica*:—

*Inglisia castilloae*, Green. Massed on the leading shoots, main branches and prominent veins of the leaves. The origin of this hitherto-undescribed species is obscure. It suddenly appeared in a small clearing of eight-year-old Castilloa trees, and rapidly spread until every individual tree was almost smothered by the insects. From this centre, it showed signs of extending on to the neighbouring vegetation, and had established itself firmly upon some tea plants in the immediate vicinity. Fortunately, the pest showed no inclination to attack the Hevea trees, some of which were growing so close to the infested Castilloas that their branches intermingled. It was remarkable that, in spite of the heavy infestation, the trees were still growing vigorously, though they had an unhealthy appearance, due—principally—to the dense coating of sooty fungus which covered every leaf. As the pest appeared to be confined to this one small spot, it was thought advisable to exterminate it by cutting down the whole, clearing and burning the trees *in situ*. The species is infested by a minute Chalcid parasite (*Coccophagus orientalis*, Howard).

*Dactylopius crotonis*, Green. Infesting the younger branches; but apparently doing little injury. The species is partly kept in check by the carnivorous larva of a Lycaenid butterfly (*Spalgis epius*, Westwood).

*Dactylopius virgatus*, Ckll. On young branches and foliage.

*Dactylopius citri*, Risso. Occasionally infesting the young shoots.

*Aspidiotus camelliae*, Sign. Occurring sparsely on the younger branches and foliage.

On *Landolphia* sp.:—

*Tachardia albizziae*, Green. A vine of this plant (species undetermined) was found to be thickly encrusted by this "lac insect." The Landolphia rubbers are not cultivated in Ceylon: otherwise this insect might prove to be a serious pest. It is parasitized by numerous Chalcids, and is extensively preyed upon by the larvae of a moth (*Eublemma amabilis*, Moore).

## Descriptions of New Species.

### **Inglisia castilloae,** n.sp.

Pl. i, figs. 1-21.

Test of adult female (figs. 1 to 4) strongly convex: bilobed, the lobes laterally divergent, forming two irregular confluent cones (fig. 1) between the apices of which is a deep furrow (fig. 4). Viewed from in front (fig. 1) or from behind (fig. 2), the base is narrowed, the sides sloping steeply outwards to the apex of each cone, which is slightly incurved. From the side (fig. 3) the base is broadest, the anterior margins sloping evenly to the apex of each cone, the posterior margin at first rising perpendicularly in a sharp keel as far as the anal aperture, where it divides and runs (with a slightly concave contour) to each apex. Viewed from above (fig. 4) there is a deep transverse furrow extending downwards from the apex of each cone: it is bordered in front and behind by rounded lips, which are medially impressed in the direction of the main axis of the body. The intricacies of form are difficult to describe lucidly, and may be more easily understood by reference to the figures. Each cone is fluted vertically and finely striate transversely. Colour dull brown to reddish ochreous. Proportionate dimensions very variable, dependent upon the angle of the divergent cones: average length at base, 3.50 mm.

The adult female insect, which is of a reddish brown colour, more or less fills the test before oviposition, but becomes shrunken afterwards. Viewed from the side (fig. 5), the dorsum is seen to rise steeply into two obtuse points with a shallow transverse cavity between them. An irregularly tubercular carina runs from the posterior edge of this cavity to the anal operculum; below which the margin is deeply cleft. There are small indentations at the stigmatic areas, and a complete marginal fringe (fig. 6) consisting of a somewhat irregular row of stout, sharply pointed conical spines, with a series of pores below them. These pores are in the form of small pits with chitinous walls, and some of them appear to be compound.

There are no specialized stigmatic spines, but the marginal spines are rather more crowded at the stigmatic areas. The anal aperture (fig. 7) is surrounded by a hoop of dense chitin enclosing the valves of the anal operculum which are of very irregular outline, the apices tuberculate and bearing several stout spine-like hairs. The anal ring carries six long stout hairs. A median dorsal series of small pores extends upwards from the anal operculum. Antenna (fig. 8) with seven joints, of which the third is the largest: a stout curved hair on inner side of 4th, 5th, and 6th, joints, and several on the side and apex of the 7th. In some examples there is a partial division of the 3rd joint, cutting off a narrow terminal chitinous ring. Legs small but well formed, claw moderate, tarsal digitules long and slender, ungual digitules somewhat broadly spatulate (fig. 9). Spiracles large and conspicuous, rather densely chitinous. Length of base 2.50 to 3.50 mm.

The newly-hatched larva is dark red, of the normal, flattish, elongate-oval form, with a marginal fringe of stout glassy filaments, supported by a series of stout conical spines, set at some distance from each other; stigmatic areas each with a single longer pointed spine; antennae rather short, 6-jointed; legs usually short and stout. Anal ring with 6 hairs. Caudal setae about half length of body. Length approximately 0.75 mm.

Subsequent growth is first in the direction of a prominent hump on the dorsum of the thorax, and is shortly followed by a second, but smaller prominence on the dorsum or the abdomen (fig. 10). This contour is masked by the two lateral glassy plates which meet along the median longitudinal line, forming an irregular cone with a flattened top (fig. 11).

Further development of the test is shown in figures 12 to 15. A median longitudinal sulca first appears (fig. 12). This gradually widens and reveals a deeper transverse median sulca. This transverse furrow lengthens (figs. 13, 14) and becomes proportionately narrower until it assumes the form (fig. 16) that persists in the fully developed insect. Arrival at the adult stage is signified by the presence of seven joints in the antennae.

The male larvae develop somewhat differently. The dorsum does not become so elevated; it is covered by a single elongate conical plate, and the margin has a fringe of flattened glassy points, which finally coalesce to form the series of conical plates found in the male puparium.

The male puparium (fig. 17) is elongate oval, with a prominent conical glassy plate covering the dorsum, and a smaller triangular plate—with a central elongate boss—above the posterior extremity. There is a marginal series of seven more or less conical plates, of which one is at the anterior extremity and three on each side, their cusps directed slightly upwards and forwards. All the plates with radiating striae. Length approximately 2 mm.

Adult male (fig. 18) bright red, head and terminal half of abdomen darker. Costal nervure of wings purplish crimson, the colour extending to the costa on the terminal half. Ocelli black, 4 on upper and 4 on lower surface of head (fig. 19), the median pair of each set larger. Rudimentary eyes black, small but prominent, situated immediately behind the outer pair of dorsal ocelli. Antennae not quite so long as body, 10-jointed; first two joints stout and short, others elongate and narrow, clothed with moderately short curved hairs; two longer knobbed hairs at apex of terminal segment. Notal plates of thorax ill-defined. Scutellum broadly rounded. Lateral margins of abdomen roundly carinate. Genital sheath long, straight, sharply pointed, rather more than half length of abdomen (in fresh and extended examples). A pair of very long, white slender waxy caudal filaments, supported by setae springing from a glandular pit on each side (fig. 20). A short, fleshy process on each side of terminal segment. Wings ample, minutely pubescent, extending beyond extremity of genital sheath. Halteres apparently wanting. Legs long and slender. Total length (including genital sheath) 1.6 mm.

Insects thickly encrusting the branches, twigs and undersurface of leaves of *Castilloa elastica* (fig. 21). Koslanda, Ceylon, July, 1910. Occurring also upon the following plants in the immediate vicinity:—*Grewia microcos, Adenochlaena zeylanica, Solanum* sp., *Vernonia* sp., and Tea.

The species is parasitized by a minute Chalcid recognized by Dr. L. O. Howard as *Coccophagus orientalis,* How.

Superficially, *I. castilloae* somewhat resembles *fossilis,* Mask., but may be readily separated from that species by the presence of well-developed limbs. Its peculiar form distinguishes it sufficiently from all other known members of the genus.

### **Mytilaspis fasciata,** n.sp.

Pl. ii, figs. 22, 23.

Female puparium (fig. 22) pale translucent yellow, sometimes, with a greenish tinge; exuviae ochreous, the larval pellicle, with the anterior and posterior extremities dark, reddish brown, the nymphal pellicle with a reddish-brown longitudinal median fascia (sometimes broken into two or more spots), and a similarly coloured rounded patch covering the pygidial area. Elongate, narrow, widening slightly behind the nymphal pellicle; sides sub-parallel; margin flattened. Length averaging 2.50 mm. Breadth 0.5 to 0.75 mm.

Male puparium not known.

Adult female very pale yellow; pygidium reddish. Anterior extremity truncate, the lateral angles tuberculate. Rudimentary antennae each with two rather long stout bristles. Pygidium (fig. 23) broadly rounded, the extremity slightly truncate; median lobes conspicuous, floreate, somewhat widely separate, with a median pointed process between them; first lateral lobes small, narrow, duplex; other lobes obsolete. There is a prominent marginal process between the median and lateral lobes, bearing a large oval pore; similar pore-bearing processes occur at intervals on each side beyond the lobes. Squames spiniform, tubular, in groups of 2 or 3. Anal aperture near base of pygidium. Circumgenital pores in five small groups, median group of 3 to 4 pores, anterior laterals 6, posterior laterals 4. A few large and conspicuous dorsal oval pores on pygidium, and numerous smaller pores on margin of abdomen. Length, 0.75 to 1 mm.

Heneratgoda, Ceylon.

Scattered on undersurfaces of leaves of *Hevea brasiliensis*; usually lying along one of the veins.

A typical *Mytilaspis*, of the *pomorum* and *citricola* group; but well characterized by the colour pattern of the puparium.

### **Tachardia albizziae,** n.sp.

Pl. ii, figs. 24-33.

Adult female concealed within a more or less globular case of resin, of a colour varying from bright fulvous to dark castaneous; the colour frequently obscured by a deposit of sooty fungus. The insects are usually so crowded together that the resinous tests become agglomerated and their normal shape is obscured. Each test has three small circular elevated apertures, arranged in a triangle (see fig. 24, which represents two confluent individuals). The aperture, which is at the apex of the triangle, is the hindermost, and represents the anal orifice; it is usually more prominent and larger than the other two. The remaining pair of apertures admit air to the spiracles; they are distinguished as the stigmatic orifices, and are sometimes scarcely raised above the surface. During the life of the insect, tufts of opaque, white, waxy filaments project from each aperture, preventing the ingress of water, while admitting the free passage of air. A shallow rounded carina extends forwards from the base of the anal orifice to a little beyond the stigmatic orifices. The surface of the test may be either smooth or irregularly rugulose or tuberculose. The resinous substance is hard, but brittle, and is readily soluble in alcohol. A single isolated test has a diameter of approximately 3 mm.

A median longitudinal section of the test (fig. 25) reveals the body of the insect occupying the anterior half of the cavity, with the abdominal segments retracted. It is normally of a uniform, rich crimson colour; but there is a variety that is of a bright gamboge-yellow colour, in all stages. Both forms often occur together on the same twig. Before gestation, the insect completely fills the cell. As oviposition proceeds, the body shrinks, and the resulting cavity is closely packed with ova, the young larvae making their exit through the posterior aperture of the test.

The fully extended insect (fig. 26, antero-dorsal view) is roughly cordate in form, with a prominent caudal extension, at the extremity of which is the anus. The dorsal area forms a broadly rounded prominence demarked by a shallow groove from the remainder of the body. The ventro-lateral areas are roundly produced on each side. The stigmatic tubercles are comparatively small, and are situated towards the posterior extremity of the dorsum. At the base of the caudal extension, situated dorsally, is a prominent fleshy tubercle, which bears at its apex a stout, pointed tubular chitinous spine. The rostral filaments proceed from between two small fleshy lobes on the ventral surface of the body. Each stigmatic tubercle is mammiform (fig. 27), and has a central pit-like depression, in which are numerous glandular pores arranged more or less in rosette-shaped clusters, with a larger pore occupying the centre of each cluster. An irregular chain of small pores connects the glandular pit with the large dorsal spiracle, which is situated at the base of each stigmatic tubercle. A second pair of small spiracles opens on the venter, close to the rostrum. The caudal extremity is partially surrounded by a deeply and irregularly toothed fringe, incomplete on the ventral margin. The anal orifice is protuberant, and is encircled by a chitinous ring, composed of six distinct plates, which support ten stout hairs, the lateral plate on each side bearing a single hair, the other eight plates having two hairs apiece. Round the base of each hair is a group of glandular pores. In the adult insect the whole organ is so densely chitinous that these details are more or less obscured, and the chitinous plates often appear to be confluent;

but the structure can be made out more distinctly in the nymphal insect in which the plates are distinctly isolated (fig. 28).

Immediately above the caudal extension is the remarkable spine that occurs in most species of *Tachardia*, the function of which still remains a mystery. That it has some definite use is evident from its connection with numerous elongate pyriform gland cells, disposed either singly or in small groups (fig. 29), which communicate by thread-like ducts with the tubular spine. In the present species, the spine is placed upon a small, stout fleshy tubercle, the extremity of which is surrounded by a rim with a tooth-like prominence on the upper border. The spine itself is slightly curved, stout at the base and tapering to a point, bluntly toothed towards the base of the ventral surface.

The diameter of the adult insect ranges from 2.25 to 2.50 mm.

Male puparium (fig. 30) oblong, slightly broader towards the anterior extremity, with a more or less distinct carina and a well-defined oval valve at the posterior extremity; colour dark brown; surface finely rugulose; length approximately, 1.50 mm.

There are both winged and apterous forms of the adult male. They are both of a rich crimson colour, with a pair of long, opaque white filaments from the caudal extremity. In the winged form the antennae are 10-jointed, and the notal plates are more or less distinct; the wing has a pinkish costal nervure. In the apterous form the antennae have 9 joints only, and the thorax remains soft and undeveloped. The terminal joint of the antenna (in both forms) bears two knobbed hairs at its apex. There are four prominent black ocelli on the head, 2 on the upper and 2 on the under surface. The genital sheath is elongate, slender, and sharply pointed, rather more than half as long as the abdomen. The total length of the insect (inclusive of genital spike) is approximately 1 mm.

Nymphal test of female (fig. 31) symmetrically 6-lobed; dorsal area with a median longitudinal rounded carina, terminating behind at the large anal orifice. Stigmatic orifices situated on the anterior half of the test, above the junction of the first and second lateral lobes. There is a prominent beak-like point above the anterior extremity.

Young nymph (fig. 32) obscurely lobed; both pairs of spiracles situated dorsally, the anterior pair larger; caudal extremity (fig. 28) similar to that of the adult, but with the anal ring more distinctly broken up into isolated plates.

Encrusting the young stems of *Landolphia*, sp. Peradeniya, Ceylon, April, 1910. Occurs also on *Albizzia stipulata, Filicium* *decipiens, Harpullia cupanioides, Theobroma cacao, Sleichera trijuga, Croton lacciferum,* and other trees.

Although the name of this insect has appeared in print on several occasions, it has hitherto been a "*nomen nudum.*" No previous description of the species has been published.

**Dactylopius crotonis,** n sp.

Pl. ii, figs 34-37.

Adult female (fig. 34) broadly ovoid, strongly convex above. Colour, brownish red, disguised by a more or less complete coating of white, mealy powder, which is more thickly disposed on circular patches (10 to 12) on the thorax, and transversely on the abdominal segments. In the early adult (shortly after ecdysis) these white areas stand out conspicuously against the darker ground colour; but in the older individuals these specialized areas may be obscured by a more general covering of the white secretion. Margin, with short, stout bluntly-pointed waxy processes, subequal in length. Antenna (fig. 35) 8-jointed; the 8th longest, longer than 6th and 7th together, with a median clearer area suggestive of a suppressed division; all the joints, with a few stout hairs, springing more particularly from the apical half; antennal formula (exclusive of 1st joint)—1, (6, 7), (2, 3), (4, 5). Legs well developed, robust; claws stout, curved; digitules hair-like, the unguals dilated at extremity, the tarsals not appreciably dilated. Mentum dimerous. Eyes broadly oval, colourless, with slight central granulation; situated just outside the base of each antenna. Posterior extremity (fig. 36) with a rounded lobe (not very prominent, except in parasitized examples) on each side, from which springs a long, stout seta, a longish stout bristle, several short fine hairs, and two acutely-pointed conical spines. A similar pair of pointed spines at intervals along the margin of the body, 17 pairs on each side (inclusive of those on the posterior lobes). Between the terminal lobes are two pairs of stout bristles. Anal ring with six longish stout hairs. Derm with numerous small and inconspicuous subtriangular pores, and sparsely scattered fine hairs, which are longer and stouter on the interantennal space. Some larger circular ceriferous pores on the venter surrounding the genital orifice. A pair of transversely elongate glandular cicatrices near the front of the dorsum, and a second pair near the posterior extremity (at the junction of the antepenultimate with the previous segment). Length (of compressed mounted examples) 2.25 to 2.50 mm. Breadth, 1.75 to 2 mm.

The insects are very frequently parasitized by a small Dipteron which pupates within the body of its host. Parasitized examples (fig. 37) are much swollen, the body of the Coccid being distended by the pupa of the fly. In such individuals, the posterior tubercles and the tuberculate margins of the abdominal segments are very prominent.

The insect makes no definite ovisac, but is ovo-viviparous.

On *Castilloa elastica*. Massed upon the young shoots and smaller branches, and sometimes upon the prominent midrib on the undersurface of the leaves. Not secreting much waxy matter, so that each individual in the mass can be easily distinguished.

Occurs also on the variegated Croton (*Codiaeum variegatum*), on *Terminalia catappa, Erythrina lithosperma,* and many other trees and shrubs.

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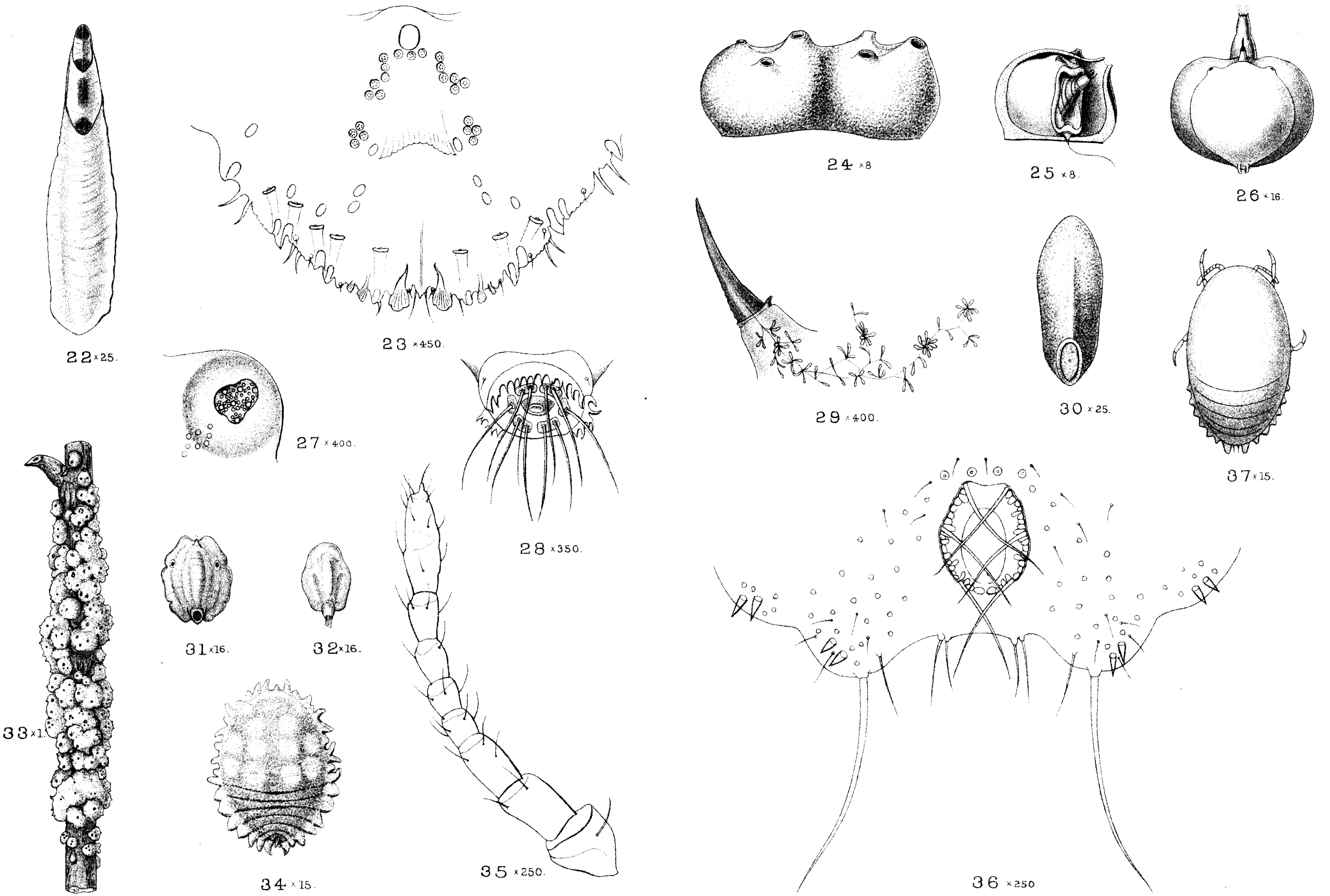
## EXPLANATION OF PLATES I AND II.

Illustrating Mr. E. Ernest Green's paper "On some Coccidae affecting Rubber Trees in Ceylon."

### Plate I.

### Inglisia castilloae.

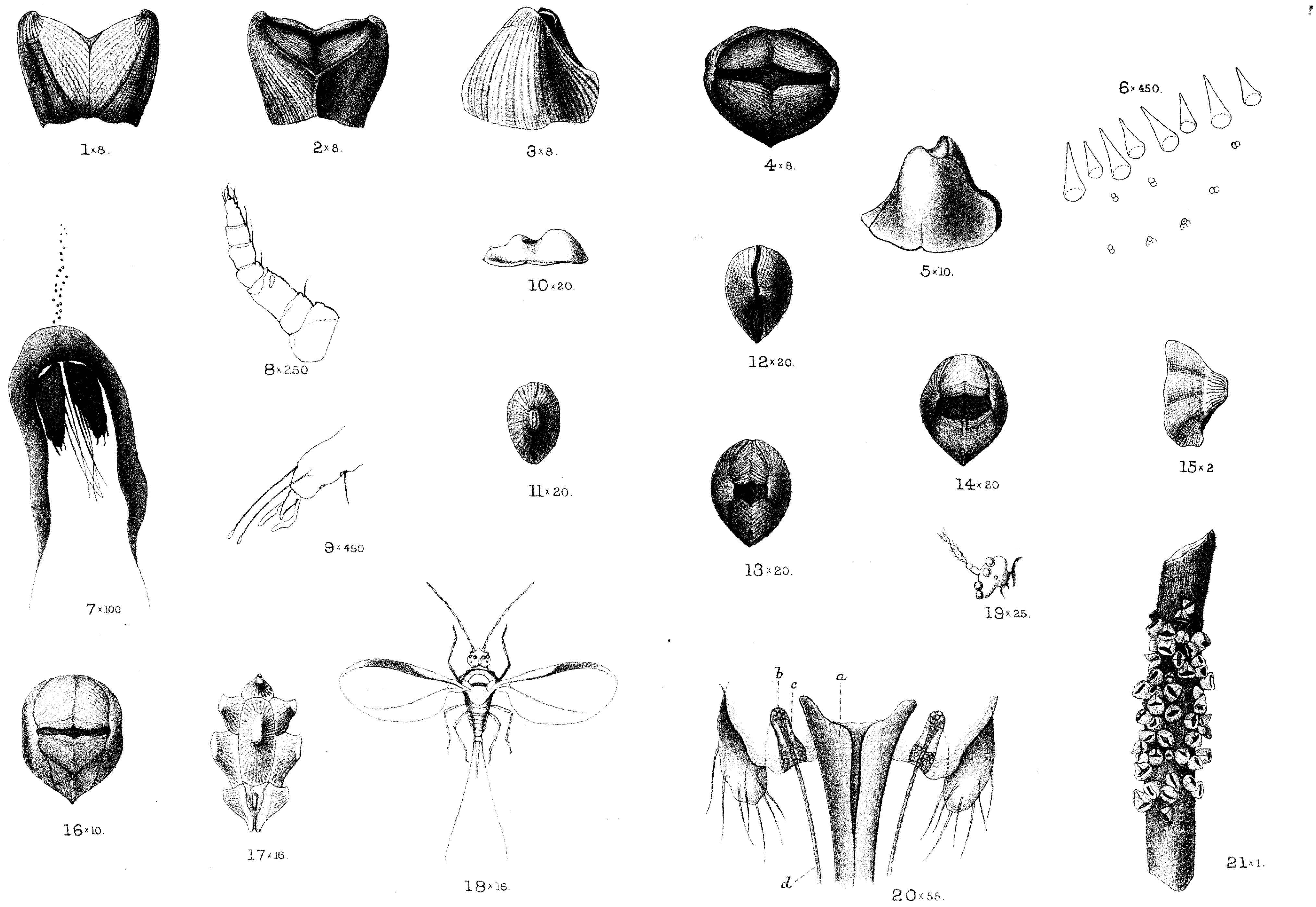
Fig. 1.—Test of adult female, front view, × 8.
Fig. 2.— ,, back view, × 8.
Fig. 3.— ,, side view, × 8.
Fig. 4.— ,, from above, × 8.
Fig. 5.—Adult female insect (removed from test), side view, × 10.
Fig. 6.—Marginal spines and pores, × 450.
Fig. 7.—Anal orifice, × 100.
Fig. 8.—Antenna, × 250.
Fig. 9.—Foot, × 450.
Fig. 10.—Early larva (removed from test), side view, × 20.
Fig. 11.—Test of early larva, from above, × 20.
Figs. 12 to 15.—Stages in the development of larval test, × 20. (All viewed from above, with the exception of 15, which represents a side view of 14).
Fig. 16.—Older larva (or nymph), from above, × 10.
Fig. 17.—Male puparium, from above, × 16.
Fig. 18.—Adult male, dorsal view, × 16.
Fig. 19.—Head of male, side view, × 25.
Fig. 20.—Abdominal extremity of male, from below, × 55.
Fig. 21.—Twig of *Castilloa,* with insects *in situ,* nat. size.




Huth, Lith.r London.

COCCIDAE AFFECTING RUBBER TREES.

Pl. I.




COCCIDAE AFFECTING RUBBER TREES.

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PLATE II.

## Mytilaspis fasciata.

Fig. 22.—Puparium of female, dorsal view, × 25.
Fig. 23.—Pygidium of adult female, optional section, × 450.

## Tachardia albizziae.

Fig. 24.—Two confluent tests of adult female, side view, × 8.
Fig. 25.—Median longitudinal section of single test, × 8.
Fig. 26.—Adult female, anterodorsal view, × 16.
Fig. 27.—Dorsal stigmatic tubercle, × 400.
Fig. 28.—Anal extremity of female nymph, × 350.
Fig. 29.—Dorsal spine of adult female, × 400.
Fig. 30.—Puparium of male, × 25.
Fig. 31.—Test of female nymph, × 16.
Fig. 32.—Female nymph, removed from test, × 16.
Fig. 33.—Insects, *in situ*, on stem of *Landolphia*, nat. size.

## Dactylopius crotonis.

Fig. 34.—Adult female, dorsal view, × 15.
Fig. 35.—Antenna, × 250.
Fig. 36.—Posterior extremity (optional section), × 250.
Fig. 37.—Parasitized female, dorsal view, × 15.

# FOUR LITTLE-KNOWN BRITISH FUNGI.

BY

W. B. GROVE, M.A.,

WITH PLATES III AND IV, AND 1 TEXT-FIGURE.

THE four Fungi which are described in the present communication have been under cultivation for a considerable time in the Botanical Laboratory of the Birmingham University. Three of them belong to the group which is often falsely called *Fungi Imperfecti*—falsely, because it is by no means true that all of them are now, whatever they may have been in their origin, mere conidial forms of more highly evolved species. The other is a species of *Mucor,* which seems to be of rare occurrence in Britain. Each of them presents several points of interest, especially from a systematic point of view.

## Mucor spinosus, Van T.

Pl. iii, figs. 1-9.

*Mucor spinosus*, Van Tieghem, Ann. Sci. Nat., 1876, iv, p. 390. Bainier, *ibid.*, 1884, xix, pl. 7, figs. 1-8. Gayon, Mem. Soc. Phys. Bordeaux, 1878, sér. 2, ii, figs. 10-12. Sacc. Syll. Fung., 1888, vii, pt. i, p. 191. Fischer, Phycomycetes, 1892, p. 203, fig. 30 *e*. Trans. Brit. Myc. Soc., 1900-1, i, 193. Klocker, Fermentation Organisms, 1903, p. 183, fig. 60 (spores incorrectly drawn). *M. aspergilloides,* Zopf.

Sporangiophore about ½ cm. high, erect, soon branched; branches sometimes erect and as long as, or longer than, the main hypha, sometimes very short, and patent or faintly recurved, with a septum usually above the insertion of each branch, colourless and granular, each branch ending in a sporangium. Sporangia all of one kind, but differing much in size, round, up to 80 $\mu$ diam., at first opalescent and densely granular, then brownish, and finally dark-brown or (by reflected light) black; membrane finely aculeate, at first tough (fig. 6), at length evanescent except for a basal collar, which is usually patent, but sometimes reflexed. Columella obovate-oblong or pear-shaped, up to 60 × 25 $\mu$ (in small lateral sporangia from 16 × 9 $\mu$), furnished towards the top with several (1-15) short, stumpy, inflated or acute, spiny processes of various shapes (figs. 2, 3), sometimes but rarely without any spines; membrane in the case of the larger sporangia distinctly pale-brown. There are occasionally additional septa in the hypha just below the sporange (fig. 5) and even in the columella (fig. 3 *c*). Spores spherical or slightly irregular (fig. 7) 4-6, or even as much as 8 $\mu$ diam., smooth, appearing greyish-brown even when seen singly. Chlamydospores not uncommon in the mycelium (fig. 8), intercalary or terminal, resembling those of *M. racemosus,* but much less numerous. Ferment-cells round (fig. 9), highly refringent. According to Gayon (*l.c.*) they ferment glucose, but not sucrose.

Var. **recurvus,** *m.*

Like the species, except that most of the branches are curved arcuately downwards (fig. 4).

*M. spinosus* is easily recognised by its spiny columella. Saccardo (*l.c.*) says that the spores are "minutely verrucose." Under a one-tenth immersion they do sometimes appear slightly punctate, but I have never seen them truly rough, and usually they are perfectly spherical and smooth. The chlamydospores of this species are not only much less numerous than those of *M. racemosus,* but also do not possess so thick and lamellated a cell-wall. Not all species of *Mucor* are provided with chlamydospores, which are the exact analogues of the *aplanospores* of the Algae. If Brefeld's genus *Chlamydomucor* is adopted for those which do possess them, it will include *M. spinosus* as well as *M. racemosus.*

The typical form branches both monopodially (fig. 5), and less often sympodially (fig. 1), but the variety *recurvus* seems predominantly sympodial (fig. 4). In this case, the septum which arises in the hypha above the insertion of each branch appears (owing to the sympodial development) to be at the base of the apparent branch.

The variety occurred repeatedly, with the type, in the Brewing Laboratory of the University; pure cultures of it were made by Mr. Compton Till (who first observed it) and by myself. It is probably merely a form, but deserves especial mention, because of its liability to be confounded with *Circinella spinosa* and *Mucor circinelloides.* On comparing fig. 4 with the figures of *C. spinosa* (Van Tieghem, Ann. Sci. Nat., 1873, pl. 22, fig. 46) and of *M. circinelloides* (Bainier, *l.c.*, pl. 7, fig. 11), the close resemblance in habit will be manifest; in fact they could with difficulty be distinguished except for the remarkable columella of the present species. There is, strange to say, however, a fungus described by Schröter (Schles. Krypt. Fl., iii, 1, p. 206), and assigned by Fischer (Phycom., p. 217) to the genus *Circinella* as *C. umbellata,* var. *asperior,* which has the columella provided at the summit with processes exactly similar to those of *M. spinosus.* It seems worthy of consideration whether this was really not a *Circinella,* but only an unusually developed sympodial form of *M. spinosus,* var. *recurvus.* The description of the spores and many of the details are not inconsistent with this supposition.

Occasionally, again, I have found the main hypha in my cultures producing one, or two very nearly opposite, branches just below the summit, exactly like the figures of *M. bifidus* in Fresenius (Beitr., pl. i, figs. 13, 19-21). Text-figure A shows two of these, one bifid, the other trifid; it is evident that these modes of branching are not peculiar to the *M. bifidus* of Fresenius, and it is in fact possible that the latter is identical with *M. spinosus.* This supposition, at least, seems more probable than Fischer's suggestion (*l.c.,* p. 190) that it is a form of *M. mucedo*; but of course it cannot be entertained unless it is permissible to believe that Fresenius entirely overlooked the spiny processes of the columella. His description of the spores presents equal difficulties under either hypothesis: the columella of *M. spinosus* may occur, very rarely, without the spines.

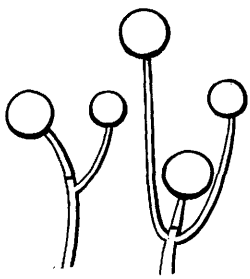
Fig. A.—Showing branches of main hypha.

## Rhopalocystis, gen. nov.

*Hyphae steriles repentes; fertiles erectae, simplices, apice vesiculoso-inflatae. Conidia basidiis sterigmatophoris suffulta, fusca, sphaeroidea.* Est Sterigmatocystis dematiea.

## Rhopalocystis nigra.

Pl. iii, figs. 10-16.

*Rhopalocystis nigra,* m. *Aspergillus niger,* Van Tieghem, Ann. Sci. Nat., 1867, p. 241. Raulin, Ann. Sci. Nat., 1869, pl. vii, fig. 4. Klocker, Fermentation Organisms, 1903, p. 277.

*Sterigmatocystis nigra,* Van Tieghem, Bull. Soc. Bot. Fr., 1877. Saccardo, Syll. Fung., 1886, iv, p. 75.

Conidiophore erect, eseptate, thick-walled (wall 2 $\mu$ thick), cylindrical or nearly so, pale-brown, often nearly hyaline at base, filled with very granular, yellowish-brown protoplasm, $\frac{3}{4}$—$1\frac{1}{2}$ mm. high, 20—25 $\mu$ broad, ending in a globose head, which is also thick-walled and of the same colour as the upper part of the hypha, 40—50 $\mu$ diam., and finely punctate all over, with the insertions of the basidia (fig. 12). Basidia crowded, radiating, oblong-clavate, 40—70 × 10—12 $\mu$, pale yellowish, each bearing a few (8—10) linear-oblong sterigmata, 10—15 $\mu$ long; each sterigma produces basipetally a long chain of spores (fig. 13) Conidia spherical, dark-brown, nearly black in mass, 4—5 $\mu$ diam., at first smooth, at length very delicately verruculose (fig. 15); each conidium is connected with the next by a slender hyaline isthmus, which at length vanishes; isthmus cylindrical or slightly swollen towards the lower end (fig. 14).

The mode of formation of the spores is as follows:—The sterigma ends in an acute point, upon which the last-formed spore is perched. The portion of the sterigma a little distance below this points swells out somewhat, and a constriction is formed below the swelling (fig. 16 *b*). The swelling increases, the constriction becomes narrower, and a fresh spore is thus formed, connected by a narrow isthmus both with the spore above and with the sterigma. No doubt a septum is formed at each end of this isthmus, though it could not be seen in progress. The sterigma (fig. 16 *a*) then enlarges to its former size, and the process is repeated. The membrane of the basidia and of the sterigmata is nearly colourless, but both are filled with a rich yellow protoplasm. The young spore is quite colourless, but soon assumes an olive colour, which gradually deepens until the mature spore is dark-brown.

This species was originally placed by Van Tieghem in the genus *Aspergillus,* but afterwards transferred by him to *Sterigmatocystis,* which differs from *Aspergillus* in having the spores borne on sterigmata, not immediately on the basidia. But it is impossible, so long as the Dematieae are maintained as a distinct group (which must be done, if only for convenience) to leave this species among the Mucedineae, since the colour in mass is distinctly a very dark olivaceous-brown, and by reflected light appears nearly or quite black. All the other species of the same section of *Sterigmatocystis* (Sacc. *l.c.*) should be transferred to *Rhopalocystis*, viz.:—

*Rhopalocystis fusca* (Bain.)
,, *antacustica* (Cram.)
,, *phaeocephala* (Sacc.)
,, *carbonaria* (Bain.)

The distinction drawn in this case is exactly that which has already been made between *Verticillium* and *Verticicladium*.

There are also dark-coloured species of *Aspergillus,* included in the section "Fuscescentes" (Sacc. Syll. Fung. iv, 70), for which presumably a separate genus should be founded; but, according to the descriptions, none of these belong to *Rhopalocystis*.

Van Tieghem at first did not observe the sterigmata, and described the basidia as simple and measuring 11—16 × 2.5 $\mu$, but these evidently were immature. Afterwards he discovered his mistake. The young head is covered with smooth, clavate basidia (fig. 11), but before they begin to produce spores the sterigmata arise at their summit, though for the following reason they are often difficult to see. The curious isthmuses which connect the spores with each other and with the sterigmata are ultimately resolved into mucus; this binds the whole mass together so that the spores do not readily separate on the addition of water, as do those of most species of *Aspergillus* and *Penicillium*. On this account a growth of *Rhopalocystis nigra* does not appear pulverulent.

This species occurred on the endosperm of coco-nut (hung out for birds to peck at) at Edgbaston and at Studley Castle; it was also independently found by Dr. Jessie S. Bayliss in a contaminated culture in the Botanical Laboratory. It is the species which has been the subject of many investigations by physiologists. According to Malfitano, Miyoshi, Raulin, Gayon, Bourquelot, and others, it produces many enzymes, such as diastase, maltase, invertase, emulsin, zymase, a protease, etc., and breaks up tannin into gallic acid and glucose. It has been found in the Brewing Laboratory of the University that it can be used as a most convenient source of invertase and emulsin.

## Monilia lupuli.

Pl. iv, figs. 1-8.

*Monilia lupuli*, Mass. in litt. *Oidium lupuli*, Matthews and Lott, The Microscope in the Brewery and Malthouse, 1899, p. 86. Lindner, Atlas der mikroskopischen Grundlagen der Gährungskunde, 1903, pl. 28. Sykes, The Principles and Practice of Brewing, 3rd ed., 1907, p. 290.

Forming an effused farinaceous stratum of a fine pinkish-salmon colour. Conidiophores up to 1 mm. high, erect, slender, septate, branched above; branches rather divaricate; chains of spores also branched in the same manner. Diameter of hyphae about 5 $\mu$; conidia roundish or oval, nearly hyaline (singly), $7—9 \times 4$ $\mu$.

Communicated by Professor Adrian Brown. Occasionally met with in breweries, on the surface of spent hops, lying in heaps exposed to the air. It looks like a salmon-coloured dust; under the microscope the colour is seen to be diffused through the protoplasm. The transition from the ultimate joints of the hyphae to the conidia is often a very gradual one.

The spores of *M. lupuli,* when plasmolysed, show a distinct "*hilum*" or mark indicating the point at which they were attached to one another; all the spores, except the terminal youngest ones, have two or three of these marks. The "hilum" is really a thickened ring of the cell-wall (fig. 4 *c*); seen in full face-view it often presents an appearance remarkably similar to that of a leaf-scar, with a few darker, thickened, and often protruding portions in the middle of the circle, which might fancifully be supposed to represent the leaf-trace bundles (fig. 4 *a, b*).

On germination, in distilled water, the spore swells up, loses its dark outline, and becomes more rounded. It then emits 1, 2, or 3 tubes, at any part of its periphery; these soon begin to branch by similar tubes (fig. 8), and produce a hyaline septate mycelium. A remarkable fact noticed on many occasions is that the branches of the mycelium anastomose freely (figs. 5, 7); even two germ-tubes may anastomose before they have travelled twice the length of the spore (fig. 5).

There were also instances which showed that the anastomosing hyphae were attracted by one another (fig. 6). In fact some such attraction must be manifested in most cases where an H-connection is formed. Instances of a somewhat similar kind are known in connection with filaments concerned in reproductive processes, *e.g.*, in the hyphae which conjugate to form the zygospore of *Mucor mucedo* (Blakeslee, Sex. Reprod. Mucor., p. 274, pl. ii, fig. 30 *c*), and in the production of scalariform conjugation in *Spirogyra*. But in the case of *M. lupili* the phenomenon is distinctly manifested by the purely vegetative hyphae.

The protoplasm of the hyphae was in streaming motion in all the cells; a small agglomeration of it could be observed to move through its own length in less than a minute. The motion was of the kind called *circulation*, the protoplasm passing along the strands from side to side, and perpetually changing the position of the vacnoles. In almost all cases there was a little accumulation of cytoplasm on each side of a septum.

Anastomoses of an exactly similar character are figured by Planchon (Ann. Sci. Nat., 1900, xi, p. 97, figs. 21-2) in his *Alternaria varians*; and by Marshall Ward (Ann. Bot. ii, pl. 22, figs. 27-30) in the *Polyactis* which causes a Lily disease; also anastomoses of the hyphae soon after they have issued from a spore are figured by Massee (Text-book of Fungi, fig. 5, 1) in *Trichothecium roseum*, and are compared by him with those which are so pronounced a feature in the germinating secondary spores of the *Ustilagineae*.

**Hormodendron**, Bon. (1851).

Sterile hyphae creeping; fertile erect, septate, more or less olivaceous, variously branched; chains of conidia at ends of branches; conidia globose, ovoid or oblong, continuous, olivaceous or brown.

## Hormodendron cladosporoides.

Pl. iv, figs. 9-15.

*Hormodendron cladosporoides*, Sacc. Mich. ii, p. 148; Syll. Fung., 1886, iv, p. 310. Lindner, Mikroskopische Betriebskontrolle, 1898, p. 237, fig. 110. Planchon, Ann. Sci. Nat., 1900, xi, p. 155, and figs. 37, 39, 44. Hedgcock, Missouri Bot. Gard., Ann. Rep., 1906, xvii, p. 98, pl. 10, fig. 1. Bancroft, Ann. Bot., 1910, xxiv, 359, pl. 24.

*Penicillium cladosporoides*, Fres. Beitr., 1850, p. 22, pl. iii, figs. 23-8.

Mycelium white or pale-olive, hyphae 3—5 $\mu$ diam.; tufts diffused, indeterminate, olivaceous, forming a thin dirty green stratum with a whitish margin. Conidiophores erect, cylindrical, branched above into two or three parts; if the former, the stem is dichotomous; if the latter, the branches are often opposite and decussate, patent or irregular; articulations of branches fusoid, passing gradually into the conidia; chains of conidia two or three together, short, branched, diverging. Conidia ovoid or elliptic, smooth, somewhat apiculate at each end, 6—7 × 3.5 $\mu$, pale olivaceous; the ultimate conidia are nearly round.

On the cut surface of a vine-stem, Bulkington (Wk.), Mr. Compton Till; also on damp wall paper, Lower Edmonton, Mr. James Scott; and on decaying leaves, Studley Castle.

The spores vary considerably in size and shape; the articulations of the branches are sometimes 1-septate or even 2-septate; and the lower articulations show occasionally indistinct markings, as if they might become polyseptate, though they were never seen to be so in reality. The mode of branching varies also, and often agrees exactly with the figure of Fresenius.

The germination of the spores of *Hormodendron* is as follows: A conidium slightly swells and emits from its surface, at any point, 1, 2, or 3 germ-tubes. If the apparent spore is two-celled (really one of the upper articulations of the branches of the conidiophore), one or both of its cells may "germinate" in a similar way. The tube soon begins to send off branches, mostly at right angles; sometimes the tube remains cylindrical, but at other times it becomes markedly torulose; both forms may issue from the same conidium. In the latter case, the cells are about as long as broad, and in all cases they remain short as compared with the ordinary mycelial cells of the majority of fungi. In most cases all the cells are olive-coloured, though slightly paler than the spore, which remains, for that reason, easily distinguishable so long as the mycelium is not too intricate. H-connections frequently arise between parallel or nearly parallel hyphae, and sometimes but rarely a slight net-work is formed.

Very soon one of the branches of the hyphae assumes the functions of conidiophore, usually by forming at its summit two buds, which gradually assume a fusoid shape, and produce at their apex two or three similar buds. The latter may become spores or may continue the growth of the hypha. Finally, spores only are produced.

Each bud arises as a circular swelling, connected with its base by a slender tube: the swelling gradually enlarges, and assumes the mature form; then or earlier the tube is closed by a septum. The order of formation is always basifugal, as in *Alternaria*, and is strictly comparable to the budding of *Saccharomyces*. Another bud may arise at the summit or side of one which is still incompletely formed. Now and then two or even three buds may arise from a single cell; in this way branched chains of spores are produced. *The true spores, forming the terminal chains, were never seen to be septate.*

The mode of formation of the spores (basifugal) is the opposite of that shown by *Penicillium glaucum* (basipetal). The former mode produces branched chains, the latter not. This mode of formation is, in general, a generic character. *Hormodendron* should be compared not with *Penicillium*, but with *Monilia*. It is a dematioid *Monilia*.

The distinction between basipetal and basifugal spore-formation has not hitherto been much regarded by systematists, but there is little doubt that it is a constant feature at least in those species which have non-septate conidia, and as such could be used in the generic character. Among the genera which have basifugal spores, like *Hormodendron*, are *Monilia*, *Amblyosporium* and *Alternaria*: while *Penicillium*, *Aspergillus*, *Sterigmatocytis*, and some species of *Torula* have basipetal spores, like *Rhopalocystis*. The aecidiospores of *Puccinia* also are produced basipetally.

Planchon (*l.c.*, p. 155) and Bancroft (*l.c.*, p. 368), as well as others, state that there is no doubt that *H. cladosporoides* is merely a form of the ubiquitous *Cladosporium herbarum*. Even if this is so, it is a form which presents an appearance so different that it must be mentioned and described particularly. Of course, in a sense, their statements may be true, since it is well-known that *C. herbarum* is a collective name, under which numerous forms have been included.

It is possibly true in a wider sense, but can scarcely be considered proved. Though both authors describe and figure branches of their *H. cladosporoides*, in which the passage to a *Cladosporium* type is stated to have occurred, their figures do not bear out their contention. So far as is shown by the cultures (on various forms of nutrient gelatine) made by Mr. Compton Till and myself, the true conidia in the *terminal* chains of the fungus were never septate; some of the upper joints of the hyphae are (fig. 14), and moreover, as shown in figure 11, these hyphal articulations can put forth tubes and form a mycelium as well as the spores. But that is to be expected in a case like this, where the transition from hyphae to spores is a gradual one. It is just as true of *Monilia lupuli;* there also the upper hyphal joints "germinate" readily, and often produce a better mycelium than the conidia, from which, nevertheless, they are easily distinguishable. When a mycelial cell thickens its walls and becomes an "oidium" (as is frequently the case in the mycelium of Hymenomycetes), this "oidium" can "germinate" exactly like a spore; it is, in fact, the analogue of an Algal *akinete*.

In the true *Cladosporium herbarum,* so far as I have seen it, there is not the same gradual transition from hyphae to conidia, and many unmistakable conidia are two or even three-septate.

Bancroft mentions (p. 368), what is quite true, that, if his view of the relation of the two forms he met with is correct, they must be considered an unusual combination among the Fungi. His further contention, that they constitute a complete life-cycle, is quite unproved; they might, either or both of them, easily be stages of a higher fungus, and yet be capable of continuous propagation in their own forms. There is no intention here of criticising his results, but, judging by his figures, it is still permissible to express the opinion that his "*Cladosporium*" is not *C. herbarum*. It is not sufficient to assume, if a hypha produces a structure like that shown in his figures 7—9, that therefore it is a *Cladosporium* spore, since it has been shown above that many of the hyphal joints of *Hormodendron* are one or more septate. Compare plate ii, fig. 14.

I do not assert that *H. cladosporoides* has not a *Cladosporium* form, but only that its identity with *C. herbarum* has not yet been demonstrated. However, even if it should be proved, the genus *Hormodendron* would still stand, until a similar fact has been shown for the other species assigned to it.

Our cultures have, nevertheless, made it evident that *Hormodendron viride* (Fres.) is only one of the earlier stages of *H. cladosporides*. The gradual change from a form like fig. 16 of Fresenius (*l.c.*) to that of his figure 23 could frequently be traced; also his *nigro-virens* (fig. 22) does not seem to present any essential difference. Whether his *chlorinum*[1] (figs. 20, 21) is different, I cannot tell.

[1] It is, in my opinion, a mistake on the part of Saccardo to consider (Syll. Fung., iv, 311) that Fresenius intended to place his *nigro-virens* as a variety of his *chlorinum*. His words (Beitr. p. 22) do not bear that meaning.

*H. elatum,* Harz (Hyphom, pl. 5, fig. 6) may well be nothing but a luxuriant state; it does not show any other character that might form a mark of distinction, but I have never seen anything quite so luxuriant as in Harz's figure.

One striking peculiarity of our cultures, on nutrient gelatine, is that the mycelium produces, below the surface, a very thick dark-green or black stratum, which at length wrinkles and contracts from the lower part which has not been penetrated by the mycelium. For this reason, the appearance of a culture changes from olive-green to brownish-green or blackish-green, as it advances. Hence we conclude that the forms mentioned above are probably only growths of *H. cladosporoides* of various ages. Their spores are all nearly identical, or at least come well within the limits observed. *H. olivaceum,* Bon., *H. solani,* Sacc., and *H. herbarum,* Sacc., on the other hand, are distinctly different, and *H. atrum,* Bon., according to the figure and description (Bot. Zeit. 1853, p. 286, pl. vii, fig. 7) looks also different, and does not agree with any stage of the fungus met with in the cultures.

In the 17th Annual Report of the Missouri Botanic Garden, 1906, p. 100, pl. 10, fig. 2, Hedgcock describes and figures a species of Hormodendron, which he names *H. griseum,* and which is evidently closely allied to *H. cladosporoides.* He also states that he grew both species, in a series of parallel cultures, for nearly a year "with no reversion of one type to the other," such as he expected. Nevertheless the only important difference observable was that due to the nearly hyaline mycelium of *H. griseum,* which imparted a grey appearance to the cultures. In his *H. cladosporoides* the mycelium was apparently always coloured. In our cultures both appearances were observed, even from the same spore (fig. 12); and as stated above, the margin of a patch of mycelium was always whitish. The conclusion is that *H. griseum* is only an accidental form of *H. cladosporoides.* It is not uncommon that, of the mycelium and the spores of Dematieae, one should be colourless while the other is olivaceous, *e.g., Stachybotrys dichroa, Acrotheca atra.*

Finally I would place *Penicillium chartarum,* Cooke (Handbook, 1871, p. 602, fig. 270), not as is done by Saccardo (Syll. Fung. iv, 305), and following him by Massee (Fung. Fl. iii, 381), in the genus *Haplographium,* but in *Hormodendron.* The original figure of Cooke in Popular Sci. Review (1871), pl. 68, fig. 4, agrees with this determination. In fact, *H. chartarum* is closely allied to *H. cladosporoides,* but probably not identical with it. Cooke's figure shows the branching of the upper part of the hypha, and, roughly drawn though it is, it seems to be different from anything met with in the latter species.

The species of *Hormodendron* may then be arranged as follows:—

| | |
|---|---|
| Conidia, oblong, fusiform or elliptic, when fully formed. ... | *H. cladosporoides*, Sacc. (including *H. viride*, Sacc.; *H. nigrovirens*, Sacc.; *H. elatum*, Harz.; *H. griseum*, Hedgcock).<br>*H. chartarum*, m.<br>*H. atrum*, Bon.<br>*H. hordei*, Bruhne, and var. *parvispora*, A. L. Sm.<br>*H. solani*, Sacc. |
| Conidia, round, when mature. ... | *H. olivaceum*, Bon.<br>*H. herbarum*, Sacc.<br>*H. chlorinum*, Sacc. (possibly). |

In conclusion, I have to thank Professor G. S. West for help in connection with this investigation.

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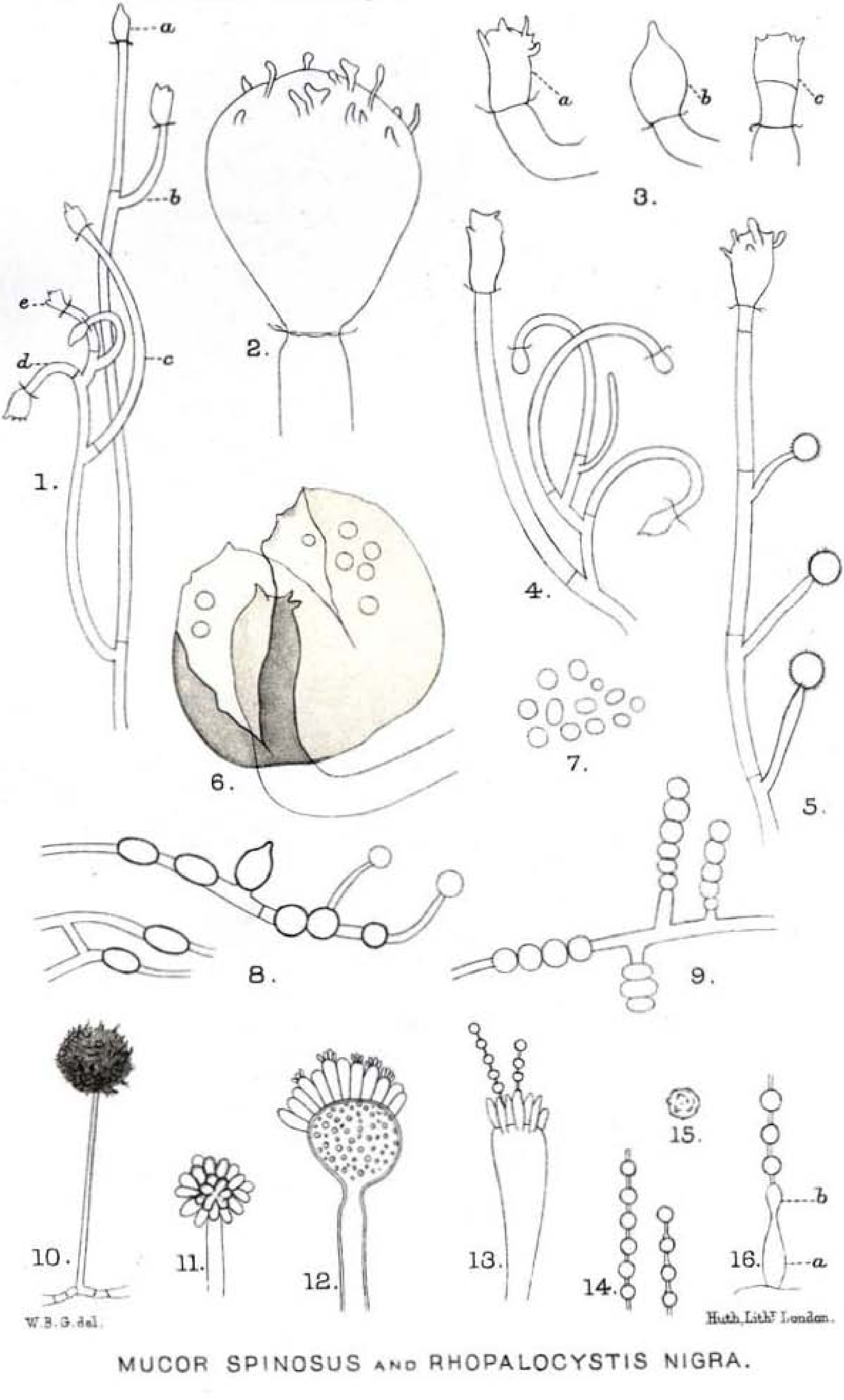
## EXPLANATION OF PLATES III. AND IV.

Illustrating Mr. W. B. Grove's paper on "Four Little-Known British Fungi."

### Plate III.

**Mucor spinosus.**

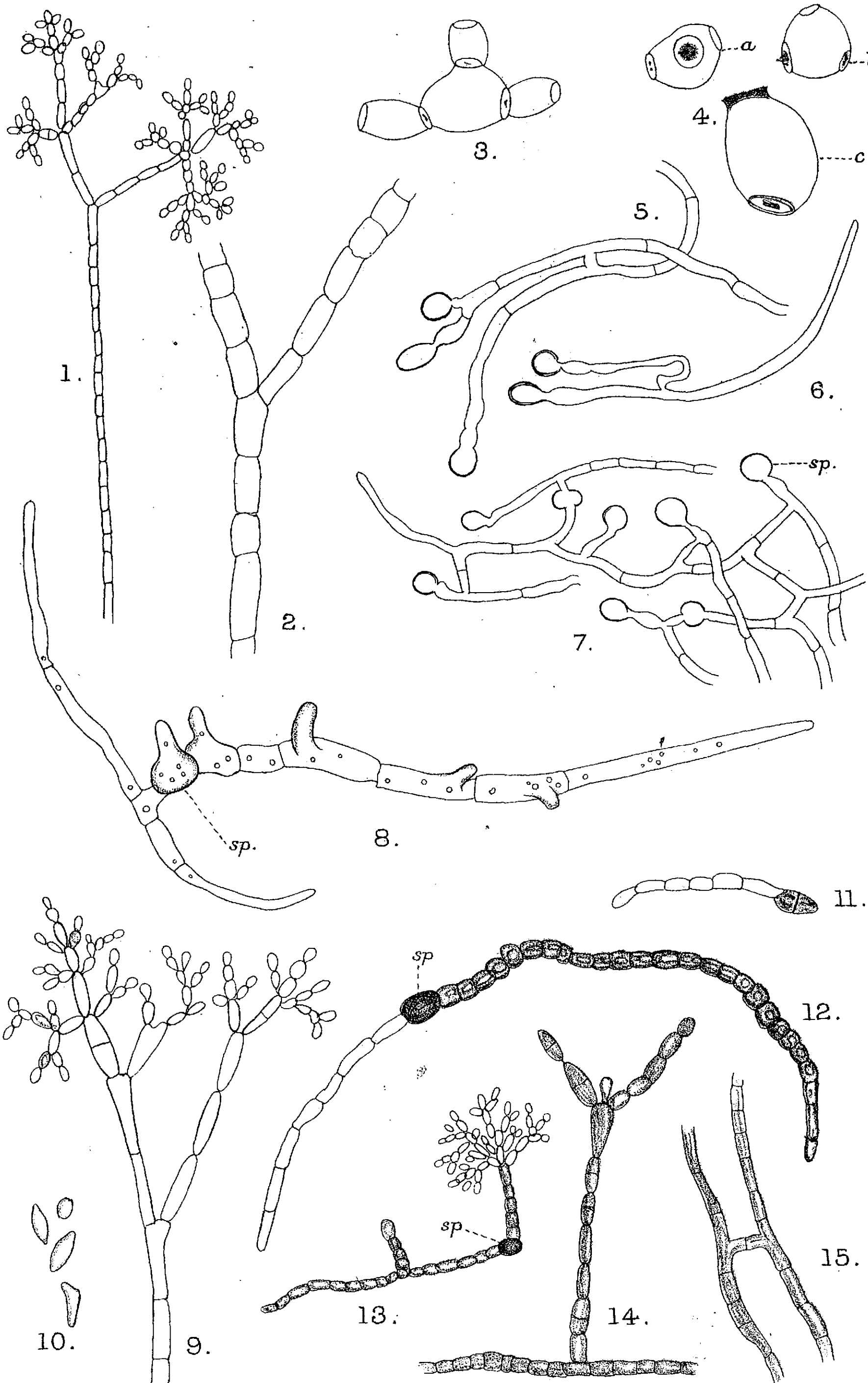
Fig. 1.—Sporangiophore showing both modes of branching, × 150; *a, b, c, d, e,* the order of formation of the sporangia.
Fig. 2.—A very spinose columella, × 600.
Fig. 3.—Various forms of columella from fig. 1, × 400.
Fig. 4.—*M. spinosus*, var. *recurvus*, × 300.
Fig. 5.—Racemose form of *M. spinosus*, × 250.
Fig. 6.—Young sporangium emptied by pressure, × 500.
Fig. 7.—Spores, × 500.
Fig. 8.—Chlamydospores (two germinating), × 300.
Fig. 9.—Ferment-cells, × 300.




W. B. G. del. Huth, Lith. London.

MUCOR SPINOSUS AND RHOPALOCYSTIS NIGRA.

Journ. Econ. Biology, 1911, Vol. VI, pt 2. Pl. IV.

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MONILIA LUPULI AND HORMODENRON CLADOSPOROIDES.

### Rhopalocystis nigra.

Fig. 10.—Conidiophore (dry), × 30.
Fig. 11.—Head with immature basidia, × 80.
Fig. 12.—Head of mature conidiophore, with basidia and sterigmata, × 100.
Fig. 13.—Basidium, with sterigmata and chains of conidia, × 400.
Fig. 14.—Chains of conidia, showing the two forms of isthmus, × 500.
Fig. 15.—Mature conidium, × 1200.
Fig. 16.—Sterigma and newly formed conidia, × 900; *a,* the sterigma; *b,* the conidium just being formed.

## PLATE IV.

### Monilia lupuli.

Fig. 1.—Conidiophore and chains of conidia, × 100.
Fig. 2.—Mode of branching of conidiophore, × 600.
Fig. 3.—Mode of branching of conidial chains, × 600.
Fig. 4.—Separate conidia, swollen in water, × 600.
Fig. 5.—Anastomosis and H-connection of germinating conidia, × 500.
Fig. 6.—Attraction of one germ-tube by another, × 500.
Fig. 7.—A network of germinating conidia (*sp.*), × 500.
Fig. 8.—A germinating conidium (*sp.*), × 600.

### Hormodendron cladosporoides.

Fig. 9.—Conidiophore and chains of conidia, × 600.
Fig. 10.—Conidia, × 750.
Fig. 11.—A hyphal joint emitting a mycelial thread, × 600.
Fig. 12.—A conidium (*sp.*) emitting two germ tubes, one olive-coloured, the other pale-grey, × 600.
Fig. 13.—A germinating conidium (*sp.*) which has produced a conidiophore directly, × 300.
Fig. 14.—A conidiophore which has not yet produced conidia, × 500.
Fig. 15.—H-connection of the mycelial hyphae, × 500.

# THE TRAINING OF AN ECONOMIC ENTOMOLOGIST.[1]

BY

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IN a recent issue of this Journal, Professor Hickson discusses the place of economic Zoology in a modern University and the best way of training students. I do not wish to discuss the former, but I would like to offer some observations on the training of the student who aims to "*deal with the problems of economic zoology* (entomology) *in a practical manner,*" *i.e.,* become an economic entomologist.

My object is to put down what eleven years practical work as an economic entomologist in the tropics has taught me should be the equipment of a man who takes up this work. Having also trained a number of entomological assistants with Indian University degrees and directed their work, I can perhaps view it from the teacher's as from the student's point of view.

There are at present a number of men working in different parts of the British Empire as "economic entomologists," mainly attached to agricultural departments, but who have as a rule to tackle every sort of problem that comes up, and the problems cover almost every aspect of entomology. Mainly, their work is the study and checking of crop-pests; starting work in a new country as so many have done in recent years, this entails also the building up of collections and records and, for teaching purposes, one must have a big collection and be prepared to give a good deal of time to general entomology. But the root idea is to study crop pests, to work out their life histories, habits, distribution, enemies, etc., with a view to recommending remedies or starting a campaign to check them.

There comes also daily a heap of letters asking advice; a lady wants a remedy for cockroaches; another has an insect, not a bed bug of course, but which bites you in bed; a farmer has a "worm" eating his crops; an intelligent farmer (or planter) has found there is a fortune in silk-worms and wants advice; another has been advised

[1] Read before the Association of Economic Biologists, Birmingham Meeting, April 6th, 1911.

that the "Mort Insect" kills every form of pest and wants to know will it kill the aphids on his chrysanthemums. The maker of "Mort Insect" is probably wanting a testimonial, and ten others are offering much better insecticides and want them tested.

If the economic entomologist holds an official position, his Government is probably demanding a scheme for exterminating insect pests by fumigating plant imports, or he is already, *ex officio,* chief inspector of plant imports; they are also demanding publications, perhaps a contribution to a volume on "Nature Study" for school teachers; certainly an illustrated Annual Report, articles for the Agricultural Journal, and eventually a book; collections for museums, exhibits for shows and exhibitions must be forthcoming; he must know all about every insect that strikes the eye of the high official or his wife, and be able to discourse learnedly; he must be a feature of the local Natural History Society. He must be a Court of Appeal in legal cases involving damage by insects, and his duties range from telling how to check fleas on a pet dog to drafting an "Act for the Extermination of Parasitic Insects on Domesticated Animals," and administering the said Act. He may of course be connected with industries such as silk, and have to suppress the enthusiast who thinks you can grow silk on prickly pears in the desert or some equally hopeless place, without having the experience of silk that gives him the means of suppressing the enthusiast. Not quite so bad, but still bad, is the rôle of silk expert—where silk is grown, and where a whole extra branch is added to your duties. There is only one worse thing possible, and that is to require scientific, practical, and trade knowledge *also* of lac, dyes, honey, blister-beetles, and other insect-industries as in India.

I pass that by as I imagine no other country can offer such a complexity of subjects of such a vast economic importance, and of such inherent difficulties as India does: a people of 300 millions and 100 races, an area cultivated of 250 million acres, problems of crops, grain, cattle, disease-carriers, silk, lac, honey, insects used as medicine, as food, as ornaments, as dyes, as hair-washes, and a people mainly inherently brought up not to take life, and you have what, I imagine, is the most varied day's work possible.

With all this, one has to fit in the enquiry and research on which progress is made, and this enquiry should form the bulk of one's work, though there is often very little time to give to it.

The most important class of work that lies before the economic entomologist as a rule is the careful study of each individual species from every point that is likely to bear upon ultimately checking it; its life-history in very full detail, its seasonal occurrence, its food plants, its peculiar habits, etc., its distribution, its parasites, its periodical occurrence as a pest—these have all to be very minutely known, and any one particular point may require very elaborate working out, as remedies and preventives suggest themselves. Probably every economic entomologist, starting work in a new country or able to give his time to what he pleased, would consider this careful working out of one or a few species at a time as the groundwork of economic entomology and undoubtedly all real progress has come from this class of work.

To do this, to do also all the miscellaneous work that comes to hand, what training is required and what mental equipment will fit the economic entomologist for his work?

I may deal very briefly with the training up to the graduate stage; it requires the general scientific training such as would secure an honours degree, zoology, botany, and chemistry being the three subjects a Cambridge student would take, the last being a minor subject; the average student finds this quite sufficient, and I would not attempt entomology specially until the third year, or preferably do it wholly as a post-graduate course. For a student who definitely had economic zoology in view, field entomology throughout this undergraduate period would be advisable, this being guided by an entomologist. This is not essential, and where it can be done the agricultural training should be got during this period, even if the honours degree were not so high a one in consequence.

As regards the post-graduate course, the first essential is a good general course of entomology, based on a wide knowledge of zoology such as is obtained in the usual zoology course of a University; with this a knowledge specially of field zoology, such as will not help towards a degree perhaps, but for which the worker must have aptitude and gain experience.

The second is a close study of one species in all detail possible, exclusive of its embryonic development and bearing more on its habits and outer morphology than on the histology of its tissues, though not totally neglecting that aspect. I would treat that by trying to refer every detail of the outer anatomy to the habits, not simply describing the structures, but referring them one by one to their function; this is generally neglected, but it is the point of view that is essential.

The third requisite in the training is the close study of one group from the systematic side, solely with a view to getting experience in the distinction of one species from another. It is, in my opinion, wrong for an economic entomologist to continue systematic work on any group, however important and necessary such work is, as there are so many others doing it and so much other work for the economic worker, but it is essential as a part of training, and if the systematic work done is on a group of economic importance, all the better; but it must be recognised as being only a part of training and not an end in itself.

A close knowledge is required, derived from literature and partly from field work, of economically important species, both of one country and of the world generally. This sounds a large undertaking, but is less so than it sounds; in no country are there more than a definite number of species that really count, that is, that do large and widespread damage; and for the world as a whole, these fall into a few classes which are easily grasped. This implies a knowledge of literature, which is essential; the literature of the ordinary systematic entomologist is not that of the economic worker, and there is no system of recording economic literature such as the Zoological Record. A new species is most carefully recorded in several publications; new facts on economic entomology have not any universal recorder, and the literature is not easy to come by always. A special knowledge of insecticides and machines is required, as also of fumigation and fumigants. This is, I imagine, a long way out of the routine of University instruction, and I imagine the average Zoological department of an University have not even heard of kerosene emulsion; but this is a necessary part of the instruction to be given.

Leaving the purely entomological training, there are two other points of the very greatest importance; they are agriculture and botany. The first thing an agricultural entomologist has to do is to study, not his insects, but the crops. If I were starting again in a new country, as I have twice done, I would, if I could, study the agriculture and the people for some time before I began on the insects at all. An entomologist under training should have a short agricultural training either before or after he does his entomology. He must also have a fair knowledge of botany, not with the aim of identifying his plants, but in view of recognising closely allied plants, of being able to get a general knowledge of the flora which will help when he is seeking out wild food plants allied to crops, and of understanding how plants suffer from pests. Both the agriculture and botany should be done before the entomological course itself starts. These are of course requisites only for the agricultural entomologist, and not required for the veterinary or sanitary officer whose own subject takes the place of agriculture and botany above.

A general economic entomologist such as Governments employ wants an all-round knowledge also of sericulture, lac, bee-keeping, and the minor insect industries, in case an opening ever offers for starting an industry; nothing brings an entomologist more closely into touch with the public than a minor industry, as it is a tangible money-making thing, whereas his usual work is intangible, preventive and educative work, not visibly directly money-making. It is not every country that has the insect-industries of India, but it has often struck me that India would not still have a monopoly of lac cultivation if economic entomologists generally understood anything about it. If England did go in for the energetic American methods, our Universities would have entomologists who knew what lac was and had seen it growing; but we have not, and the result is that our Colonies recruit their entomologists from America.

It is not necessary, of course, for an economic entomologist who is going, say, to Uganda, to know sericulture in all its details, but he should know generally about it, what cocoons are of value, how they are grown or collected, used and sold, and be able to get a valuation for any wild cocoons he might come across. I do not think the average University includes on its staff anyone capable of helping the student in that.

There are a few points left which will help when one is starting new work. One is a little training in methods of producing and printing illustrations. This is a very important part of work, and without some technical knowledge one is terribly handicapped. A short course of instruction in this is really a necessity.

Another is a training in technical methods of setting, preserving collections, making up show cases, etc. I would add to it a training in office methods, in methods of recording information, and in such methods as card-indexing. Each worker, of course, develops his own methods, but a small amount of training in methods is extremely useful. The last I can think of, and not the least, is some amount of literary training. A fluent pen is a great boon to an economic entomologist, both in letter writing and in writing bulletins, leaflets, etc. For eight years I have written daily for at least an hour, often two or more, when my work was over for the day, simply to get and keep my pen fluent, and I think every economic entomologist in training should deliberately cultivate his literary faculties, especially in the "popular article" direction.

This closes my sketch of the training required, except that I have not sufficiently emphasised the "atmosphere" of the general training in entomology. I would dissociate this training entirely from the general zoological training, doing it as a post-graduate course; the trend of the course must not be that of the comparative anatomist, the evolutionist, the systematist, or the histologist; embryology does not come into it, nor does field entomology in the general sense. The atmosphere is difficult to realise because the word "economic" in this connection means so little to some people; but it is perhaps best expressed in this way; if a systematist picked up an insect on the road he would regard it as a beetle, sub-order so and so, family so and so, division, etc., and would probably, if interested in beetles, be able to name it and then care no more; that attitude we do not want; the general zoologist would regard it as an insect, perhaps a beetle, and then drop it; the comparative anatomist would pick it up, wonder how many and what sort of egg tubes it had, wish he had time to tackle it and drop it; a few entomologists would pick it up, wonder where it came from, what it was doing there and so on; the man we want would do that and also think of its place in nature as regards man, if it was predaceous or herbivorous, if it did damage, of its allies and their place, and of how one would tackle a large increase in their number. To that view, a working knowledge of embryology, other than as gained in a very general zoological course, would not be of the least use, and the difficulty in making economic zoologists in England will be the preponderance of the Academic view and the total absence of the economic view based on experience. Economic entomology is not taken seriously in England, not as it is in America or the Colonies; I do not know about economic zoology as regard fisheries and such industries; but I do think English Universities have a very long way to go before they can turn out entomologists of the practical stamp that America does.

Field entomologists who study the living insect are rare enough; of these a very small percentage have that rare addition of "applied common sense"; and if that rare combination has appeared, there is not a University that can give him the practical economic training.

I have happened to have a good deal to do also with medical entomology, and the lack of knowledge of entomology of the medical men who have to apply themselves to entomological problems is very painful; but we realise that there are very few places in England where medical men can get their training, and even then the training seems to lack a great deal. I came across a series of experiments being done with hydrocyanic acid in a prominent bacteriological laboratory once, and the trained investigators, working on an entomological problem, were wholly ignorant of the use of cyanide as a fumigant and of the literature there is on its use. In another case, oil was being used as an insecticide and was abandoned as it was messy, the investigator regretting it was not an emulsion; yet crude oil emulsions are generally known, outside England, as insecticides, only these investigators happened to be English and had never heard of it.

Professor Hickson points out quite rightly that even if an University can give training in agricultural pests, it cannot do so in forest pests; let me state at once that the last thing a student wants is detailed knowledge of the pests he is to fight. No man will ever do good unless he studies the matter afresh for himself and then reads up what his predecessors have done or others have done.

The only useful piece of knowledge that can be taught to a man is how to recognise the stages, what the group generally does, and, if possible, to recognise the most important pests of the world in their imago stage. To give a student field experience of the pests he is to fight is absolutely fatal; if he is to do any good he will study his pest *de novo* and then read afterwards what others have written. If he has not grit enough to take on the investigation of new pests under new surroundings, he will never be any good, and if I were training a man for India, I would never teach him more than methods, certainly not cram him up in what was known of Indian pests. The real things that matter in agricultural entomology are (1) the local agricultural practices, (2) the people and their resources, (3) the pest. So I would have a worker tackle the first two first and the pest last, but the last he should tackle with a first-rate all-round general training. This kind of training can be given anywhere, but I fail to see how any University can give it at present or how the demand for men in the Colonies is to be met by Universities staffed by men who never leave England. Out in the Colonies, one is directly up against large problems requiring practical solutions, suited to ordinary folk; with all due respect to our Universities, from one of which I went to this work, the atmosphere is too "academic," and this atmosphere is reflected in the article of Professor Hickson.

Throughout this article I am thinking of the entomologist who will be working outside England, and it may be thought that the training I have outlined is an impossibly wide one; I may point out that in our Colonies, one has to be "self-sufficing" to a very large extent; one cannot always get help, or go round the corner and consult a botanist or a chemist, or visit museums, libraries, etc. The facilities of civilization are often conspicuous by their absence; one may be working for or with the people whose standard of life does not include any metal or woodwork, whose vessels do not go beyond pottery and basket work. Nor can we get a "Pest Act" passed and enforce it always on uneducated agricultural peoples. I imagine that many an English entomologist or zoologist put down in a far country to tackle one of the big problems would be very much surprised indeed, and that the deeper he went the worse it would get. So that, if my training seems wide, it must be remembered that it covers the knowledge I have wanted or found useful and that, except in entomology and the local agriculture, it need not be very profound. An agricultural entomologist wants a working knowledge only of botany and chemistry, he cannot also be a botanist and chemist, but he must understand how to utilise them and how to bring his difficulties to the botanist and chemist eventually.

Finally, it may happen that this article may be read by prospective candidates for posts as economic entomologists. Let me remark therefore that the life of an economic entomologist is not a pleasant daily round of entomology and investigation; the investigation is much of it done in spare time; the publication of learned papers drops, in favour of publishing bulletins for the public; to deal with the letters from the public, whose servants you are, is not easy unless you prepare a stock of leaflets on every subject and answer by that means. The life of an economic entomologist is that of any busy business man, if his work is any good to the public, and the quiet necessary to research and enquiry is not to be found in it. This too applies not only to one's work at "headquarters"; one's work in the field is of a very unacademic and rough kind, which makes demands more on the body than on the mind. Of course there are many who regard the public as an enemy and that, at all costs, research is to be carried on; those persons should be in the places provided for research—universities—and not in government service. If economic entomology is ever to have a practical meaning, and is to do its share in agriculture, medicine, sanitation, and other practical things, the economic entomologist has got to be there, putting forth his practical knowledge and not be shut up in a deep research. In the ideal state, entomologists will, of course, abound, and while one researches, another will write, another classify and so on; in our imperfect civilisation, the one man must do all, and if the subject is to go forward, he must be trained to do it in a business way with the least waste of time, and must, as things now are, aim at making himself felt by the public so that the value and need of scientific inquiry may be realised.

We are on the threshold of greater things, and to whatever problem comes, one must put one's hand. Only so is the practical entomologist going to convince an unlearned public and sceptical governments that there is anything at all in it, and we are, in England certainly, beginners who must look to the future. England should be the source at least of the entomologists of her Empire, but she is not, and unless radical changes take place in the atmosphere of her teachers, she will not be. The training will have to be that of practical field entomologists if the demand is to be met from England, and the last thing it wants to be is the academic zoological training of the average English University.

## REVIEWS.

**Jörgensen, A.**—Micro-Organisms and Fermentation. Trans. by S. H. Davis. 4th ed. Pp. xi + 489, 101 figs. London: Charles Griffin and Co., Ltd., 1911. Price 15/- net.

This is the fourth English edition of Jörgensen's well-known text-book, a fact which in itself indicates the esteem in which it is held in this country.

A considerable amount of new matter has been incorporated and many alterations have been made, so that we may really regard the book as a new one.

The plan followed is as of old. There is an excellent introduction, followed by the consideration of the biological examination of air and water, and chapters on bacteria, moulds, yeasts, and the pure culture of yeast on a large scale. A copious bibliography and index compile the work.

The thoroughly practical nature of the book and the lucid yet concise manner in which it is written, fully entitles it to be still regarded as a standard work on the subject.

**Lundbeck, W.**—Diptera Danica Genera and Species of Flies hitherto found in Denmark. Pt. III. *Empididae*. Pp. 324, 141 figs. Copenhagen: G. E. C. Gad. 1910.

In referring to the previous parts of Professor Lundbeck's monograph, we spoke in highly appreciative terms of the scope and style of this valuable work, and the third part now before us fully merits all we then said.

The same care has been expended upon the descriptions of genera and species, and numerous notes on the habitat of the larvae and habits of the imagines are recorded.

The developmental stages of the Family are only imperfectly known, as in many other families of the Diptera.

About 675 species are known from the palaeartic region, of which 164 are described in the volume before us; many of these are illustrated by excellent text-figures showing the wings, antennae, legs, genitalia, etc.

The work bids fair to become one of the leading monographs, and we trust it will receive the support of all British dipterologists.

W. E. C.

**Willey, A.**—Convergence in Evolution. Pp. xv + 177, 12 figs. London: John Murray, 1911. Price 7/6 net.

This work, so the author informs us, may be regarded as an attempt at a reply to Dr. Gaskell's remarkable work on the "Origin of Vertebrates."

The term "convergence" is not a happy one if indeed it is better than the old one of "parallel evolution," it would therefore perhaps be better to adhere to Lankester's term "homoplassy."

Although biologists have been, and many still are, loath to admit that there are many instances of similarity of form which have no connection in regard to inheritance, the cases daily becoming more numerous, and we regret that the author of the work before us has not given more illustrations of this kind. Interesting as his work is, his exposition is by no means clear, yet biologists will welcome a work in which convergence is dealt with as a general and positive phenomenon of equal importance with orthogenesis or normal morphology.

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We have to thank Dr. Hopkins for a further excellent monograph on economic entomology. Beyond stating that the high standard set in his previous works is fully maintained we need not comment upon it.

It is a great pity that better paper has not been used for the plates.

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THE

# JOURNAL OF ECONOMIC BIOLOGY.

## SOME DIPTEROUS LARVAE FROM THE TURNIP.*

By

Prof. GEORGE H. CARPENTER, B.Sc., M.R.I.A.

With 7 Figures.

In July and again in September, 1910, I received from Mr. A. W. Oldershaw of Dundalk, examples of curiously deformed Swede Turnips, the leaf-stalks showing abnormal swellings just above the roots, and the leaves displaying a strange crumpled and distorted

Fig. 1.—Young Swede Turnip plant deformed by Dipterous larvae.

* Read before the Association of Economic Biologists, Birmingham Meeting, April 6th, 1911.

[Journ. Econ. Biol., July, 1911, vol. vi, No. 3.]

aspect, which led Mr. Oldershaw to apply the appropriate name "cabbage-headed" to the affected plants (Fig. 1). The roots also were eaten away both at the crown, and at the sides, and in the worst cases there were large hollows or masses of decaying tissue in the middle of the turnip.

This damage to the root was plainly due to maggots of the common Cabbage-fly (*Phorbia brassicae*, Bouché), which were found abundantly in the material sent in autumn. The interest of Mr. Oldershaw's observation lies in the discovery of at least two dipterous insects hitherto little known or unrecognised as enemies to cruciferous crops, and worthy of further study.

## CECIDOMYID LARVAE.

Between the bases of the leaf-stalks, which formed the swollen growths referred to above, were found larvae of a gall-midge, feeding usually six or eight together (Fig. 2). These larvae were first

Fig. 2.—Larvae of Cecid *(gen. et sp. incert.)* feeding between petiole bases of Turnips. Magnified.

noticed by Mr. F. V. Theobald,[1] to whom also Mr. Oldershaw had sent examples of the strangely deformed turnips, the appearance of which Theobald has illustrated by some good photographs. As regards the feeding habits of these larvae, I can do no more than confirm Theobald's account, and mention that in September I found some of them crawling over the surface of the leaves in company with the other larvae described below. Theobald was able to observe that these grubs enter the soil to pupate; unfortunately he succeeded in rearing only a single female midge, which is believed both by Mr.

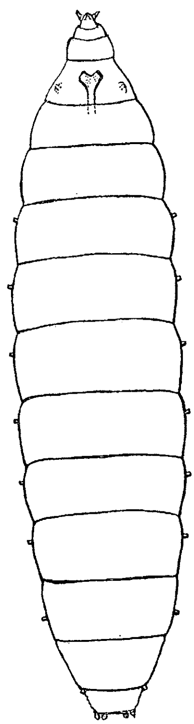

Fig. 3.—Larva of Turnip Cecid, Ventral View. Magnified 30 times.

E. E. Austen, of the British Museum, and by the Abbé Kieffer, well-known as a Continental authority on the *Cecidomyidae*, to belong to a new species of the family. My own attempts to rear the midges were unsuccessful. It is worth while, however, to give some account of the larva.

The grub is 3 mm. long and about .65 mm. broad, of the usual

[1] S.-E. Agric. Coll. Rpt. Econ. Zool. for year ending September 31st, 1910, pp. 90-91, plts. xli, xlii.

cecid shape, and creamy-white in colour. The ventral "anchor-process" or "breast-bone" is very deeply emarginate in front, with prominent quadrate side-outgrowths, this front part of the anchor-

Fig. 4.—Deformed Turnip leaf, with maggot of *Scaptomyza flaveola* feeding. Magnified.

process is strongly chitinized and deep yellow in colour. The prothoracic spiracles are situated dorsally, the abdominal spiracles, as usual in the family, are lateral. At each side of the hindmost segment are two minute rounded tubercles, the outer pair carrying short spines. (Fig. 3).

We must hope that the Abbé Kieffer will soon be able to identify this interesting insect for us. There is no doubt that the basal swelling of the shoots must be attributed, as Theobald states, to the presence of these cecid larvae between the leaf-stalks.

### **Scaptomyza flaveola,** Meig.

The curiously crumpled leaves of the turnips under examination have already been mentioned. On the upper surface of these leaves (Fig. 4) were found both in July and in September maggots of small muscoid diptera with elongate tail-spiracles (Fig. 5). These maggots were tearing at the leaf-tissue with their mouth hooks, and there can, I think, be no doubt, that the damage to the foliage, must be at least partly attributed to their presence, though it is very likely, as Theobald suggests, that the irritation set up by the cecid larvae at the base of the shoots is not without influence on the leaves.

Some of these maggots, received early in September, pupated after a few days, and before the end of the month they had developed into flies of the genus *Scaptomyza,* which belongs to the *Drosophilinae*. There was a larger yellow species (Fig. 7), which I identified as *Scaptomyza flaveola,* Meig.[1] This identification has been kindly confirmed by Mr. P. H. Grimshaw, of the Royal Scottish Museum, Edinburgh, who believes the other species, smaller and dark grey in colour, to be *S. graminum,* Fall.

As these *Scaptomyza* maggots are undoubtedly injurious to turnip foliage, it is worth while to give a fuller account of their form and outward structure than has yet been published.

The maggot (Fig. 5) measures 3 mm. in length, and is of the tapering form and whitish colour usual in muscoid larvae. The head region (Fig. 5, *c*) shows the typical anterior processes, and the rugose areas before and behind the mouth-hooks; the latter are provided with three or four sharp teeth. Each prothoracic spiracle (Fig. 5, *c*) consists of seven or eight open tubes of varying lengths, which arise irregularly from a common trunk, and are clustered together like the fingers of a hand. The appearance of this spiracle differs markedly from the regular fan-like form that is familiar in the maggots of *Musca, Calliphora* and their allies.

A remarkable feature in this larva is the presence of numerous short spines or fine hair-like outgrowths of the cuticle on all the body-

[1] See G. H. Verrall, "List of British Diptera," p. 34, and Schiner, "Diptera Austriaca," vol. ii, p. 279.

segments (Fig. 5, *a, b, c*). These are most prominent on the dorsal aspect. Towards the front edge of a segment one finds minute short, stout spines, these soon give place to more elongate hair-like structures, which are arranged in fairly regular transverse rows. The hindmost segment of the larva bears four pairs of conical processes, one dorsal and vertical, two lateral, and two ventral (Fig. 5, *a, b*);

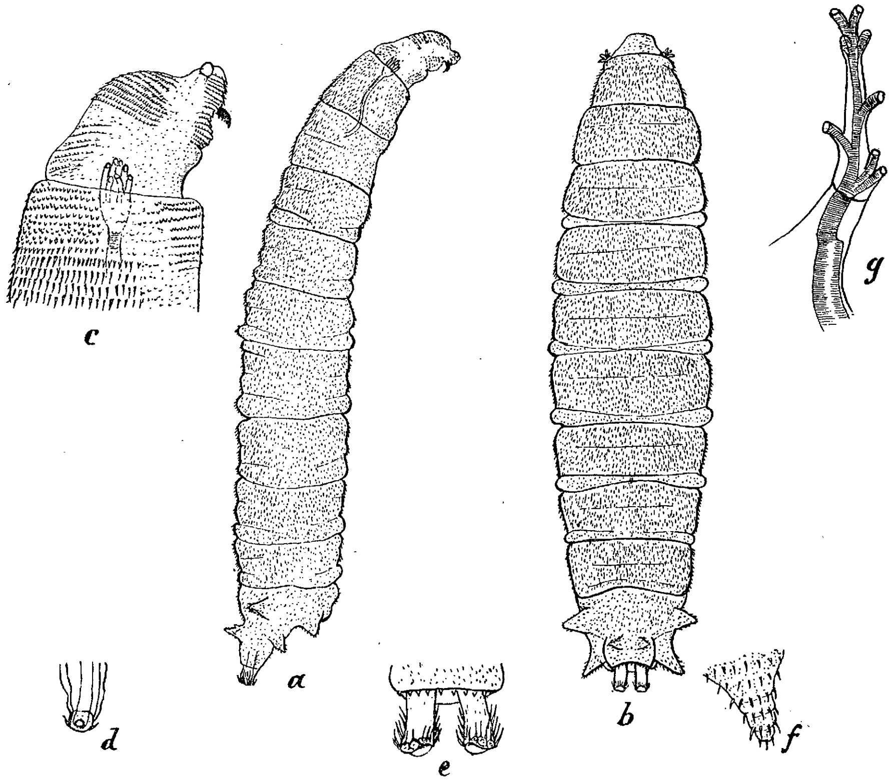


Fig. 5.—Larva of *Scaptomyza flaveola*. *a*, Side view. *b*, Dorsal view. Magnified 30 times. *c*, Anterior end, showing mouth hooks, spiracles, and armature of cuticle. Magnified 80 times. *d*, Posterior spiracle, lateral view. *e*, Posterior spiracles, dorsal view. *f*, Postero-lateral process. Magnified 80 times. *g*, Anterior spiracular process of puparium. Magnified 120 times.

these processes are beset with fine curved bristles arranged in whorls (Fig. 5, *f*). The tail spiracles are situated at the end of a pair of prominent tubes, which project from below a toothed dorsal ridge on the hindmost segment (Fig. 5, *b, d, e*). The sides of these tubes, and the circumference of their extremities are beset with numerous rather long bristles backwardly directed (Fig. 5, *d, e*).

The puparium of *Scaptomyza* (Fig. 6) is remarkable for the long elongation of the prothoracic spiracles, which project on either side of the head region like stags' antlers to which the branching air-tubes give them, indeed, some resemblance (Fig. 5, *g*).

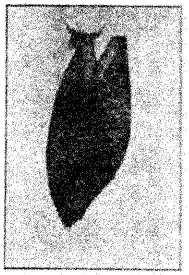

Fig. 6.

Fig. 7.

Fig. 6.—Puparium of *Scaptomyza flaveola*. Magnified 10 times.
Fig. 7.—*Scaptomyza flaveola*. Imago. Magnified 6 times.

Most students of British economic entomology will remember Curtis' description of the "Yellow Leaf Miner" of the Turnip, *Dropsophila flava*, Fallen.[1] Curtis gives a small scale figure of the maggot of this insect, showing clearly the elongate tail-spiracular processes. He also figures the puparium and calls attention to the the "two divaricating horns on its head." Curtis's *Drosophila flava* is now placed in the genus *Scaptomyza*, so that it is nearly allied to the insect whose maggot is here described.

Quite recently the larva and puparium of a *Drosophila* have been described and figured by Martelli.[2] They agree with those of *Scaptomyza* in the prominent tail-spiracles of the larva, and the elongate anterior spiracles of the puparium.

The two species mentioned above, *Scaptomyza flaveola* and *S. graminum*, have been recorded by Coquillet[3] and Chittenden[4] as mining the leaves of cabbage, cauliflower, and turnip in the United States. The figure of *S. flaveola* given by Coquillet, and copied by Chittenden, shows mines made by the maggots, in radish leaves. It is noteworthy that in the present case the leaves were not mined, the larvae, both in a very young stage and fully grown, being found

1 J. Curtis. "Farm Insects," p. 84.

2 G. Martelli. Notiza sulla *Drosophila ampelophila*, Lw. Bull. d. R. Scuola d'Agric., Portici, 1910, vol. iv, pp. 163-179.

3 D. W. Coquillet. Two Dipterous Leaf-miners on Garden Vegetables. Insect Life. (U.S.D.A.), 1895, vol. vii, pp. 381-4.

4 F. H. Chittenden. Some Insects injurious to Vegetable Crops. U.S. Dept. Agric., Div. Entom., Bull. 33 (n.s.), 1902, pp. 75-77.

on the surface. Coquillet states that "five larvae sometimes occupy the same mine, and, when the leaf containing the mine is small, they usually desert it and form new mines in the adjoining leaves." Evidently the feeding habits of these larvae vary with differing conditions.

### Phytomyza flavicornis.

In the Report already referred to, Theobald states that he reared flies of this species from maggots burrowing in the petiole and mid-rib of the Dundalk Swedes. I did not find this insect. It is note-worthy that Curtis's "Black Turnip leaf-miner" is a *Phytomyza* (*P. nigricornis*).

### SCAVENGING DIPTEROUS LARAVE.

As might have been expected, the plants which had been badly damaged and whose tissues were decaying, furnished an attractive breeding-ground for several species of Diptera whose larvae live as scavengers. Among the flies thus reared were a species of *Sciara*, *Phora rufipes*, Meig., and *Homalomyia canalicularis*, Fab. (the "Small House-fly"), whose brown maggots beset with their curious elongate processes were very common.

During the present year, I hope to have an opportunity of studying further the life-history both of the unknown cecid and of the *Scaptomyza*, and determining, if possible, the share that each takes in causing the curious distorted growth of the Swedes. Mr. Oldershaw states that this condition has been very prevalent throughout a large district in Co. Louth for the past two years. The deformed condition of the plants must indeed be distressing to the farmer. I trust to have shown that they are of no little interest to the student of the life-history of Diptera.

# COCCIDIOSIS IN BRITISH GAME BIRDS AND POULTRY.

By

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*Christ's College, Cambridge; Protozoologist to the Grouse Disease Inquiry.*

With 2 Figures.

Contents.



## I.—Introduction.

Spring is the season of rejuvenescence and of the general awakening of Nature. It is especially the season for young plants, young birds, and young mammals. To the naturalist it is a time of great pleasure for the domestic habits of parent birds, and their tiny offspring can be observed in all their beauty. To the sportsman, gamekeeper, and poultry-raiser it is, however, a period of anxiety, for on the upbringing of healthy young stock depends much of the success of the forthcoming season—whether from the sporting or the economic point of view. How many a careful keeper rejoices in fine and numerous young broods in the spring, and later is saddened at the greatly

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diminished numbers that he can find. How has such a fatal dwindling been brought about? It is here that the aid of the scientist has been recently invoked, more especially in the case of the game and domestic birds, with the result that the problem of why large broods dwindle in a somewhat mystifying manner has been solved, at any rate in the case of young grouse and pheasants.

Before proceeding further, it would be well to dispel the common error made by people who speak of "the grouse disease." Like most animals, grouse—and incidentally many other birds—are beset by complications of many diseases. These may be co-existent or may occur progressively. Undoubtedly some diseases occur more commonly among young birds, while older birds may be far less susceptible to the same complaints. From the biological point of view there is no such thing as "the" grouse disease, for several diseases are known to afflict the unfortunate birds.

Prominent among the diseases of poultry is one known to the poultry-breeders variously as "white scour," "scour," "white diarrhœa," or "enteritis." The same disease afflicts game birds, and is even more fatal to them than to poultry, the domesticated conditions under which poultry exist rendering them far more amenable to treatment.

The causal agent producing the above-mentioned disease has now been proved to be a small, one-celled animal parasite belonging to the sub-kingdom Protozoa. As the parasite produces resistant spores, it is a member of the Sporozoa, and belongs to the genus *Eimeria,* formerly known as *Coccidium*; hence the malady is known scientifically as coccidiosis. It may be noted that coccidiosis is not restricted to birds, but is known to occur in many other Vertebrates, in Arthropods and in Molluscs. Coccidiosis is especially fatal to young Vertebrates.

Though the structure and life-cycle of the particular *Eimeria* (*Coccidium*) that infests the common garden centipede, *Lithobius forficatus*, has been known for some years, due to the researches of the late Dr. Schaudinn, yet the life-history of scarcely any other Coccidian has been worked out in detail until last year, when the life-history of the parasite so singularly fatal to young grouse was fully set forth by the present writer. There are many differences between the life-cycles of the parasite of the grouse and that of the centipede, and inasmuch as the former animal may be said to have a more human interest, the *Eimeria* that infests the grouse is chosen as the central subject for this brief account.

## II.—Occurrence of Eimeria avium in the Host.

*Eimeria avium,* to give the parasite its full name, is a small Protozoön endowed with a great capacity for existence under unfavourable conditions for long periods, and with an almost infinite capacity for penetrating and destroying the delicate mucous membrane lining the alimentary tract of its host. The whole food tract is not affected as a rule, but there have been cases where every part of the intestine has been literally riddled by the parasite (Fig. 1). More

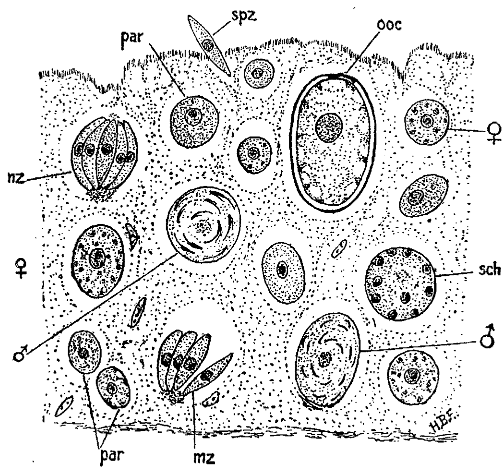


Fig. 1.—Portion of the gut (caecum) of a grouse infected with *Eimeria avium,* showing the lining epithelium riddled with parasites. Many stages in life history of *Eimeria avium* are shown in section therein.

par = Parasite.
spz = Sporozoite or primary infecting germ.
sch = Schizont or dividing form.
mz = Merozoites (daughter forms).
♂ = Microgametes (male elements), attached to the microgametocyte (male mother cell.
♀ = Macrogamete (female).
oöc = Oöcyst (cyst).

Original. After Fantham, "Encyclopaedia of Sport" (1910).

particularly, however, does it infest the duodenum, that highly important part of the digestive canal where the most active digestive processes go on, and then it passes along the food canal until the long-paired caeca or "blind guts" (especially long in grouse) are reached. Here the parasite finds a most suitable environment and active multiplication occurs again, sexual forms leading to resting bodies being ultimately produced (as also in the duodenum) and the caecal walls reduced to extreme thinness, their lumina, however, being considerably enlarged. The *Eimeria* does not appear to attack the liver or gall bladder of the grouse, nor of its other game bird victims, which I will list later, and in this respect is in marked contrast with the *Eimeria* of the rabbit, which organism has also been known to be fatal to man. However the liver of turkeys and occasionally of fowls may be infected with Coccidia.

## III.—Symptoms of Coccidiosis in Birds.

As already remarked coccidiosis is especially prevalent among young birds. The symptoms of grouse, fowls and pheasants suffering from natural coccidiosis, as well as those of captive grouse, fowl-chicks and pigeons in which the disease has been artificially induced, are identical. The birds, when early infected either by way of their food or drink, stand about more than healthy young control birds do, droop their wings and utter plaintive cries. They, however, eat and drink far more greedily than do healthy birds, but in spite of this the victims rapidly become thinner, the muscles of the breast and legs showing this to a marked degree. The loss of weight is remarkable. One instance was that of a fowl chick which I artificially infected by means of its food. It and its control sister chick weighed 7½ ounces each at the time of infection, but when the infected bird died two months later its weight was 5 ounces, while that of the control bird was 1lb. 6oz. Other equally striking results were obtained during the course of the investigation.

In addition to loss of weight, infected birds become markedly anaemic, the comb, wattles and cere becoming pale and bloodless, The feathering also is very weak compared with that of healthy birds; that of the legs is ragged, the quills are less rigid, the sheen on the feathers is less developed, and the replacement of nestling down by ordinary feathers is much retarded in diseased birds.

Owing to the attack of the parasite on the mucous membrane of the alimentary canal digestive troubles occur, and the faeces voided by the grouse are the best ordinary index of its condition. The soft droppings of such grouse (which are caecal in origin) are very fluid, the condition being one of diarrhoea. The dejecta are very pale, softer than usual and of a sulphur yellow colour; those of normal grouse being olive green to brown in hue. Examined microscopically, a small portion of infected faeces, diluted with water, shows myriads of small oval bodies, which are the resistant forms of the parasite, known as oöcysts (or cysts)—forms by which the infection of new hosts is readily brought about. Death from coccidiosis is often sudden, and, a point of great importance, corpses of all diseased birds should be burned and never buried, for, as I have proved experimentally, the cysts remain infective for long periods, even for a year or more—long after the disintegration of the body of the first host. Some details may now be added regarding the life-history of this devastating parasite.

## IV.—Life-History of Eimeria avium.

The life-cycle of the parasite is complicated, as there are two distinct phases in its developement: (i) a phase of asexual multiplication, known as schizogony, during which there is increase in the number of the parasites in the gut-epithelium of the avian host, and (ii) a reproductive phase leading, after a sexual act, to the formation of resistant cysts and spores adapted for life outside the body of the host.

### (*a*) The Young, growing Parasite.

The resistant form of the parasite reaches the host in the food or drink of the latter, for the resistant cysts are scattered on the heather and in the tarns at which the grouse drink. The oöcysts reach the duodenum uninjured, and here, under the influence of the powerful digestive juices present, the hard cyst-wall is softened and allows the escape of four smaller oval bodies or spores contained within. From each of these in turn emerge two minute, active, motile bodies, the primary infecting germs or sporozoites. These measure from 7 $\mu$ to 10 $\mu$ in length. Each sporozoite is a small vermiform organism with a single uniform nucleus (fig. 2, A). The sporozoite is rather more pointed at one end, and secretes a small amount of mucilaginous material, which rapidly hardens, and on the smooth surface thus provided, it glides forward with a gentle undulatory movement, recalling the "billows" that pass along the foot of the snail. The sporozoite remains free only a very short time in the lumen of the gut, but rapidly passes to the wall, where it attaches itself to an epithelial cell and proceeds to bore its way inwards. Once within, the parasite curls on itself (fig. 2, B) and gradually loses its vermicular form and becomes spherical (fig. 2, C, D). It grows steadily at the expense of the host cell, and soon the latter becomes greatly atrophied, its nucleus is much displaced and the parasite lies in a clear space within the host cell. The passive, feeding stage of the organism is known as the trophozoite phase (fig. 2, D).

### (*b*) Asexual Multiplication or Schizogony.

Growth continues for some time, and then the parasite prepares for multiplication. When this time is reached the trophozoite has grown large and rounded (fig. 2, D), and is about 10 $\mu$ to 12 $\mu$ in diameter, the nucleus has become large and contains chromatin in a more or less compact mass or karyosome. The nucleus proceeds to divide into a number of portions that travel outwards and finally become disposed in a zone at the periphery (fig 2, E) of the parasite. The organism in this multinucleate condition is known as a schizont. Protoplasm collects around each nucleus (fig. 2, E, F), and the result is the production of a group of daughter individuals (fig. 2, G)—the merozoites. Each vermiform merozoite is from 6 $\mu$ to 10 $\mu$ long and greatly resembles a sporozoite, but differs from the latter in that its nucleus contains a minute dot of chromatin—the karyosome. The merozoites of a group are arranged "en barillet" (fig. 2, G), much like the segments of an orange.

The merozoites separate from one another (fig. 2, H), and each one is capable of infecting another epithelial cell of the gut-wall of the avian host, and does so. The processes of growth and multiplication are repeated until the duodenal lining is reduced to an almost structureless mass (fig. 1). The number of merozoites formed from each schizont seems to vary; 8 to 14 appear to be common numbers, but as many as 20 merozoites have been found to be produced by a single schizont. The process of formation of merozoites is known as schizogony.

In most cases, some of the merozoites pass down the lumen of the gut and reach the caeca, where they proceed to penetrate the lining epithelium, round off and multiply by schizogony as in the duodenum. Probably coccidiosis set up in the duodenal wall is sufficient to kill very young birds; for example, grouse chicks from 8 to 10 days old, while older chicks, dying at the age of 4 to 6 weeks, may have partially recovered from duodenal coccidiosis and succumb to coccidiosis in the caecum (typhlitic coccidiosis). In the case of intense duodenal coccidiosis I have found free merozoites in the intestinal contents and even in freshly shed faeces.

It is of great importance to note that the period of schizogony of the parasite is the most critical time for the infected bird, for during this period there is derangement of the digestive processes and acute inflammation of the intestines (enteritis).

### (c) GAMETOGONY.

After several generations of merozoites have been produced, both in the duodenum and caecum, a limit is reached both to the multiplicative power of the parasite and to the capacity of the host to provide the invader with nourishment. Consequent on this, the parasite begins to prepare for extra-corporeal life and to produce sexual parasites by whose union resistant forms result. Two forms of parasites now are produced. The one form is large and contains much granular food material (fig. 2, I ♀). This type of organism is destined to become the female mother cell or macrogametocyte. The second form is slightly smaller than the first, and is far less granular (fig. 2, I ♂). Like the macrogametocyte it is more or less oval in shape. But whereas the female mother cell gives rise to one female cell or macrogamete only, the male mother cell or microgametocyte will produce ultimately a very large number of minute, biflagellate, active microgametes or male cells (fig. 2, K ♂).

The processes leading to the formation of the male and female gametes is termed gametogony.

### THE MACROGAMETOCYTE AND MACROGAMETE.

The macrogametocytes or female mother cells really are modified schizonts whose growth is slow, and hence they are able to accumulate much reserve food material within themselves. When full-grown they are from 11.8 $\mu$ to 17.5 $\mu$ in length, by 6 $\mu$ to 11 $\mu$ in breadth in section. In the richly granular cytoplasm are two kinds of granules (fig. 2, J ♀, K ♀). One variety of granule is much more stainable than the other, and is known as the chromatoid granule, while the other kind, well seen in life, forms large, roundish, refractile masses appearing yellow or greyish green in fresh preparations. These are known as plastinoid granules.

As the parasite grows, the plastinoid and chromatoid granules travel towards the periphery, and at this period a cyst wall is formed around the macrogamete (fig. 2, K ♀). The use of the chromatoid granules is then seen, for they pass out and form part of the inner layer of the cyst wall. The formation of the cyst takes place while the parasite is still within the epithelium of the host. Hence the macrogamete encysts precociously, but a thin spot or micropyle is left in the cyst wall, and by means of this pore the microgamete or male cell can enter at the time of fertilisation.

### THE MICROGAMETOCYTE AND MICROGAMETES.

The microgametocyte or male mother cell is an ovoid cell about 13 $\mu$ long and 8 $\mu$ broad as seen in the sections that I have examined. The formation of the numerous microgametes (male parasites) from it is interesting. The chromatin of the nucleus at first is concentrated in the karyosome, but it soon breaks up into a number of minute granules of chromatin, called chromidia, which travel outwards to

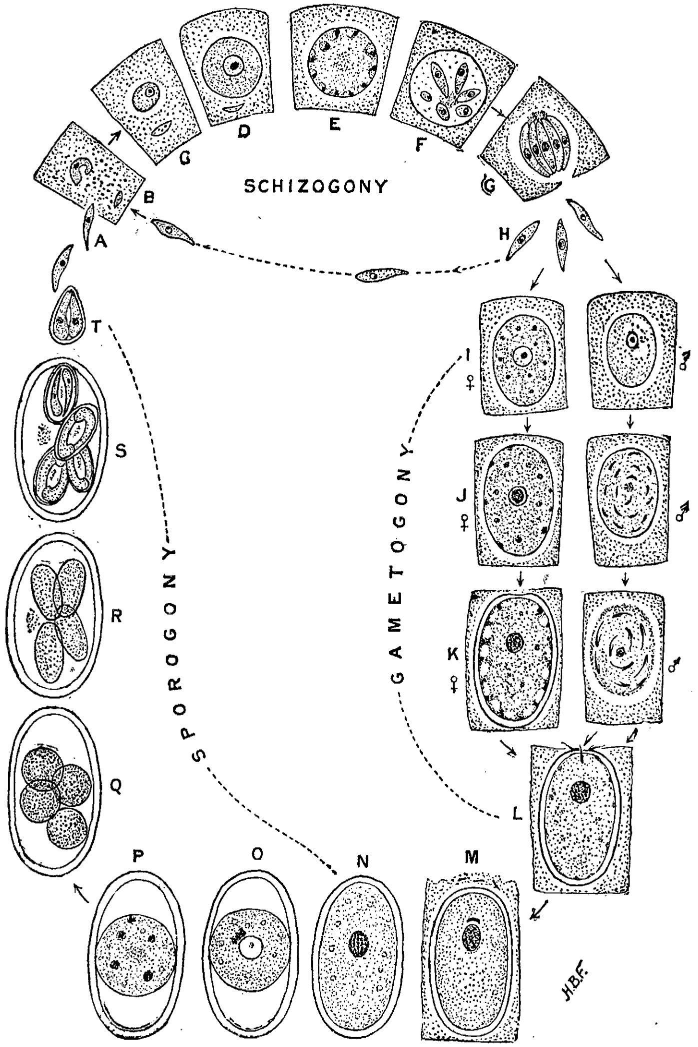


Fig. 2.—Diagram of Life-cycle of *Eimeria* (*Coccidium*) *avium*. (Original. After Fantham, from Proc. Zool. Soc., 1910, p. 684).

Fig. 2.—B-H. Illustrate the asexual reproduction (schizogony) of *E. avium*. Epithelial host cells diagrammatically outlined.

Fig. 2.—I-L. Illustrate the production of sexual forms (gametogony).

Fig. 2.—N-T. Illustrate spore formation (sporogony).

A. Sporozoite or primary infecting germ which penetrates the epithelial cell of the duodenum of the host.

B. Sporozoite curving on itself before becoming rounded within the host cell.

C. Young, growing parasite.

D. Fully grown parasite. (Trophozoite).

E. Schizont, with numerous daughter nuclei peripherally arranged. (Seen in transverse section).

F. Schizont, showing further differentiation of merozoites.

G. Merozoites arranged "en barillet," about to issue from the host cell.

H. Free merozoites.

I. ♀ Young macrogametocyte with coarse granules.

I. ♂ Young microgametocyte with fine granules.

J. ♀ Growing female mother cell, showing chromatoid and plastinoid granules.

J. ♂ Microgametocyte with nucleus divided to form a number of bent, rod-like portions, the future microgametes.

K. ♀ Macrogamete which has formed a cyst wall for itself but left a thin spot for the entry of the microgamete.

K. ♂ Microgametocyte with many biflagellate microgametes about to separate from it.

L. Fertilisation. One microgamete is shown penetrating the macrogamete, while other male cells are near the micropyle but will be excluded.

M. Fertilisation. The male pronucleus is lying above the female chromatin. Degenerating microgametes are shown outside the oöcyst.

N. Oöcyst (encysted zygote) with contents filling it completely.

O. Oöcyst with contents concentrated, forming a central, spherical mass. Many such cysts seen in infected caecal droppings.

P. Oöcyst with four nuclei.

Q. Oöcyst with contents segmented to form four, rounded sporoblasts. (As seen in fresh preparations).

R. Oöcyst with four sporoblasts which have grown oval and are becoming sporocysts.

S. Oöcyst with four sporocysts, in each of which two sporozoites have differentiated.

T. Free sporocyst in which the sporozoites have assumed the most suitable position for emergence.

the surface of the microgametocyte, where they form a very fine network. The chromidia then collect into small groups or patches arranged in the form of minute irregular loops with central hollows. The chromatic loops form a number of flexible rod-like bodies (fig. 2, J ♂), composed almost entirely of chromatin. When completely formed, the minute male parasites are only about 3 $\mu$ to 4 $\mu$ long (as measured in section), and the chromatin of their bodies is surrounded by a film of their protoplasm prolonged outwards to form two extremely fine flagella (fig. 2, K ♂). One flagellum trails behind the body, of which it is practically a continuation, while the other is anterior.

The microgametes gradually separate from the mother cell, of whose body a large proportion remains unused. The microgametes, when free, move about in the lumen of the gut with a gliding serpentiform movement, but it is only with the greatest difficulty that they can be distinguished as they move among the epithelial and food débris and the other fauna of the gut of the host.

### (*d*) FERTILISATION.

This process has been watched in life. When the macrogamete has attained its maximum development, it often comes to lie close to the lumen of the gut, with its micropyle directed outwards.

Sometimes the macrogamete (♀) bursts through the wall and lies free in the lumen of the gut. Meanwhile the microgametes (♂) break free from their parent cell and swim out with rapid lashing of their flagella into the gut, where they are attracted, possibly by some chemiotactic substance, towards the female gamete. The minute microgametes swarm around the micropyle (fig. 2, L), and several have been seen vigorously endeavouring to enter at one time. One at length succeeds, and appears spirally to bore its way into the macrogamete, whose nucleus moves up to meet it (fig. 2, L), and finally is lost to view. The macrogamete at once secretes a plug of protoplasm that blocks the micropyle and excludes the other microgametes that finally degenerate.

The macrogamete, as before mentioned, is heavily laden with food granules, and these make it difficult to follow the subsequent details of fertilisation. There are indications of the formation of a small fertilisation spindle at times (fig. 2, N), but the nature of the material frequently prevented observation of this structure. When fusion of the nuclei of the two gametes (fig. 2, M, N) is accomplished, a zygote is formed, and the latter—inside its cyst (oöcyst)—proceeds to spore formation or sporogony.

## (*e*) Sporogony.

The onset of sporogony of *Eimeria avium* usually means either the recovery or the death of the infected chick. When the infection has not been acute, the oöcysts pass from the body, and the internal gut-lining may be able to regenerate and the bird gradually regains weight. Sometimes infiltration of connective tissue into the lesions formed by the parasite aids in this recovery. But when the attack is acute too much gut-epithelium is destroyed, and owing to complications arising therefrom the bird dies.

The oöcyst at first has granular contents with a yellowish or greyish appearance. The contents then completely fill the cyst (fig. 2, N), but after a short time they shrink away, so that it is common to find oöcysts with a central mass (fig. 2, O). But this does not obtain in every oöcyst, for some are found with the contents nearer one pole than the other. The central position of the contents is much the more common in the Coccidium of the grouse, while the asymmetric position is usual in the nearly allied parasite of the pheasant.

Whatever the shape of the oöcyst, the changes that follow take the same course. The nucleus (synkaryon) of the zygote divides directly first into two and then into four, the divisions following one another rapidly (fig. 2 P). Around each of these nuclei the general cytoplasm segregates, with the result that four rounded bodies now are present inside the oöcyst (fig. 2, Q). Each of these bodies is the precursor of a spore, and is termed a sporoblast. After a time the sporoblasts become oval (fig. 2, R), and each invests itself with a cell wall (sporocyst) and forms a uninucleate spore.

The development of spores usually goes on when the oöcyst is outside the body of the host and the dejecta of infected grouse chicks contain myriads of oöcysts in various stages of development. But, in the acute cases of coccidiosis, it is possible to find oöcysts with fully-developed sporocysts actually within the wall of the gut as well as lying free in the lumen of the caecum.

The further development of the spores is largely determined by the conditions under which they are placed. Ordinarily the oöcysts develop sporocysts in about three days, at room temperature (fig. 2, S).

On the moors the dejecta of the grouse gradually crumble into a fine dust, which is disseminated by the wind over the heather and into the tarns at which the birds drink. The oöcysts can retain their vitality and infectivity for very long periods—over a year. I have shown experimentally that some uninucleate oöcysts, kept in a mass of grouse faeces, have developed their four sporocysts eighteen months after they were collected. On the heather and in the water on the moors are thousands of oöcysts. Should a grouse eat some of the heather the oöcysts are ingested with it, and pass unharmed through the gizzard of the bird into its intestine, the heat of the bird's body meanwhile accelerating the formation of sporocysts, should the sporocysts not have been already formed in the ingested oöcysts. In the duodenum, under the influence of the pancreatic juice, the oöcyst wall softens, the four sporocysts emerge (fig. 2, S, T), and in turn there issues from each two small, vermiform, young parasites, the primary infecting germs or sporozoites (fig. 2, A).

The mode of formation of the two sporozoites within each sporocyst is somewhat complicated. In the fresh condition two shining vacuoles, often centrally placed, appear in the sporocyst contents. These vacuoles gradually extend and finally coalesce to form one vacuole, the greater part of the cytoplasm being arranged around the one vacuole, that is, at the poles of the sporocyst. The nucleus of the sporocyst at the same time divides into two, and one daughter nucleus passes to each pole. Gradually the protoplasm arranges itself around each nucleus in the form of a long, somewhat sickle-shaped sporozoite, the two being arranged tête bêche within the sporocyst (fig. 2, S). This arrangement is altered later, for when the sporozoites are ready to issue from the sporocyst they move so that their broad ends lie near one another, their narrow ones pointing to the weakest spot in the sporocyst wall through which they ultimately emerge (fig. 2, T, A). The sporozoites proceed to penetrate the epithelium of the duodenum of the host, where, owing to the destruction by them of the epithelium, grave digestive troubles are set up. Inflammation and diarrhœa occur, and the host, consequent on mal-nutrition, becomes emaciated, and, unless it is able to react with sufficient vigour upon the parasites, ultimately succumbs.

*Variations in Oöcysts.*—While the majority of the oöcysts are typically oval, yet variations occur, not only of size, but also slightly of shape. The size of the oöcysts varies from 25 $\mu$ to 35 $\mu$ long by 14 $\mu$ to 20 $\mu$ broad. But from my investigations I am forced to conclude that size is merely a factor of environment, and the amount of nutriment available for the parasite (macrogamete). Wherever a heavy infection of *Eimeria* occurs the parasites are crowded, they do not get as much food as where they are few, and their growth consequently is both slower and more restricted. Where abundant nourishment and space are available the oöcysts are larger.

Shape again is a factor of the environment. Mutual compression, or lack of space for development, produces variations. Sometimes the oöcysts are not oval, but sub-spherical. These are from 18 $\mu$ to 20 $\mu$ in diameter. Somewhat pyriform or egg-shaped oöcysts also are found, such being intermediate between the oval and sub-spherical forms.

Again, among the oöcysts of *Eimeria avium* some may be found with somewhat squarish ends, while others have a slight depression at the apex. But in every case, the further internal development follows exactly on the same lines.

*Period of Life-Cycle.*—From experiments made by feeding fowl chicks with Coccidian oöcysts, I conclude that schizogony takes from four to five days. Gametogony then occurs. Uninucleate oöcysts mature their sporocysts in two to three days. The period for the total life-cycle of the parasite is from eight to ten days.

## V.—Notes on the Condition of the Internal Organs of Infected Birds.

In the case of grouse infested with *Eimeria avium* the parasite is restricted to the intestinal tract, and especially to the walls of the duodenum and caeca. The blood-vessels of the intestine become engorged with blood, and inflammatory areas mark the points of most heavy infection by the parasite. The gut-contents contain much degenerated epithelium, which is particularly abundant in regions where active schizogony and gametogony are proceeding. In many cases the intestinal walls, particularly those of the caeca, become extremely thin and almost transparent. In other cases this effect is not so marked.

The large intestine also may show inflammatory patches, and blood has been found in the rectal contents. The rectum itself is but rarely attacked, though oöcysts occur in its lumen.

Examination of kidneys, spleen, liver and gall-bladder of infected grouse has yielded negative results. Occasionally oöcysts were found in the trachea, bronchi and bronchioles of the lungs of grouse, and it is probable that they had reached that position by passage of food into the trachea instead of the oesophagus.

Careful examination of the genitalia of both grouse and fowls has hitherto failed to show coccidiosis of these organs. Some investigators, however, have suggested that the eggs of fowls may be infected with Coccidian oöcysts and the young birds be born infected. Such does not appear to be the case with grouse and fowls that I have examined, but there is always the possibility of eggs becoming contaminated during their passage through the cloaca of the mother bird by Coccidian oöcysts sticking to the egg-shell. Unless suitable precautions are taken in such cases the young chick is hatched in contact with infected material and is in a suitable position to acquire the disease by the mouth during its first feed.

In coccidiosis of fowls the intestine is the chief seat of infection, but the liver is occasionally infected with *E. avium*, as in turkeys. In the coccidial disease very prevalent in some parts of America among turkeys and known as "blackhead," a large proportion of the birds suffer from coccidiosis of the liver, as well as of the intestine. In this case when the infection is fairly heavy, the liver shows a number of rounded, yellowish patches, which are separate at first, but later become confluent and form huge necrotic masses. This infectious enterohepatitis—as it has been called—is more marked in older turkeys than in turkey poults, and pathological changes and enlargement in the liver occur in nearly all the chronic cases. It has been stated that coccidiosis of the oviduct may occur in turkeys suffering from "blackhead," but so far the evidence in support of this view is somewhat meagre, the condition mentioned appearing to be rather uncommon.

Young turkey poults succumb to intestinal coccidiosis alone. The duodenum of the infected birds presents much the same appearance as that of the grouse, but in turkeys the caeca are often thickened and distended with pasty contents; while in the grouse the caeca often become thin-walled, due to great destruction of the lining epitherium.

A reflex of coccidiosis is seen in the blood of the infected grouse and fowls. These birds become markedly anæmic, and there is an alteration in the relative numbers of the blood elements, particularly of the leucocytes. Infected birds show an increase in the number of polymorphonuclear leucocytes compared with the number found in the blood of normal birds.

The rôle of various bacteria in coccidiosis may be noted. Many bacteria are always present in the alimentary tract, and so long as they are confined to the lumen thereof they are mostly harmless. But the Coccidia, when penetrating the epithelial cells of the intestines, may act as inoculating needles and admit bacteria into the tissues of the host with disastrous results.

## VI.—The Dissemination of Coccidiosis.

The various methods whereby coccidiosis is spread from bird to bird and from one estate to another have been investigated in the cases of infected grouse, pheasants, fowls and pigeons by the present writer, while other workers have mentioned the droppings as the only source of infection. Coccidiosis spreads with remarkable rapidity, and undoubtedly the faeces of infected birds are the chief source of contamination. The droppings gradually crumble into a fine dust, that is distributed in the main by the wind over considerable tracts of country. This dust contains numbers of oöcysts in all stages of development. Deposited as they are on the food plants of birds, such as grouse, they are easily ingested, and the parasite recommences its life-cycle in the new host.

Water also is an agent of infection. I have collected Coccidian oöcysts from the tarns at which grouse chicks drink, and have shown experimentally that even 40 days' exposure to the action of water does not kill the encysted parasite. Again, from the dew collected off the heather in Scotland, I have been easily able to recover oöcysts in practically their full maturity.

Rain has a great share in causing local contamination of both soil and water, the latter more especially. After heavy rain the dejecta of infected birds are dispersed and washed down to lower levels of land, where the contaminated water either forms pools or soaks into the soil.

Grouse that are infected have very fluid droppings, and it has been possible sometimes to track the birds through the snow by the trails left by them on their way to their drinking places. When it is remembered that young birds are far more susceptible to coccidiosis than older ones, the question of providing uncontaminated food and drink becomes of the utmost importance.

Again, it has been my experience to find adult birds that have become chronics. They are then veritable reservoirs of infection and a prolific source of danger to young and old birds alike, at all times of the year, and from year to year. I may mention here, as being of great economic importance, that fowls suffer from the same form of coccidiosis as the grouse and pheasant, and that infected hens used as foster-mothers have been definitely tracked as the instruments for the commencement of heavy epizootics. This has been particularly the case in dealing with outbreaks among pheasants. In such cases the remedy is obvious—the carrier of infection must be destroyed and the corpse must be burned and never buried. If burial is resorted to, the oöcysts (resistant forms of the parasite) are merely put into the soil with the carcase, and there is more trouble in store when the oöcysts reach the surface and a new epizootic breaks out, often with renewed vigour.

The mutual infection of such birds as turkeys, fowls and pigeons frequenting the same or neighbouring soiled grounds, even after the lapse of a year, should be mentioned here. It is discussed further in Section VIII. (pp. 91-94).

In Nature wind and rain are not the sole agents of dissemination of coccidiosis. There are numerous coprophagous flies, such as *Scatophaga stercoraria,* whose eggs and larvae develop in the droppings of infected birds. Such larvae and flies from grouse droppings have been most carefully examined by me, after taking every precaution to avoid external contamination of the bodies of the flies. Yet in the intestines of these flies and their larvae unchanged Coccidian oöcysts occurred, and they were also found in the dejecta of the flies voided during examination. Here, again, is a fruitful source and agent of infection on the moors, especially where there is a vigorous insect population.

To sum up, wind and rain are the most powerful agents in the dissemination of coccidiosis over tracts of country, and their action is aided by that of coprophagous and other flies found in the neighbourhood, infected droppings being the source of supply of the Coccidian cysts.

## VII.—Duration of Vitality of Coccidian Oöcysts.

The duration of vitality of the oöcysts and spores of *E. avium* is a matter of considerable practical importance. It is vital to the healthy development of young birds that they should not be raised on soil contaminated by their diseased predecessors, for after even considerable intervals such ground is still infected. With the object of aiding those engaged in the raising of young birds, I have made a series of experiments relating to the time during which the Coccidium can retain its vitality and power of infectivity under varying conditions.

Faeces from infected grouse were kept under different conditions approximating as far as possible to the natural ones, and the results carefully noted.

Coccidian oöcysts, with undifferentiated contents, were kept in water at about 20° C. Ordinarily the oöcysts develop sporocysts very rapidly—within two to three days. But in cysts kept in water a period of nine days elapsed before any development occurred. At the end of that period, a few oöcysts showed differentiated sporoblasts and still fewer showed four sporocysts. Two days later many more oöcysts contained sporocysts, and this progressive development continued for some days. Scarcely any signs of degeneration were seen until about the fortieth day, when some showed signs of gas bubbles in their interiors. Others, however, had completed their development, and the sporocysts, apparently unharmed, were in some cases set free into the liquid. By the fiftieth day all the öocysts had either matured or degenerated, and some of the sporocysts had begun to deteriorate.

When oöcysts were kept in much colder water I found that the development of sporocysts was retarded for a longer period. Further, very damp air has a similar effect to exposure in water.

When freshly voided soft grouse droppings, containing Coccidian oöcysts, are allowed to dry, the oöcysts in the surface layers rapidly develop sporocysts, the inner ones remaining unaffected.

Faeces kept *en masse* in dishes for as long as twelve months have retained the power of infecting birds, as I have been able to prove experimentally. Such material still contained undifferentiated oöcysts, while the outer layers mainly contained oöcysts with four sporocysts within them.

I now have infected faeces from young grouse received nearly two years ago. Recently some was spread into a thin layer and examined microscopically. Some undifferentiated oöcysts were seen, but four days later the oöcysts had nearly all developed four sporocysts, and so had retained their power of infectivity for nearly two years.

For experimental purposes, it was sometimes necessary to delay the development of sporocysts. This was easily done. The infected dejecta were transferred to a chamber kept at 10° C, having previously been kept at 15° C. Further development of oöcysts and sporocysts was thus retarded for a considerable time. Smaller changes of temperature also arrested the development of sporocysts, though the effect, naturally, was not so marked.

## VIII.—Some Preventive Measures and Suggestions for Treatment.

Inasmuch as the hosts of various pathogenic *Eimeria* are game birds little can be done in the way of direct treatment, though the same remark does not apply to domesticated or even "game" birds in captivity, as in pheasantries. The old saw that prevention is better than cure can, however, be realised to some extent. Even in epizootics among game birds it cannot be too strongly insisted upon that *all corpses should be burned and not buried*. Every buried bird is a new source of infection, and the polluted soil is distributed in many and unseen ways by earthworms, the round worms of the soil, carnivorous beetles, flies, moles, etc., so that the infection can be extended over a much wider area than was originally the case.

Again, in the case of pheasantries, in which havoc has been made by coccidiosis, it is as well to consider the direction of the prevailing winds and to place the new rearing pens in such a position that they are not windswept from the infected and fouled areas. This is not an easy matter in many cases, but should be observed wherever possible.

In dealing with coccidiosis in grouse, heather-burning is most efficacious in destroying oöcysts. Unfortunately heather is rather slow growing, and in consequence the remedy of heather burning is somewhat restricted in its area of application.

In the case of birds either partially or entirely under domesticated conditions (*e.g.*, fowls, hand-reared pheasants, grouse in captivity) great care should be taken to burn all infected droppings, and to prevent fouling of food and drink as far as possible. This can be achieved to a considerable extent by providing movable boards on which food and drink can be placed. These boards can be removed and thoroughly cleansed, while the pens should be so constructed that easy cleansing can be done daily. Lime-washing of all coops, etc., once a week is useful. Wherever possible healthy birds should be taken off the infected areas, and their coops, etc., placed in new positions as remote as possible from the former ones. The fouled soil should then be thickly treated with quicklime, which, after an interval of about a week, should be well dug into the soil, the latter being turned to a depth of at least 1½ feet. No birds should be raised on this land for at least a year. Where the infected run is relatively small, the top soil can be taken off to a depth of three or four inches and then burned. Even under this condition it is advisable to lime the soil.

It is useless to remove *heavily* infected stock to fresh places, for it is far better to destroy such birds and to place healthy stock on fresh, unpolluted ground. All other suspected birds should be isolated, and careful examination made of their excrement. In the case of epizootics among fowl chicks, one recent experience of mine was that of a case where over fifty birds died in a very short time of undoubted coccidiosis. Tracing the history of the remainder I found that they had come from broods reared by handsome hens obtained from an estate where, on enquiry, I found there had been heavy mortality the previous year. The foster-mothers were all carefully isolated, and examination made of their faeces from day to day. In a very few days, two fine hens were discovered whose dejecta showed daily crops of öocysts of *E. avium,* and I do not think there is any doubt that these two birds had become chronics and that their excrement had fouled the large grass run, and was the source of the trouble among the young birds. It may be added that the washings of the grass and clover in the run also yielded the oöcysts of the parasite when examined microscopically.

Fowls and turkeys should never be reared on grounds where much mortality from white diarrhoea or blackhead has been known to occur. If the original occupants of the land were turkeys, the oöcysts of *E. avium* producing "blackhead" are present in the soil, and when taken up with grit, food, or drink by fowls, produce the coccidiosis popularly known as "white diarrhoea," especially in young fowls. Conversely, fowl coccidiosis can be the source of infection of turkeys. Pigeons, feeding in infected fowl yards, themselves become infected, and whole cotes have been wiped out by coccidiosis thus acquired.

Wherever possible eggs should be disinfected before they are set for hatching. A solution of 90 to 95 per cent. alcohol (strong methylated spirit will do) has been recommended for wiping the eggs and found efficacious. Eggs should be carefully dried after the application.

With regard to treatment, it is almost impossible to give any advice in the case of wild birds. Any condition that tends to raise the vitality of the chicks is of service and should be used. Experiments are still in progress with regard to the treatment of infected birds in captivity.

Recently I have completed and extended some experiments on the treatment of avian coccidiosis by means of catechu. The procedure may be briefly indicated. Ten to fifteen grains of *crude* catechu are dissolved in one gallon of water. The dark sherry (or ale) coloured solution so obtained is administered to the birds as drinking water. The solution often darkens in the air, but its usefulness is not impaired thereby. The birds drink it with avidity and rapid improvement follows. The treatment is usually only necessary for about ten days. A solution containing ten grains of catechu per gallon is strong enough in most cases. The birds successfully treated were fowls, ducks, pigeons, hand-reared pheasants and grouse in captivity. The treatment, successfully determined by laboratory experiments, was tried on a small scale with infected birds on a small, covered, earth run, and on a grass run, and has been very successfully applied, at my suggestion, on several large poultry farms where heavy mortality through coccidiosis has occurred in previous years. Although the objection might be raised that catechu is merely an astringent, yet the great success of the treatment up to the present justifies me in bringing it before the notice of the scientific agricultural public.

During the course of my investigations experiments were made with other chemical substances. Ferrous sulphate (10 grains to the gallon), introduced into the drinking water of penned birds, was of service as tending to raise the general tone of vitality of the birds and so render them able to resist the action of the Coccidium to a greater extent. Sodium salicylate had a similar effect. These substances were also used in experiments directed towards the destruction of oöcysts and proved of some service. Infected faeces mixed with quick lime were rapidly caked, and hence the spread of the cysts was prevented to a great extent. The cysts were ultimately burst by the quick lime and so rendered innocuous. Gas lime and slaked lime are somewhat less efficacious. When sodium solicylate was used in the place of quicklime, the mixture of salicylate and faeces rapidly liquefied. A somewhat similar effect was produced by mixing ferrous sulphate with the faeces. Ultimately the oöcysts became wrinkled and cracked and the contents destroyed, but the process took much longer than in the case of quicklime.

Nitrate of soda acts on oöcysts after a lengthy exposure. It might be of service indirectly, for when scattered on the land it is a valuable stimulant to plant growth, and so might ensure a supply of healthy young vegetation.

It is of interest to note that grouse moors situated near the sea and swept by "salt" winds seem almost free from coccidiosis as well as other diseases of grouse, while inland moors are more susceptible to the ravages of disease.

## IX.—Some other Coccidia and their Hosts.

Much of the foregoing part of the paper has dealt with the life-history of *E. avium,* a Coccidium pathogenic to grouse, fowls and pigeons alike, and communicable from one to the other without alteration of its morphology. But *E. avium* is but one member of a fairly large group of parasites, enjoying a rather wide distribution.

It is not intended to attempt to give here a complete systematic survey of the Coccidia, but rather to indicate a few members of the group that appear to have specially interesting features or are of economic importance.

The parasite of coccidiosis in pheasants is very like *E. avium* of grouse, and has equally fatal effects.

The parasite of "blackhead" in turkeys is *E. avium*, and the disease can be transmitted to fowls. The *Amoeba meleagridis* of Smith, formerly said to be the causal agent of blackhead, is now generally considered to be a stage in the schizogony of *E. avium* in turkeys.

*E. pfeifferi* (Labbé) is allied to *E. avium,* and may be naturally pathogenic to pigeons. Apparently the same parasite occurs in the common English sparrows (house, tree and hedge varieties), the parasites being found sometimes in small, sometimes in large numbers. The organism is widely distributed among sparrows in England and a somewhat similar parasite infests sparrow-hawks, owls, chaffinches, greenfinches, thrushes, and blackbirds, though to a less extent. I believe that I have good evidence to show that the sparrow is the carrier of infection, and that the other bird hosts named acquire the oöcysts viâ their food, which becomes contaminated by the dejecta of sparrows. I hope to publish in greater detail on this subject in the near future.

Ducks and geese are liable to coccidiosis to some extent. Coccidiosis in quail has been reported in America.

Marine birds, such as gulls, guillemots, choughs, etc., are very liable to coccidiosis, but an *Eimeria* is not the causative agent of their complaint. Coccidia belonging to the genus *Diplospora* infest the alimentary tract of these birds. In the main the life-history of a *Diplospora* follows that of an *Eimeria* until sporogony is reached. When this occurs, two sporoblasts only are produced and develop into sporocysts. But within each sporocyst four sporozoites differentiate, so that in the end each oöcyst gives rise to eight sporozoites as in *Eimeria,* but the method whereby the result is attained is of a slightly different type.

*Eimeria stiedae* (Lindemann), variously known as *E. cuniculi, Coccidium oviforme,* and *C. perforans* is the pathogenic agent of heavy mortality among rabbits. Coccidiosis in rabbits is often both intestinal and hepatic. Although *E. stiedae* of rabbits resembles, in its morphology and life-history, *E. avium,* yet it is not the same parasite, as some American investigators have asserted. I have shown experimentally that if infected faeces of rabbits, containing many cysts of *E. stiedae* be fed to fowl chicks or young pigeons, the cysts merely pass through the alimentary tract of the birds practically unchanged, and the young birds do not develop coccidiosis.

A few cases of coccidiosis in man have been recorded. It is usually considered that the parasite is *E. stiedae,* derived from rabbits.

Coccidiosis may be a serious pest to cattle.

## X.—Concluding Remarks.

From the foregoing the importance of coccidiosis in relation to mortality among birds, and especially young birds, can be well estimated. In England, where owing to the development of motor traffic, the character of the country side is rapidly becoming altered, and the air is now polluted with the impalpable dust arising therefrom, the problem of "white diarrhœa" and other forms of coccidiosis seems to be becoming more acute. It is highly important, then, to take every precaution to prevent pollution of air or soil by Coccidian oöcysts, and to adopt any conditions which, by raising the general vitality of the birds, render them the better able to resist the onset of disease.

Preventive measures, so far as our present knowledge goes, have been discussed in Section VIII. (pp. 91-94). For the stamping out of the disease, at any rate among birds under confined conditions, the strictest possible attention must be given to the thorough cleanliness both of the young birds and their surroundings. It is probable that by such preventive measures the disappearance of coccidiosis may be attained in the future.

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# NOMENCLATURE OF ECONOMIC INSECTS.*

By

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IN 1908, I wrote a paper for the *Journal of Economic Biology*,[1] in which I suggested certain measurers for securing uniformity of nomenclature in economic entomology and gave reasons for doing so. I wish now to follow up the suggestions and to suggest a definite scheme whereby we may make an organised effort to secure this object, in view mainly of the fact that the International Congress meets next year at Oxford, and if this association can make the start and do the preliminary spade work, we may have a good solid basis of work to go on.

I may remind you that the nomenclature of our insects is constantly changing in uniformity with the rules of priority adopted by the body of zoologists.

This is being done in two ways:—

(1) Work on the types proves that certain genera and species, described we will say in the 19th. century, were really described by Linnaeus and others in the 18th, thereby altering the designation of that species, of that genus and of that family in some cases.

(2) The splitting of a large genera into smaller ones as more material accumulates and the groups are revised.

These changes are a natural result of researches into types and of our growing knowledge particularly of the fauna of places not hitherto well investigated; they are inevitable, and the progress of economic entomology depends as much upon this work as on any other. We have no quarrel with those who do this and who, rightly, conform to the international agreements on the question of nomenclature. But the changes entail immense confusion, and there are now arising a mass of new names for well-known pests which makes reference to the literature an impossibility unless we also keep up with the changes of nomenclature, which few of us can do. To workers, to teachers, to students, the growing confusion entails an

* Read before the Association of Economic Biologists, Birmingham Meeting, April 7th, 1911.

1 Priority and Practical Entomology. Journ. Econ. Biol., 1908, vol. iii, part iv.

intolerable burden, and it is made worse because there are no means of ensuring that all workers either do or do not adopt the changes.

In the case of *Coccidae*, for instance, *Dactylopius* was formerly used for the mealy bugs, but is now for the cochineal insects; a writer nowadays may use *Dactylopius* for either, and you have to find out which he means before you can follow him.

I will quote a number of instances:—

| | | |
|---|---|---|
| Lita solanella ... | = | Phthorimaea operculella. |
| Gelechia (part) ... | = | Sitotroga. |
| Bruchus obtectus ... | = | Acanthoscelides o. |
| „ lentis ... | = | Laria l. |
| „ chinensis ... | = | Pachymerus. |
| „ trifolii ... | = | Bruchidius. |
| Doryphora decemlineata | = | Leptinotarsa d. |
| Hypothenemus eruditus | = | Stephanoderes hispidulus. |
| Xyleborus pubescens ... | = | X. affinis. |
| Cecidomyia destructor ... | = | Mayetiola d. |
| * „ leguminicola | = | Dasyneura l. |
| Tephritis cerasi ... | = | Rhagoletis c. |
| Trypeta pomonella ... | = | „ p. |
| Anthomyia brassicae ... | = | Pegomyia b. |
| Phytoptus ... ... | = | Eriophyes. |
| Tomicus ... ... | = | Ips. |
| Scolytus ... ... | = | Eccoptogaster. |
| Epacromia dorsalis ... | = | E. tamulus. |
| Calandra ... ... | = | Sitophilus. |
| Hieroglyphus furcifer ... | = | H. banian. |
| Pachytylus ... ... | = | Locusta. |
| Acridium septemfasciata | = | A. purpuriferum. |
| Acridium (part) ... | = | Cyrtacanthacris. |
| Gryllotalpa ... ... | = | Curtilla = Scapteriscus. |
| Psocus ... ... | = | Atropos = Troctes. |
| Pentatoma ... ... | = | Cimex. |
| Cimex ... ... | = | Acanthia = Klinophilos = Clinocoris. |
| Pyrilla lycoides ... | = | Zamila aberrans. |
| *Macrosiphum pisi ... | = | Nectarophora destructor. |
| Lecanium ... ... | = | Coccus. |
| Dactylopius ... ... | = | Pseudococcus. |
| Coccus ... ... | = | Dactylopius. |
| Mytilaspis ... ... | = | Lepidosaphes. |
| Lecanium (part) ... | = | Saissetia. |
| Mytilaspis pomorum ... | = | Lepidosaphes ulmi. |
| „ citricola ... | = | „ beckii. |

| | | | |
|---|---|---|---|
| Heliothis armigera | ... | = | Chloridea obsoleta. |
| Agrotis (part) | ... | = | Euxoa. |
| Prodenia littoralis | ... | = | P. litura. |
| *Euplexia conducta | ... | = | Perigea capensis. |
| *Caradrina exigua | ... | = | Laphygma exigua. |
| Aletia xylina ... | ... | = | Alabama argillacea. |
| Leucania ... | ... | = | Cirphis = Heliophila. |
| *Nonagria ... | ... | = | Sesamia. |
| Orgyia ... | ... | = | Hemerocampa. |
| Euproctis ... | ... | = | Porthesia. |
| Porthetria ... | ... | = | Ocneria. |
| Liparis ... | ... | = | Psilura. |
| Protoparce carolina | ... | = | Phlegethontius sexta. |
| ,, celeus | ... | = | ,, quinquemaculata. |
| ,, convolvuli | ... | = | ,, c. = Herse c. |
| Sylepta multilinealis | ... | = | S. derogata. |
| Aegeria cucurbitae | ... | = | Melittia satyriniformis = M. ceto. |
| Grapholitha ... | ... | = | Enarmonia. |
| Cemiostomum coffeellum | | = | Leucoptera c. |

*Families:*—

| | | | |
|---|---|---|---|
| Acridiidae ... | ... | = | Locustidae. |
| Locustidae ... | ... | = | Phasgonuridae. |
| Gryllidae ... | ... | = | Achetidae. |
| Scolytidae ... | ... | = | Ipidae. |
| Bruchidae ... | ... | = | Lariidae. |
| Pentatomidae | ... | = | Cimicidae. |
| Cossidae ... | ... | = | Zeuzeridae. |
| Nemeobiidae ... | ... | = | Lemoniidae = Erycinidae. |
| Lymantriidae | ... | = | Liparidae. |
| Malacodermidae | ... | = | Cantharidae. |
| Trogositidae ... | ... | = | Temnochilidae = Ostomidae. |
| Parnidae ... | ... | = | Dryopidae. |
| Ptinidae ... | ... | = | Anobiidae. |
| Cistelidae ... | ... | = | Alleculidae. |

* These changes are, in my opinion, necessary.

What I propose is that we endeavour to meet this difficulty by making a standard catalogue of the important species with the name most in use in biologist literature definitely decided on, so that the further changes in nomenclature need not effect us, and so that the systematists and others may have one name to refer to which will cover the economic literature. I propose also that we definitely settle on the names of families, as unit divisions as it were.

The guiding principles I would suggest are as follows:—

1. In view of the constant changing of familiar names of pests, in accordance with the rules of priority, a permanent nomenclature is required for insects of economic importance on which there is a literature.

2. This nomenclature should be independent of and unaffected by the rules of priority.

3. It should be based on the name used in important biological literature, notably that which contains an account of the life-history, habits, and economic importance.

4. Genera in which there is a close uniformity of habits and life-history or which form a distinct class of pest shall, for this purpose, be retained whole and not be sub-divided. (Ex. *Lecanium, Dactylopius, Agrotis, Gryllotalpa*).

5. The constitution and names of families to be retained, the latter not being influenced by changes of nomenclature of type genera.

6. It is recognised that when a stable nomenclature shall be adopted by systematists, the possibility of unifying the economic and the systematic nomenclatures shall be considered.

7. If agreement cannot be obtained among economic entomologists it is hoped that all will at least use the double nomenclature, putting the Standard Economic with the systematic when they differ. (Ex. *Alabama* (Aletia) *argillacea* (xylina).

8. In the case of those pests of which an account is written for the first time, in an accessible publication, replacing notes or references only in an inaccessible one, the name used in the former, whether accurate at the time or not, shall be adopted. (Ex. *Synclera multilinealis* in *Ind. Mus. Notes* in 1890 gives way to *Sylepta derogata* in *Mem. Agric. Dept. India* in 1908).

9. The guiding principle is to make the existing and future biological literature accessible by adopting and making permanent the name under which it was written, and is not to perpetuate inviolate the author of a name or description as in the systematic literature.

10. Whenever possible the existing popular names in the English, French, and German languages shall also be recorded with the Standard Economic, with a view to fixing them.

Now to do this will involve a great deal of work by someone, and I have not come here to make suggestions which I am not prepared to carry out as far as I am able to. The easiest way to carry out this scheme seems to me to be:—

(1) To catalogue the species of insects, etc., which have a definite economic importance as affecting:—

(*a*) Crops.

(*b*) Forests.

(*c*) Domestic animals.

(*d*) Stored produce.

Recording the name under which these species are known in the important literature.

(2) To refer these catalogues to the workers in the subject in each country for their opinion and suggestion.

(3) To collate the suggestions and prepare a revised catalogue.

(4) To submit that at the next Annual Meeting, with a view to suggesting action at the International Congress of Entomology in 1912.

I suggest that this Association elect a Committee to carry this out, authorising the preparation of the catalogue, the preparation of a list of persons to whom it should be submitted, the printing of sufficient copies for that purpose, and the collation and preparation of a final catalogue to be submitted at the next annual meeting.

I have at present a card-catalogue of the more important species of crop pest derived from the existing literature; I do not pretend that this list is complete, but I think it could soon be made reasonably complete and ready for submission, if the members of the committee could revise it for this country and Europe, and could prepare a list of workers to whom we would submit it. The actual collation of their suggestions could be done fairly quickly, and I think the list could be prepared by next March. I am not clear as to how we can pay for printing and postage, which is the only expenditure required, but I hope that the Association can meet the difficulty.

This list would cover only the crop-pests, and I think we might find it possible to do this only; the question of doing it also for forest pests for instance is a large one, and I think we might consider how far that could be done or left to the Committee to do what they could.

So also for pests of stored produce and cattle; the former is easy, I think, and could be done quickly; the latter again requires consideration, as it is not quite clear at first sight where that would lead us to; it might lead us into insects carrying disease, and I am not sure that we could carry this all through in the time.

With regard to the crop-pest list, I do not suggest our listing all species attacking every plant of economic value; it would doubtless be useful, but I think we shall do well at first to try to keep out the unimportant pests; in a paper on the insects of the olive, Ribaga cites 63 species; of these I imagine only perhaps seven as being really important.

I hope I have made clear what I mean and, before proposing any definite resolution, I think that the question should be thoroughly discussed. I foresee many difficulties, but I think we can meet them, and I am convinced that we shall be undertaking a piece of work that will be of practical use, and which is, I consider, one that only this Association can, so far as this country is concerned, carry into effect.

## REVIEWS.

**Austen, E. E.**—A Handbook of the Tsetse-Flies (Genus *Glossina*). Pp. x + 110, 10 plts. and 24 figs. London: 1911. Published by the Trustees of the British Museum. Price 5s. 6d.

Detailed descriptions and accurate figures of those insects concerned in the dissemination of disease are yearly becoming more and more important to Colonial Medical Officers and others, and the present work will be welcomed by such officials in Tropical Africa, as a valuable aid in recognizing and accurately identifying the Tsetse-flies found in their districts.

The author informs us in his introduction that eight years have elapsed since the publication of his "Monograph of the Tsetse-Flies," which work contained descriptions and figures of seven species. At that time the connection between *Glossina palpalis* and Sleeping Sickness was not established, and practically nothing was known as to the habits of that particular species. Much progress has been made even in so short a space of time, but there is still a wide field for further investigation and observation.

In the "Handbook" before us fifteen species are treated of, two of which are new. We are no longer compelled to form our ideas of the Genus upon the life-history and habits of one particular species, as is evidenced by Mr. Austen's excellent chapters on the general characteristics and distribution, and the external characters of the Genus.

The Genus is divided into four Groups, viz., the *palpalis, morisitans, fusca,* and *brevipalpalis* Groups, and Tables for the determination of these and their included species are given. These are followed by detailed descriptions of each species, with remarks on the bionomics, distribution, and affinities and distinctive characters.

Under distribution we note the absence of any reference to Mr. S. A. Neave's paper on the distribution of *G. palpalis* (Journ. Econ. Biol., 1909, vol. iv).

The work is beautifully illustrated both by coloured plates and text figures.

We congratulate the author on the completion of an exceedingly useful and interesting piece of work, and our National Museum in publishing the same.

W. E. C.

**Miall, L. C.**—History of Biology. Pp. vii + 151, 10 figs. London: Watts and Co., 1911. Price 1s. net.

Professor Miall has written an interesting little work, and our only regret on laying it down is that there is not more of it. It is a masterpiece of succinctness, but we should have liked to know more.

After a brief introduction, he divides his work up into five periods, and reviews in each the chief characteristics and discoveries, incidently giving us various interesting biographical details of the leading workers. It is an admirable piece of work, serving as an introduction to a vast subject, and written in a delightfully fresh style.

W. E. C.

**Morgan, C. L.**—Animal Biology. Fourth ed., revised. Pp. viii + 416, 144 figs. London: Longmans, Green and Co., 1911. Price 8s. 6d.

Professor Morgan's text-book is too well known to require recommending, and the fact that it has become necessary to issue a revised edition of the fourth edition speaks itself for its retention by many teachers.

We note with satisfaction that the author has reintroduced from an earlier edition, chapters or sections dealing with the Codfish, the Cockroach, the Snail, the Liver-Fluke and the Tapeworm. The work still, however, lacks any account of so important a group of animals as Nematodes.

A new chapter on evolution and heredity has been introduced, which will serve as a useful introduction to the subject for the student.

In its new and revised form the work will no doubt enjoy as wide a circulation and popularity as its predecessors have each done.

W. E. C.

**Stevens, F. L., and J. G. Hall.**—Diseases of Economic Plants. Pp. x + 513, 203 figs. New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1910. Price 8s. 6d. net.

We are informed in the preface of this work that it is designed to meet the needs of "those who wish to recognize and treat disease, without the burden of long study as to their causes; and those who desire to study the etiology of diseases, and to become familiar with the parasites which are often the cause." In our opinion the authors have failed to meet either of these needs; nevertheless, they have produced an interesting and very useful little handbook.

The early chapters are devoted to a consideration of the historical side, the damage caused by plant diseases, the symptoms of disease, the prevention and cure of plant diseases, public plant sanitation, fungicides, spraying machinery, the costs of and profits from spraying, and soil disinfection.

The bulk of the work is devoted to short, indeed often very scrappy, descriptions of the diseases attacking special crops, and practical directions as to the remedial measures to be applied.

We cannot congratulate the authors on their attempt to make "popular" names derived from the scientific name of the genus of the fungus giving rise to the disease, a feature certainly out of place in a book of this character.

The illustrations are numerous and good.

W. E. C.

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THE

# JOURNAL OF ECONOMIC BIOLOGY.

## OBSERVATIONS ON *MARASMIUS OREADES* AND *CLITOCYBE GIGANTEA*, AS PARASITIC FUNGI CAUSING "FAIRY RINGS."

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WITH PLATES V, VI, AND VII, AND 7 TEXT FIGURES.

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### I.—INTRODUCTION.

DURING the last three years I have been watching the growth and gradual extension of numerous "fairy rings." All these rings have been formed by the fungus *Marasmius oreades*, with the exception of two particularly large ones, which are due to the fungus *Clitocybe gigantea*. I have taken measurements and made records of the annual extension of some of the *Marasmius oreades* rings, since they are in a field which is not used for grazing purposes, but I have not been able to do the same with those formed by *Clitocybe gigantea,* because any stakes used to mark boundaries always disappeared—no doubt trodden down by cattle.

"Fairy rings" have been noted from very early times, and have more often been the subject of rhyme and romance than of scientific investigation.

In the *Wild Garland,* by S. Waring (1837), the death of the grass was said to be due to the spawn of the fungus enveloping the roots so closely that absorption was prevented.

In 1846 Way[1] suggested that the zone of luxuriant grass was due to the valuable manuring of phosphoric acid, potash and sulphate of lime left by the fungus of the previous year, and he considered that the fungus might still grow on that same zone were it not for competition with the now vigorous grass.

In 1875 Gilbert[2] published a paper "On the Occurrence of Fairy Rings," and in 1883 Lawes, Gilbert and Warrington[2] published a paper entitled "Contribution to the Chemistry of Fairy Rings."

These gave the results of an investigation which was undertaken to determine the source of the nitrogen of the "Fairy Ring" fungi, which evidently were the cause of a natural rotation of crops. It was concluded that the source of the nitrogen was the organic nitrogen of the soil itself.

In 1898, in Australia, McAlpine[3] published a paper "On Fairy Rings and the Fairy Ring Puff-Ball." He gave a brief account of the "Fairy Rings" caused by a puff-ball, *Lycoperdon cyclicum,* and was successful in exterminating them by means of the application of a 10 per cent. solution of sulphate of iron, and also by means of a Bordeaux mixture (Copper sulphate 6 lbs., quick lime 4 lbs., and water 25 gallons).

In 1905 Fr. Thomas[4] published the results of his observations on the growth of a fairy ring caused by *Hydnum suaveolens.* He found the average yearly increase was about 22 cms., and from that calculated that the ring must have been 45 years old.

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[1] Way. On the Fairy Rings of Pastures illustrating the use of Inorganic Manures. Chem. Sect. Brit. Assoc., 1846.

[2] J. H. Gilbert. Note on the Occurrence of "Fairy Rings," 1875. Sir J. B. Lawes, J. H. Gilbert, and R. Warrington. Contribution to the Chemistry of "Fairy Rings," 1883. Rothamsted Memoirs, vol. v.

[3] D. McAlpine. Report on Fairy Rings, and the Fairy Ring Puff-Ball. Dept. of Agric., Victoria, 1898.

[4] Fr. Thomas. Die Wachstumsgeschwindigkeit eines Pilzkreises von *Hydnum suaveolens.* Scop. Ber. d. deutscher Bot., Ger., 1905, Bd. 23, p. 476.

In 1910 Massart[1] published a paper on "Fairy Rings," a summary of which was given in the *Journal of the Royal Microscopical Society*.

In this the sterility, as regards fungus growth of the ground enclosed by the ring, was noted, and also the fact that no fungi grew at the point of contact of two rings. From analogy with higher plants he argued that probably the mycelium secreted some poison fatal to further fungal growth, though not to the growth of higher plants.

From this review of the literature on the subject it will be seen that comparatively little is known about it. A satisfactory explanation as to why a "Fairy Ring" extends as a ring and not as a disc is still required; as yet no one knows how the fungus first infects the soil, and there appears to be only one good record of the yearly increase in radius of a ring. The rings caused by *Marasmius oreades* have received most attention from other workers, but hitherto the life-history of the fungus does not seem to have been worked out nor the problem of parasitism involved sufficiently investigated.

"Fairy Rings" often continue to extend for many years, possibly in some cases for fifty or even a hundred years. Sometimes they disappear unexpectedly and thus put an end to observations on yearly extension. Sometimes, too, segments of rings, after disappearing for a year or eighteen months, reappear again. It is obvious, therefore, that an investigation upon "Fairy Rings" must of necessity be incomplete unless extended over a long period of years.

## II.—"Fairy Rings" formed by Marasmius oreades.

Observations were first made in the middle of June, 1908; the rings were then very conspicuous because of the dead grass on them (fig. A *b*), and because of the zone of rich dark green grass just within the ring of dead grass (fig. A *a*). These two zones have always been commented upon whenever fairy rings have been under discussion, but outside the ring of dead grass another ring (fig. A *c*) of dark green grass can invariably be seen also showing more vigorous growth than that of the field generally. This band is at first only an inch or so in width, but as the summer advances it extends, and towards the end of September it is broader than either the inner ring of dark green grass or the ring of dead grass. This

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[1] Massart. Ann. Jard. Bot. Buitenzog. supp. 3, pt. 2, 1910, pp. 583 6; also J. R. M. S., 1910, p. 749.

outer ring of dark green grass has perhaps hitherto escaped notice because, by the time it attains a width of several inches, the grass of the field generally with advancing summer and autumn has also

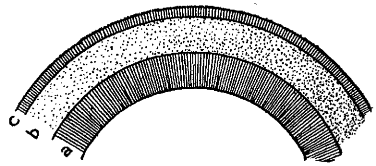


Fig. A.—Diagram showing the different zones of a "Fairy Ring."
*a*. Inner dark green grass zone. *b*. Dead grass zone.
*c*. Outer dark green grass zone.

deepened in colour, and does not present the contrast noticeable in connection with the luxuriant inner dark green band in spring and early summer.

The soil underneath these three zones, when examined, was found to be well penetrated by mycelium to a depth of about a foot, and under the ring of dead grass this was especially noticeable, since dense wefts of fungus hyphae among particles of soil could easily be discerned by the naked eye (Pl. v, fig. 5). In sods from nearer the centre of the ring than the inner dark green band of grass, there is no trace of fungus mycelium, other than that which is to be found in soil taken at random from any part of the field, for it is impossible to find turf quite free from fungus hyphae. The grasses killed by the fungus include *Holcus lanatus, Anthoxanthum odoratum, Agrostis stolonifer, Avena flavescens, Lolium perenne, Poa pratensis, Dactylus glomerata,* and with these were *Trifolium repens* and *Plantago lanceolata.*

During late summer and autumn the dead grass of the middle ring (fig. A *b*) is gradually replaced by dark green grass similar to that on the inner (fig. A *a*) and outer zones (fig. A *c*). This apparent revival is due to rhizomes from neighbouring living grass plants, for all rhizomes and roots connected with the surface dead grass are quite killed by the fungus and become thoroughly rotten. This also applies to the plaintain and clover associated with the grass, but docks and sorrels seem able to withstand the fungus.

During December, January and February, these fairy rings are hardly visible, but the soil contains just as much mycelium as at any other time of the year, only with this difference—the mycelium in the outer dark green grass zone has increased very much in quantity; here it has become so dense that it forms a white felt-work which is very readily seen at the surface of the ground round the bases of the living grass shoots, and when plucked away looks like fragments of cotton wool.[1] About February or March, or later if the season is not mild, the grass on this zone begins to flag and finally dies, and what was the outer dark green grass zone of one year becomes the dead grass ring of the succeeding year.[2]

The dense white weft of mycelium on the surface remains visible for several months in fields of mowing grass, but it always disappears in summer in grazed fields or on lawns, no doubt because of the dry atmosphere to which it is subjected under exposed conditions. If the weather is mild and damp, about a month after the dying down of the

Fig. B.—A sod from a *Marasmius oreades* ring showing the fungi springing up on the dead grass zone. × ⅔.

grass, the sporophores of the fungus begin to appear and these are always most numerous were the surface mycelial weft is densest.

## 1.—The Influence of the Mycelium on the Absorption of Water by the Soil.

A very striking feature in connection with Fairy Rings is the influence the fungus mycelium has on the absorption of water by the soil. The earliest notice of this known to the author is in a small

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1 This mycelium when pressed against litmus paper has an acid reaction.

2 This year (1911) the grass on one ring was dead in January; this was probably due to the very mild weather during December favouring the growth of the fungus.

unscientific publication, called *The Wild Garland*, by S. Waring, 1837.

Gilbert and Lawes[1] also drew attention to this fact. They pointed out that under the dead grass zone (fig. A *b*) the soil was very dry and could only be wetted with difficulty. This is characteristic of both the *Marasmius oreades* and *Clitocybe gigantea* rings. The soil under the dead grass, even after continuous rain for a week or more, is always drier and paler in colour than that of the field generally; the soil under the inner and outer dark green grass zones (figs. A and C) is also always considerably drier than that well without or well within the ring, but it is not quite so impervious to moisture as the soil under the middle dead grass band (fig. A *b*).

Often in summer, after continuous rain for two or three days, sods from the dead grass zone, when examined, have been found to be quite pale in colour and only slightly damp compared with the saturated sods from well outside the ring; and after heavy rain, lasting nearly twenty-four hours, the moisture has not even penetrated the surface, whereas the soil at a distance of two feet either way has been damp to a depth of four inches or more.

This rendering of the substratum impervious to moisture seems not an uncommon characteristic of fungi. Falck[2] notes a similar phenomenon in connection with *Coprinus stercorarius*, and it is a matter of common observation that blotting paper grown over with *Mucor* can only with difficulty be wetted. Infected soil, even after sterilization, still offers resistance to the percolation of water.

In order to find some explanation of this phenomenon a series of experiments were made in which the rate of flow of water through infected and uninfected soil was tested in tree-pots. The pots held 60 cc. of soil.

In the first experiment a potful of ordinary uninfected soil was placed in each of three saucers; over the first was poured an extract, made by pounding up an equal quantity of infected soil with sufficient water to just cover it and leaving for twenty-four hours before straining; over the second saucer was poured an equal quantity of tap water; both lots of soil were well stirred up and made into a thick paste; the third lot was left untouched. These three lots of soil were left for two days to dry at a temperature of 40° C, after which the soil of each lot was pounded up in a mortar and replaced in a pot; equal quantities of water (7 cc. at a time) were then poured over the

[1] Gilbert and Lawes. *l. c.*

[2] Falck. Beitr. z. Biol. d. Pflanzen., 1902, Bd. viii. Die Cultur des Oidien und ihre Rückführung in die höhere Fruchtform bei den Basidiomycetes.

three pots simultaneously, and the time taken by the water to soak into the soil was noted. In each case the first 14 cc. of water sank rapidly, taking one and a half minutes to soak in, but afterwards the water took from a half to six minutes longer to soak into the soil which had been treated with soil extract or with water. This experiment was repeated three times with similar results.

It is known that solutions of organic matter, especially those which have little oil in them, have a surface tension below that of water[1]; hence it might perhaps have been inferred that the water of infected soil, since it undoubtedly contains some organic matter (enzymes, etc.) in solution, had a surface tension appreciably lower than that of soil-water generally. If this were so, less water would be raised from the subsoil, and water would percolate only slowly from the surface during rain, and in consequence infected soil would be drier than uninfected soil. But the above experiment seems to prove that the amount of organic matter in solution in infected soil is insufficient to lower the surface tension to a degree which would account for its dryness out in the field.

The following experiment has led to the conclusion that the dryness of the infected soil is due to the air entangled in the meshes of mycelium. Pots of infected and uninfected soil which had been made as damp as possible by pouring water over them, were placed in beakers which nearly fitted them, and the very narrow space (a few millimetres only) between the beaker and the pot was filled with water. These beakers containing the pots were placed in a water bath and boiled in order to drive all the air out of the soil and render it thoroughly water-logged. After boiling for one and a half hours the pots were taken out of the beakers, and the contents of the beakers were poured over the soil in the pots; when this had drained away the pots were watered simultaneously with equal quantities of water, and no difference was observed between the rate of flow through infected and uninfected soil.

Since the rate of flow of water through infected soil which has merely been subjected to steam in a steam sterilizer for three hours is still very slow compared with the rate through uninfected soil, sterilization, unlike actual boiling in water, evidently does not displace all the air which is entangled in the meshes of the mycelium; hence it may be concluded that the resistance infected soil offers to the passage of water through it, is due to the air entangled within the meshes of the mycelial network occupying the spaces between the particles of soil.

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[1] A. D. Hall. The Soil, 1904, p. 78.

## 2.—Measurements.

The following table gives measurements of the annual extension of three rings during four successive years, but it shows little save the fact that the rings increase in width and diameter annually.

RADIAL INCREASE ALONG SEVERAL DIFFERENT RADII.

| | RADIUS OF RING | RADIAL INCREASE ALONG SEVERAL DIFFERENT RADII. | | | |
|---|---|---|---|---|---|
| | 1907. | 1908. | 1909. | 1910. | 1911. |
| Ring A. | 2 ft. 7½ inches | 6 inches | 7 inches | This ring had disappeared except one patch 14 inches in diameter. | The patch had become a disc 26½ inches in diameter. |
| | | 6 ,, | 9 ,, | | |
| Ring B. | 4 ft. 4½ inches | 6 inches | 9½ inches | 10½ inches | 13½ inches. |
| | | 4 ,, | 9 ,, | 9¼ ,, | Was not visible; near is a well manured tree, planted 1909. |
| | | 6 ,, | 7½ ,, | 13 ,, | |
| | | 3 ,, | was not visible | 10½ ,, | 13½ inches. |
| Ring C. Part of a ring only. | | | 6 inches | 9 inches. | 13½ inches. |
| | | | 7 ,, | 11 ,, | 13 ,, |
| | | | 5 ,, | 11 ,, | 13 ,, |

The inner dark green grass zone does not always coincide with the dead grass zone of the previous year. It may also cover part of that of the year before; hence the effect of the fungus may even last three years. Also the whole of the dead grass zone does not always recover within one year and become covered by dark green grass; this year, 1911, in which the spring and early summer were very dry, in ring C the dead grass zone of last year was still visible to some extent and was separated from this year's zone of dead grass by a zone of living grass six inches wide. From the fourth measurement of ring B it will be seen that it is quite possible for the mycelium to grow outwards, and only occasionally be present in the soil in sufficient quantity to kill the grass. Other instances besides this have been observed; so that frequently the dead grass zone of one year is separated from that of a following year by an inch or two of grass which has never died down.

### 3.—The Colour of the Grass.

The grass of most pasture fields is not of a uniform green colour, but lighter and darker green patches give a mottled effect. Sods from many dark green patches taken from fields known to be free from "Fairy Rings" were examined with the idea that perhaps the richness of some of the grass might be due to mycelium being more abundant in those areas; but such is not the case. A little mycelium is nearly always present, but no more than is to be found in turf generally; and in the autumn, when fungus sporophores are plentiful in pastures, these are just as frequently found on the lighter as on the darker patches of turf. Nevertheless, the presence of fungus mycelium in turf seems associated in many instances with a darker green colour of the grass, even when it apparently does no harm, as in the case of *Tricholoma personatum* and others.

This dark colour of the grass may perhaps be correlated with the presence of ammonia in some combined form in the soil, for it is well known that many fungi produce ammonia as the result of their metabolic activity. Some experiments by Hutchinson and Millar[1] have shown that the percentages of nitrogen in the mixed herbage from the Rothamsted grass plots were greater when the manure used was mixed with ammonium salt or even consisted of ammonium salt alone, than when sodium nitrate was used, and the grass containing the higher percentage of nitrogen was a darker green.

### 4.—The Relation of the Fungus to the Grass.

The connection between the fungus and the grass is best seen by studying the grass plants on the outer edge of the outer dark green grass zone. Here the first attack of the fungus on the grass plant can be readily observed. The presence of the fungus mycelium among the roots is indicated by a brownish discolouration of the delicate root tips or of the external cortical tissue of the root just above this region, and by loss of symmetry of the root-hairs (Pl. v, fig. 6).

At this stage very few hyphae are present, and these are only loosely applied to the roots, but with an increase of mycelium the discolouration becomes more pronounced, and at the same time the root-hairs and young tissue are seen well invested and freely penetrated by hyphae. One or more hyphae can be seen traversing the length of a root-hair (Pl. v, fig. 6).

[1] H. B. Hutchinson and N. H. J. Millar. Jour. of Agri. Science, 1909, vol. iii, pt. 2. Direct assimilation of ammonium salts by plants.

If grass plants be taken from an infected area during January or February and be compared with those from an uninfected area, no difference between them will be apparent except at the roots; if these are washed free from soil the rusty colour of the infected roots will readily distinguish them from the pale healthy uninfected roots. The roots of infected plants also have a tendency to branch more than uninfected ones, and the root-tips, instead of having the usual slender tapering form, are frequently stunted. The rusty colour of infected roots is due to the great mass of dead and dying rootlets and rhizomes. The fungus penetrates and entirely consumes the soft parenchymatous parts of these structures and leaves untouched the tough axial stele, though this in time becomes rotten, and can be crumbled between the fingers, micro-organisms having no doubt continued the destructive work of the fungus (Pl. vi, figs. 11 and 12). The fungus finally enters the grass leaves, but not until they are almost dead; it is difficult to find any fungus in merely flagging leaves, though the leaf-sheaths of these show hyphae everywhere except in the vascular bundles (Pl. v, fig. 7). When the leaves are dead, mycelium abounds in all the tissues except the vascular bundles. Dead grass leaves from plants entirely unconnected with Fairy Rings always have fungus hyphae in them, but the mycelium belonging to *Marasmius oreades* cannot very well be mistaken for that normally found in such leaves, since the hyphae seen in the latter are generally of much larger diameter and usually fewer in number.

## 5.—Experiments on Grass Roots, with an Extract of Infected Soil.

From experiments made to see the influence of a water-extract of infected soil on normal grass roots, it appears that the fungus excretes some substance which has a fatal action on root-tips. In these experiments soil taken from below a dead grass zone was well stirred up with water to the consistency of a thin paste, and the roots of an uninfected grass plant were left in this for twenty-four hours. A similar experiment was arranged, but the mixture was boiled before the roots were placed in the liquid, and a third experiment using ordinary uninfected soil was kept as a control. To each extract a few drops of toluol was added as an antiseptic. These experiments were repeated many times, and always most of the root-tips which had remained for twenty-four hours in the extract of infected soil[1] turned brown or black (Pl. vi, fig. 13); the effect was

[1] The extract of infected soil is neutral to litmus paper, whereas the extract of uninfected soil is faintly alkaline.

less marked when the extract was boiled first, since then only a slight browning appeared. Young roots also turned black at the tips when allowed to remain twenty-four hours in an extract of infected soil from which all soil and fungus mycelium had been filtered off. In the control the root-tips remained unchanged and uninjured. In five similar experiments using a weak extract[1] of fungus sporophores instead of the soil extract the results were identical.

A similar extract of sporophores of *Agaricus campestris* discoloured and doubtless killed the young roots of grass, but the discolouration here differed from that produced by the extract of *Marasmius oreades,* in that it was a general discolouration, the whole root being blackened, more especially in the region of the stele as well as the root-tip. The discolouration was not so intense as that produced by the extract of *Marasmius oreades.*

These experiments, together with observations made on roots which have just been attacked, suggest that the fungus first excretes some toxic substance which kills the sensitive root and root-hairs, then penetrates and consumes the tissue of the root-apex, finally attacking the cortical tissue of the older parts of the root. The more copious branching which seems to accompany infected roots, is no doubt due to a constant effort on the part of the plant to make up for the continuous destruction of root-apices which goes on in the presence of the fungus.

## 6.—Proteolytic Enzymes.

Since a crop of grass is always more abundant and deeper in colour after the application of nitrogenous manure, the fungus sporophores and the soil containing mycelium were tested to see if perchance they contained any proteolytic enzymes, by the help of which they could easily assimilate nitrogenous compounds.

An extract of sporophores was obtained by pounding in a mortar 10 gms. of shredded sporophores with 20 cc. of water; this was left for twenty-four hours and strained and filtered before using.

The extract of infected soil was obtained by pounding up the soil with sufficient water to cover it, and after leaving for twenty-four hours, filtering before using. Toluol was used as an antiseptic, and the experiments were repeated several times.

In testing for peptase 0.5 gm. of vegetable fibrin was digested with 40 or 50 cc. of the extract of sporophores or of infected soil at a temperature of 40° C.; after twenty-four hours there was a great

[1] This extract was made by pounding up four or five grams of the sporophores with 100 cc. of water.

contrast between the size of the granules in the experiment tube and those in the control tubes of boiled extract; the diminution in size of the fibrin granules was more conspicuous in the case of the sporophore extract than with the soil extract.

In testing for ereptase 0.5 gm. of Witté peptone was digested with 45 cc. of sporophore extract. After twenty-four hours the liquid in the experiment tube gave a tryptophane reaction with Bromine water, whereas the control tube containing boiled extract gave no reaction.

These results showed quite clearly that an active peptonizing enzyme (peptase), which digests vegetable fibrin, and also a peptolytic enzyme (ereptase) which digests Witté peptone, were produced by the fungus.

These enzymes are no doubt the cause of the stimulating action of the fungus when it first attacks the grass plants, since by means of them it breaks up organic compounds of the soil which would otherwise be unavailable for the grass. Some of these no doubt the fungus itself assimilates, while others are absorbed by the grass roots.

### 7.—The Effect of the Mycelium on the Grass.

The amount of mycelium at first is not excessive, so that its destructive influence is more than compensated for by the extra supply of nitrogenous food material it renders available for the grass plant.

This stimulating effect of the fungus on the grass shows above ground in the darker colouration and improved growth of the grass just outside the dead grass ring. During the summer, autumn, and winter the mycelium increases in this outer zone until in early spring it becomes so copious that the grass can no longer withstand its attack, and so flags and finally dies. Then for three months or more a zone of dead grass is apparent, while crops of fungus sporophores appear on this zone at intervals for five or six months.

It has been mentioned that the fungus mycelium renders its substratum somewhat impervious to moisture; it might be thought that this aided the fungus in its attack upon the grass by enfeebling the latter and rendering it a more easy victim; but this does not appear to be the case, for prodding and watering a section of a fairy ring does not have the effect of delaying the death of the infected grass. Moreover, at the period when the grass is rapidly dying the soil has been found to be quite moist, and was known to have been so for weeks previously; also, the soil under the dark grass just within the dead ring always contains very much less moisture than that of the field generally, and it cannot be said that lack of moisture enfeebles the plants of this zone.

After the fungus has destroyed the ring of grass, and even while still producing crops of sporophores, the grass on the ring appears to be recovering, but this recovery is due to the penetration of rhizomes from outside the dead grass ring. If the season is damp this takes place fairly rapidly, though excessive rainfall is unfavourable to the production of sporophores.

The luxuriance of the dark green grass which succeeds on the same zone, the dead grass of the previous year, may thus be said to be due partly to the activity of the fungus mycelium, which is still living but yet dying down since the substratum is almost unfit for its use, partly to the soil, from which for several months of the previous year no food substances were removed by grass, but especially to the nitrogenous manure contributed by the now dead mycelium, a manure which consists in part of the decaying mycelium itself and in part of easily assimilable products formed by it from dead roots in the soil.

## 8.—Intersecting Rings.

In pastures where fairy rings are numerous, instances often occur of one ring meeting and then gradually intersecting another (fig. C), in which case the rings are exterminated between the points of intersection so that in time one large ring is formed. Instances of this kind support the view that the fungus in some way renders the substratum on which it has been growing unfit for its further growth. Hence, the meeting of two rings must cause their extermination

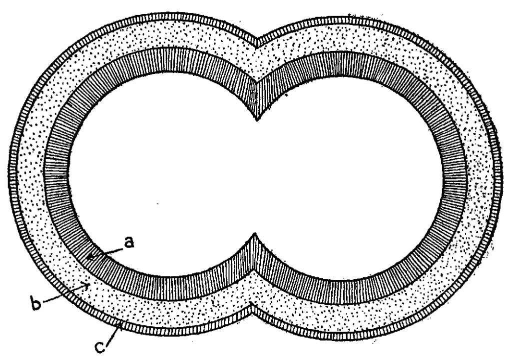


Fig. C.—Diagram showing the intersection of two rings. *a*. Inner dark green grass zone. *b*. Dead grass zone. *c*. Outer dark green grass zone.

between the places of interesection; also, the fact that the fairy ring extends as a ring and not as a disc, adds support to this hypothesis. This view receives further support from some culture experiments.

The culture medium was made either of a gelatine preparation (10 gms. gel., 3 gms. glucose, 2½ gms. peptone, 2½ gms. meat extract, and 100 cc. water), or of bread soaked with grass and horse-dung decoction, mixed with an equal volume of the gelatine preparation. This was placed in a shallow glass vessel in the centre of which was fixed a large watch glass. The latter contained equal parts of the culture medium used and a similar culture medium on which the fungus mycelium had been growing for twelve months and had become too exhausted for further growth to continue. This apparatus was placed in a glass jar and covered up with a glass disc. Every precaution was taken to obtain sterile apparatus and culture mediums. The cultures were infected by hyphae about 1.5 cms. long, taken from the middle of a stripe of a sporophore and placed so that half lay on the culture medium in the shallow glass vessel and the other half on the medium in the watch glass. Many of these cultures were utterly ruined by *Penicillium*, but several remained pure, and these answered expectations, for the growth of the mycelium over the medium in the watch glass was very poor and slow compared with that over the medium outside.

This seems to imply that some substance is excreted by the fungus which renders the substratum harmful to itself, rather than that it gradually uses up some essential food material, for in the watch glass there was at least half of the medium suitable for the growth of the fungus and there was no apparent reason for the fungus not flourishing on that.

It has been suggested that the fungus can only attack enfeebled grass plants, because it is well known that "Fairy Rings" of *Marasmius oreades* only grow on poor pastures. Now, if the outer zone of dark green grass were left out of consideration, this might be offered as an explanation of intersecting rings becoming exterminated between the places of intersection, since the mycelium of the touching dead grass zones would have to attack the vigorous plants of the inner dark green grass zones before being able to extend within the touching rings.

But it will be seen from figure C that before the mycelium of one ring can extend into another it would have to pass the stimulated plants of the outer dark green grass zone, and since these outer zones, as well as the other zones between the points of intersection of the rings, become gradually exterminated, there seems little doubt that the extermination is caused by some toxic excretion of the mycelium of one ring rendering the substratum unfit for the growth of the mycelium from the outer ring.

During this investigation segments of "Fairy Rings" have disappeared if for any reason the ground in their immediate neighbourhood was much interfered with, as for instance by the planting of fruit trees in soil especially prepared for them. Under these circumstances the grass became very strong and vigorous near the trees, because the manuring of the soil stimulated it to increased growth and evidently brought about in some way the obliteration of parts of Fairy Rings.

This evidence supports the view that the grass if vigorous will resist infection by the fungus and offers some explanation of Fairy Rings usually only appearing on poor pastures.

It may perhaps be as well to point out that the manured grass just referred to resists infection because of its vigorous growth, but the luxuriant grass on the inner dark green grass zone resists infection because the mycelium growing in the same substratum is dying down owing to its own toxic excretions.

There are many instances known of one fairy ring growing within a much larger one, so that although soil in which mycelium has been growing will not allow of the growth of a second crop immediately following the first, in time it evidently recovers its normal state and the fungus once started continues its destructive work.

Many attempts have been made to start fairy rings on lawns and fields by using sods taken from rings of *Clitocybe gigantea* and *Marasmius oreades,* and by spores from the sporophores of these fungi, but without success. This has been a matter of surprise since two lawns laid with turf from a field containing rings of *Marasmius oreades* were kept under continuous observation, and although segments of rings appeared and grew for three years they did not flourish, and in the fourth summer, a very damp one, they never appeared at all.

It seems probable that sometimes the numerous fairy rings which occur in pastures have arisen from the breaking up of others; that is, the small segments of a large ring have formed the starting places of other rings, such as are represented in fig. D, and possibly this may be the reason why sections of rings are more frequent than whole rings (fig. D). For instance, it will be seen from the table of measurements given on page 118, that ring D, after being quite conspicuous in 1908 and 1909, disappeared in 1910, except for one round patch fourteen inches in diameter; the ring did not appear again in 1911, but the patch increased in size apparently in nearly all directions.

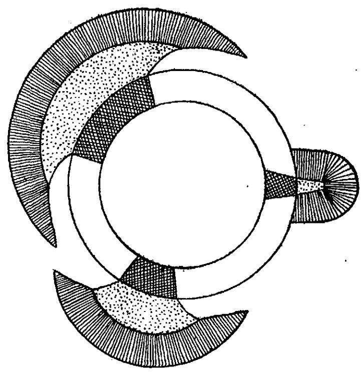

Fig. D.—The diagram represents the position of the dead grass zone of a ring in three successive years, and shows how segments of one ring might have the appearance, after several years, of belonging to entirely different rings; the patches of dead grass which were formed in the same year are shaded similarly.

Gilbert and Lawes[1] mention that rings on which few sporophores grow soon break up. This has also been observed during the present investigation, but the breaking up of rings is not directly connected with the absence of fruit bodies, except in so far as this implies a poor development of the fungus mycelium, and evidently unfavourable conditions for growth.

The mycelium of the rings is perennial, so the extension of a ring is not interfered with in the slightest degree if its sporophores are continually plucked as they appear, and the ring is thus kept free from any spore fall for a whole season. Fairy rings on lawns where constant cutting always interferes with the fruiting of the fungus, have been known to persist for years and cause considerable annoyance to owners uninterested in mycological studies.

## III.—Fairy Rings formed by Clitocybe gigantea.

The Fairy Rings formed by the fungus *Clitocybe gigantea* (fig. E) agree in a general way with those just described. They appear about a fortnight or three weeks later, and their fruiting season is not so extended since their large sporophores (figs. F and G) are only to be found for about three or four weeks at the end of September and during October.

[1] Gilbert and Lawes. *l.c.*

The dead grass zone does not recover nearly so quickly from this fungus as from *Marasmius oreades,* in fact one ring in a field on the side of a hill at Sutton Coldfield, Warwickshire, was bare of grass for more than a whole year.

In the same neighbourhood there is a remarkably large oval ring incomplete only on the side where it meets a hedge. In 1910 the long diameter of this ring was about 168 feet and the narrow one

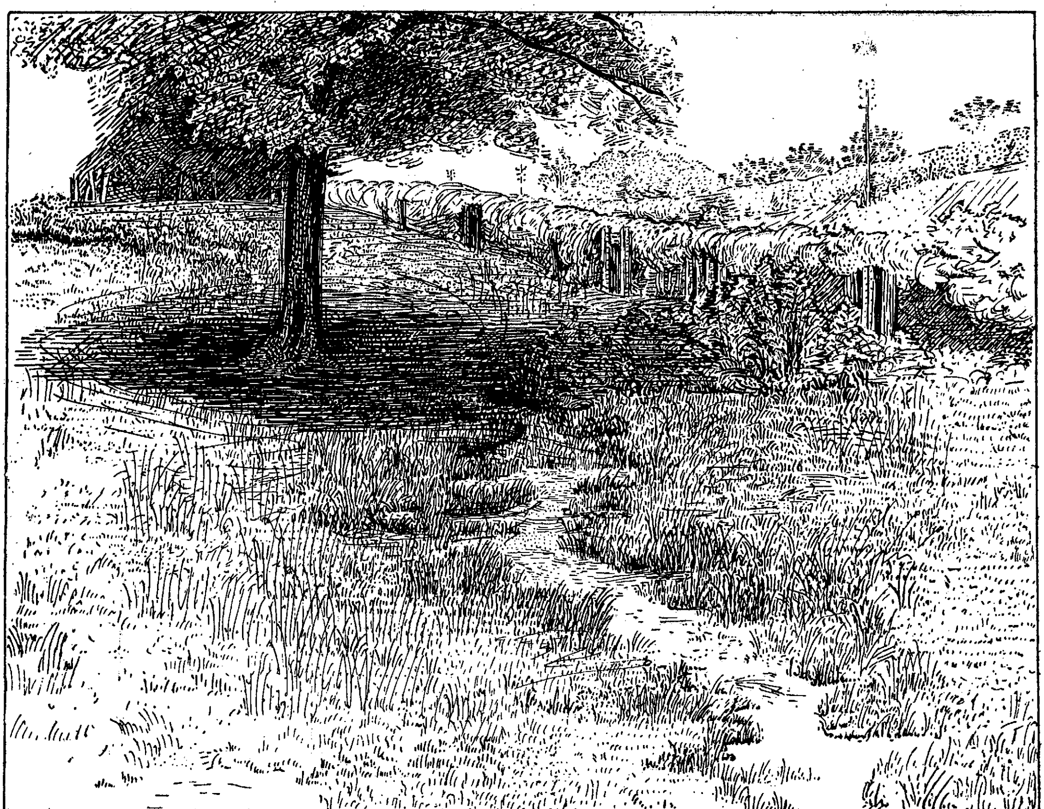

Fig. E.—The general appearance of part of a *Clitocybe gigantea* ring in 1911; the light streak in the field is due to the zone of dead grass.

84 feet. In 1908 the width of the dead grass zone measured in some parts fourteen inches, in others twenty-nine inches, and again thirty-one inches, but the general average lay somewhere between eighteen and twenty inches; the average did not increase during the next three years. Although the form of this ring is oval, the outline is extremely sinuous (Pl. vii); evidently the rate of growth of the fungus mycelium in this field is very variable.

This ring, at a distance of about half a mile when covered with dead grass, has the appearance of a well-trodden field footpath (fig. E). It has been known for at least seventeen years, and is said to have arisen from the intersection of two rings, although no trace of this is to be seen now.

Another very large, nearly perfect, circular ring, due also to *Clitocybe gigantea*, with a diameter of 48 feet, has shown two bare zones for two successive years—an inner one separated by a foot of grass from the usual outer one. There was also a slight trace of this inner bare ring in the large ring just referred to, but this showed only for a few weeks in the summer.

Fig. F.—Underside of the sporophore of *Clitocybe gigantea*. × $\frac{1}{6}$.

Very few sporophores have appeared on these rings except at long intervals. In September, 1906, there was an exceedingly fine show, and the rings were so conspicuous that the white line of sporophores (Pl. vii) formed a remarkable object even when seen a mile away; many of the sporophores were more than half a yard in diameter (figs. F and G); even the dark green grass zone within the dead ring can in summer and autumn be distinguished three-quarters of a mile away.

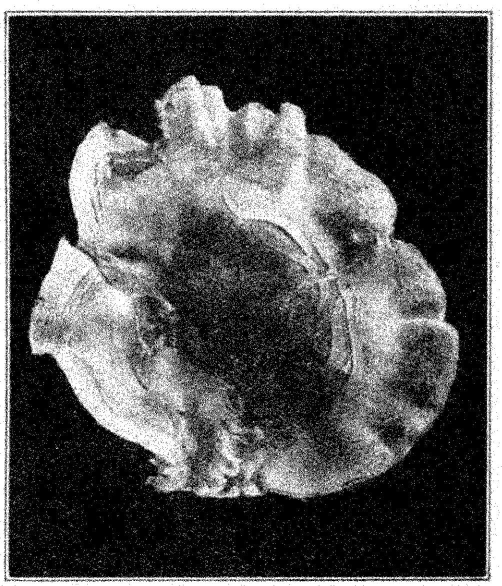

Fig. G.—Upper surface of the pilius of *Clitocyle gigantea*. × ⅛.

## IV.—The Germination of the Spores of Fairy Ring Fungi.

### 1.—*Marasmius oreades.*

The spores of *Marasmius oreades* are white oval bodies, which germinate very slowly. They measure 6 × 4 $\mu$ (Pl. v, fig. 3). They germinate after three days in a weak decoction of grass and in a nutrient solution of gelatine.[1] They will not germinate in tap water, or horse dung decoction, or in malt extract. Spores will germinate if kept dry for five or six days, but those six months old or more will not germinate.

It may be that these spores in order to germinate easily need to pass through the alimentary canal of some animal, such as a sheep, bird, or slug. Slugs (*Arion subfuscus*) have frequently been seen in the dead grass of a fairy ring, and many sporophores have been found partly devoured by slugs, but these creatures kept in captivity could never be induced to touch them.

The mycelium formed from the spores after one month breaks up into oidia, which germinate immediately and produce another mycelium consisting of a tangle of very fine hyphae, with frequent H-and clamp-connections.

[1] 10 gms. gelatine, 3 gms. glucose, 2½ gms. peptone, 2½ gms. meat extract, and 100 cc. water.

The mycelium from large cultures made on bread soaked with the gelatine nutrient solution, or malt extract, or on sterilized grass, showed a massing together of the hyphae into long branching strands or thin rhizomorphs similar to those which are to be seen in mycelium taken from infected soil (Pl. v, figs. 4 and 5).

None of these cultures ever produced sporophores, nor did the mycelium when buried in turf out in the open fields ever infect grass.

### 2.—*Clitocybe gigantea.*

The spores of *Clitocybe gigantea* are oval, and when seen in a mass have a very rich cream colour. They measure $6 \times 4\frac{1}{2}\,\mu$. They germinate within twenty-four hours in horse-dung decoction; they will also germinate in a strong decoction of grass, but then they require at least two days. After four days in horse-dung decoction all the spores were found to have germinated, while only 50 per cent. had germinated in the grass decoction. They will not germinate in tap water.

The germ tube arises at any position of the spore, and when only three or four times the length of the spore it begins to branch (Pl. v, figs. 8 and 9). Sometimes two germ tubes are produced. The mycelium produced from spores which have germinated in hanging drops after three weeks or a month begins to form large oidia (Pl. v, fig. 1), which germinate immediately (Pl. v, fig 2). Good cultures of mycelium were obtained upon bread soaked with horse-dung decoction and a few drops of grass decoction; this mycelium when examined, after growing for three months, bore a great resemblance to that of *Marasmius oreades* in having the hyphae of very narrow diameter, but there were no rhizomorphs. Occasionally enlargements of the hyphae, which might indicate the beginning of clamydospore formation, were met with (Pl. v, fig. 10); similar enlargements were found in mycelium permeating a sod taken from a fairy ring in December. No sporophores ever appeared on these cultures.

The sporophores of both *Marasmius oreades* and *Clitocybe gigantea* are edible.

## V.—SUMMARY.

1. *Marasmius oreades,* a common fairy ring fungus, is a parasite on grass.

2. It attacks young roots, kills them by means of some toxic secretion, and gradually destroys the whole plant except the steles.

3. The fungus is stimulating at first, and the grass assumes a darker colour owing to better nitrogenous nutrition due to the proteolytic enzymes of the fungus acting on the dead roots, hence there can be distinguished a zone of dark green grass outside the dead grass zone as well as inside that zone.

4. Infected soil is very impervious to moisture owing to air entangled within the meshes of the mycelium.

5. The fungus secretes some substance toxic to itself and so is not able to grow in the same soil three years in succession; during the second year the fungus dies off and the grass gains the upper hand and flourishes owing to the increased nitrogenous food available; hence, the "fairy ring" of rich luxuriant grass within the dead grass zone.

6. The secretion of this toxic substance accounts for the disappearance of rings between the places of intersection when fairy rings meet.

7. Fairy rings formed by the fungus *Clitocybe gigantea* agree in general with those formed by *Marasmius oreades*.

In conclusion, I wish to thank Professor West for the helpful criticism he has given me during the course of this work, and also Professor Buller, to whom I am indebted both for the subject of this investigation and for a number of suggestions made in the course of it.

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## EXPLANATION OF PLATES V, VI, AND VII.

Illustrating Dr. Jessie S. Bayliss' paper on "Observations on *Marasmius oreades* and *Clitocybe gigantea* as Parasitic Fungi causing 'Fairy Rings.'"

### PLATE V.

Fig. 1.—Hyphae of *Clitocybe gigantea* breaking up into oidia. × 800.

Fig. 2.—Oidia of *Clitocybe gigantea* germinating. × 800.

Fig. 3.—Spores of *Marasmius oreades*, one is germinating. × 800.

Fig. 4.—Mycelium from a culture of *Marasmius oreades* showing massing hyphae (rhizomorphs). × 170.

Fig. 5.—Soil infected by *Marasmius oreades*. × 170.

Fig. 6.—A root tip of grass attacked by *Marasmius oreades*, showing the first stage. The shaded parts indicate a brown colouration caused by a toxic secretion of the fungus. × 800.

Fig. 7.—Mycelium of *Marasmius oreades* entering a leaf sheath. × 800.

Fig. 8.—Mycelium produced from the spore of *Clitocybe gigantea* after four days' germination. × 800.

Fig. 9.—Germinating spores of *Clitocybe gigantea*. × 800.

Fig. 10.—Structure probably representing the first stage in Chlamydospore formation of *Clitocybe gigantea*.

## PLATE VI.

Fig. 11.—Root of grass with cortex partly consumed by *Marasmius oreades*. × 800.

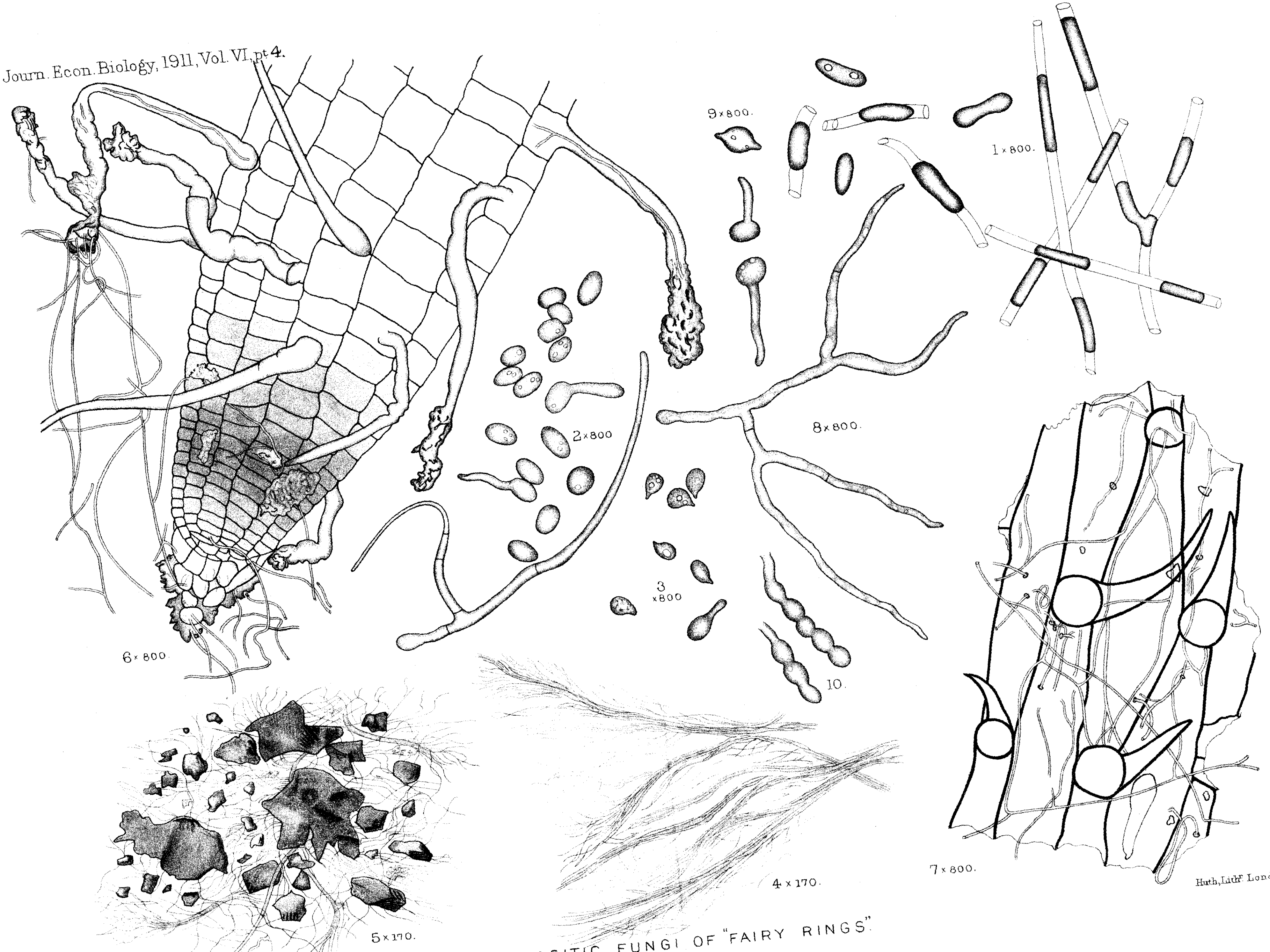
Fig. 12.—Root of grass with nearly all the cortex consumed by *Marasmius oreades*.

Fig. 13.—Roots whose tips have turned black owing to the toxic action of a watery extract of soil infected by *Marasmius oreades*.

## PLATE VII.

Fig. 14.—The general appearance of part of a *Clitocybe gigantea* ring in September, 1906. Many of the sporophores measured more than half a yard in diameter.

Journ. Econ. Biology, 1911, Vol. VI, pt 4.




PARASITIC FUNGI OF "FAIRY RINGS".

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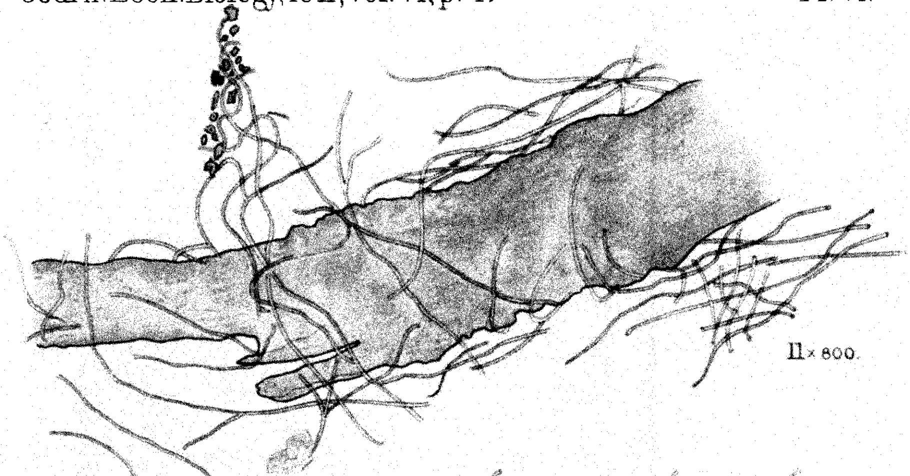

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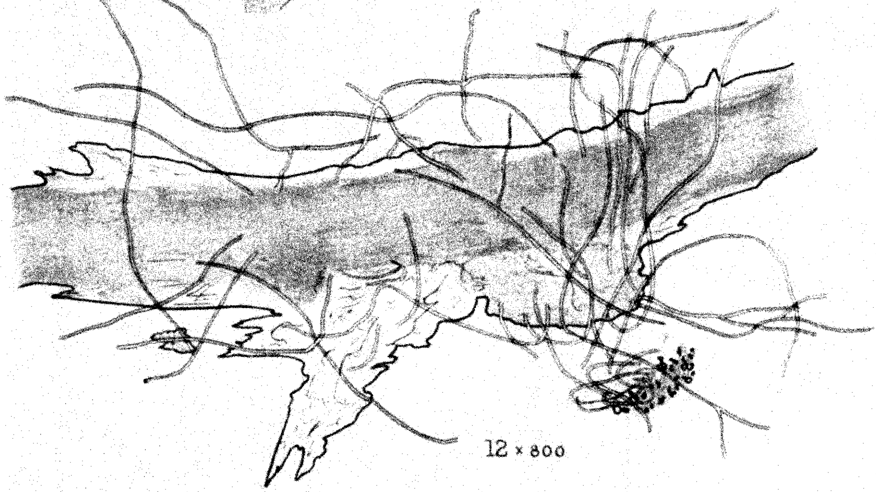

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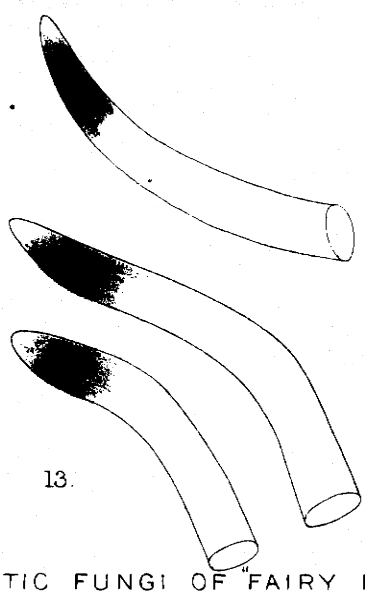

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PARASITIC FUNGI OF "FAIRY RINGS."

PARASITIC FUNGI OF "FAIRY RINGS.

# THE OCCURRENCE OF *NECROBIA* AND *DERMESTES* IN COTTON BALES.

BY

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WITH 4 FIGURES.

TOWARDS the latter end of May, 1910, some samples of cotton matted by the cocoons and infested with the active larvae and beetles of *Necrobia rufipes,* De Geer, were forwarded to the University with the information that all the bales of that portion of a consignment of Egyptian Cotton distributed to Belfast were affected in this manner to a depth of six or eight inches from the covering (fig. 1). From the carnivorous habits of this species, and from the absence of all but mature larvae, it was obvious that the insects were not feeding upon and multiplying within the cotton, but that they had merely invaded it for the purpose of pupation. The discovery that another portion of the same consignment was similarly attacked supported the idea that the bales had become contaminated while in the hold during the voyage from Alexandria, and all doubt upon this point was removed when further investigations revealed that the cargo of the vessel, besides cotton and sundry merchandise, consisted of skins, rags, bones, and dried blood. This year a very similar case of invasion of cotton bales by *Necrobia* larvae attracted attention, and again the source of infection proved to be the bones, dried blood, and such like materials carried by the steamer transporting the cotton.

That larvae of *Dermestes,* if afforded an opportunity, may in like manner seek to pupate in cotton was made evident by the receipt of a sample badly infested with mature larvae and pupae of *Dermestes vulpinus,* Fab., and *D. frischi,* Kug. It transpired that the larvae had penetrated beneath the surface of the bales just as in the previous cases. As this species pupates without spinning any cocoon, the cotton in this instance was not matted together, but on the other hand the workers handled it with great aversion and complained of the very objectionable smell. This particular consignment had been associated during transit from Alexandria with some 700 bags of bones.

Extended enquiries failed to elicit any further instances of the occurrence of *Necrobia* or *Dermestes* under such circumstances as the foregoing. As similar cases may occur from time to time, and give

Fig. 1.—Cotton matted by the paperlike cocoons of *Necrobia rufipes*. Also showing beetles which have emerged. Natural size.

not a little anxiety to those concerned, it seems advisable to refer to the matter at greater length and to include some particulars as to the life-history and habits of these beetles.

## NECROBIA.

The genus *Necrobia* belongs to a family of beetles, the *Cleridae,* the members of which are carnivorous in the larval state, usually preying upon the larvae of various other insects. The three European species of *Necrobia,* small brightly coloured beetles, with strongly clavate antennae and four-jointed tarsi (fig. 2), are very familiar to coleopterists, and as a result of commerce have become practically cosmopolitan.

In *Necrobia ruficollis*, Fab., which proved instrumental in saving the life of the celebrated Latreille during the French Revolution, a fact commemorated in the appellation *Necrobia,* the head and part of the elytra are shining blue, the base of the elytra, the thorax and the legs, bright red. The precise means of subsistence of the larva, usually found in association with skins, bones and other animal matter, is uncertain, as Perris (1) has shown that it may prey upon the blow-fly larvae present rather than upon the animal substances

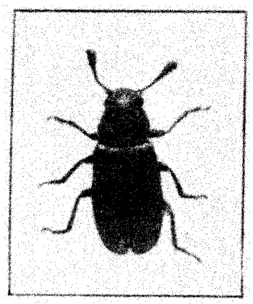

Fig. 2.—*Necrobia rufipes.* × 4.

themselves. He also made the interesting observation that the larvae pupated within the empty pupa cases of the blow-flies, constructing no cocoon with the exception of a little white material employed to close up the opening. Westwood's observations (2) suggest that it is capable of subsisting on the larva of *Dermestes*.

A couple of specimens of *N. ruficollis* were found in one of the samples of infested cotton, but since it is possible that they normally pupate within the cast skins or pupa cases of other insects it is unlikely that their larvae are of such importance in this connection as those of the next species.

The head, thorax, and elytra of *Necrobia rufipes*, De Geer (fig. 2), are entirely shining blue; the legs and base of antennae red. Length, one-sixth of an inch. The larva (fig. 3) is a slender active grub, with a small elongate brown head, brown prothorax, the other segments greyish white, with peculiar violet brown mottlings on the dorsal surface of each, and bearing thinly scattered setae. The last segment bears dorsally a strongly chitinised brown sclerite, which is elevated into two short, blunt, hooklike processes. Pupation seems to always take place within a perfectly white cocoon of paperlike texture, and it is by adhering to this during its formation that the cotton becomes matted together.

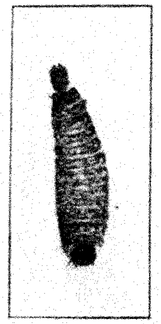

Fig. 3.—Larva of *Necrobia rufipes*. × 4.

There is no doubt that the larva can subsist entirely upon dead animal matter, for in America this species is known to dealers in dried meats as the Red-legged Ham Beetle or "paper worm," and its habits in this connection have been investigated by Dr. Howard (3). The larvae, after a rapid growth at the expense of the fatty tissues of the ham, "either gnaw into the muscle of the ham or occasionally eat into a neighbouring *beam*," there forming their paperlike cocoons. Usually found in the vicinity of skins, carcases, old bones and such other animal matter, it is just possible that in such situations this beetle may subsist by preference upon the other carnivorous larvae which feed on these substances.

*Necrobia violacea,* Linn., an entirely blue species, with dark legs, does not occur so commonly as the other two, but has a similar habitat. I did not at any time find specimens of this species in the cotton.

## DERMESTES.

Many members of the family *Dermestidae* enjoy wide notoriety in consequence of the frequent and severe depredations wrought upon furs and hides, food stuffs and fabrics by their voracious larvae. *Dermestes vulpinus,* Fab., one of the most destructive of these beetles, seems capable of subsisting in the larval state upon most animal substances, and a cargo of cork even has been destroyed by its agency. It is a dusky, oval insect, closely covered with white hairs on the ventral surface (fig. 4, *c*). The well known dark brown hairy larva (fig 4, *a*), when fully grown, pupates within the last larval skin, which the perfectly white pupa (fig. 4, *b*) partially or entirely forsakes through a slit along the head and dorsal surface.

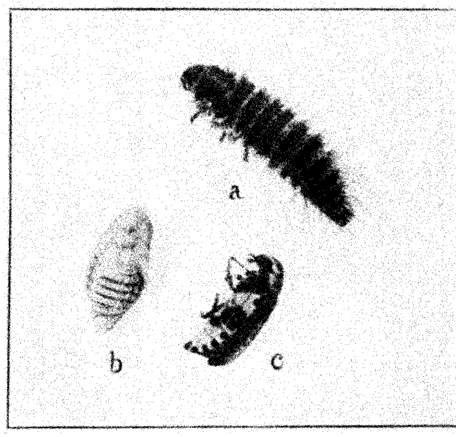


Fig. 4.—*Dermestes vulpinus*. *a*. Larva *b*. Pupa. *c*. Imago. All × 2.

Specimens of *Dermestes frischi*, Kug., a very closely allied, but less commonly occurring species, formed about a third of the adult individuals secured from the sample of infested cotton.

That cotton in the vicinity of material infested by *Necrobia* and *Dermestes* should be invaded by the fully grown larvae of these beetles is not surprising, as it is their habit to bury themselves away before pupating. The meshes of the jute or canvas wrapping of the bales can offer but slight impediment to them, as they are known to penetrate into woody and even, in the case of *Dermestes,* into bony substances. Moreover the bales are usually somewhat torn and gaping about the edges and elsewhere.

Though their presence may be disconcerting, these beetles are never likely to cause serious damage in such cases as the foregoing, as they do not appear to penetrate further than some seven or eight inches into the bale, but the sorting out of the infected material is of course a necessity. These consignments were always handled with a considerable amount of aversion by the workers, and where the *Dermestes* larvae were present they experienced a very objectionable smell. Hence it is clearly advisable to avoid the juxta-position, during transit and storage, of cotton, and of skins, hides, dried blood, or other animal products capable of harbouring such insects as *Dermestes* and *Necrobia*.

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# ON THE LOCOMOTION AND LENGTH OF LIFE OF THE YOUNG OF *PULVINARIA VITIS* VAR. *RIBESIAE*, SIGN.

By

WALTER E. COLLINGE, M.Sc., FL S., F.E.S.

In the June issue of the *Journal of Economic Entomology*,[1] Mr. H. J. Quayle has an interesting paper on locomotion of certain young scale insects. At the time of its publication I was carrying out experiments myself on the subject, and as some of these confirm Mr. Quayle's conclusions, and other interesting facts have been brought out, of economic importance, they are described here in detail.

The species experimented with was the White Woolly Currant Scale (*Pulvinaria vitis* var. *ribesiae*, Sign.). The life-history is well known, having been described in various works on economic entomology, and need not be entered into here.

My first experiment was made by placing six newly-hatched scales on three separate sheets of smooth white paper, each measuring 72 × 42 inches. Previous experiments had shown that the scales invariably travelled towards the light, the papers were therefore placed on the laboratory bench facing the window, in a temperature of 78° F. The young scales were placed at the side of the paper furtherest from the light, and the distance travelled was marked off each half hour for two hours, and then carefully measured.

The second experiment was a repetition of the first in a temperature of 82°, and a third was tried in 84°.

The results are tabulated below.

RATE OF TRAVEL ON SMOOTH PAPER.

| Exp. No. | Date. | Time. | Temp. | Distance each ½ hour. | Total. |
|---|---|---|---|---|---|
| 1a | June 19, 1911 | 10-30—12-30 p.m. | 78° F. | 20, 19, 20, 15 | 74 |
| 1b | „ 19, 1911 | 11-30—1-30 p.m. | 78° F. | 20, 20, 19, 16 | 75=75·1 inches |
| 1c | „ 19, 1911 | 2—4 p.m. | 78° F. | 20, 21, 20, 16 | 77 |
| 2a | June 21, 1911 | 10-30—12-30 p.m. | 82° F. | 21, 19, 19, 17 | 76 |
| 2b | „ 21, 1911 | 11-30—1-30 p.m. | 82° F. | 22, 21, 18, 16 | 77=76·1 inches |
| 2c | „ 21, 1911 | 2—4 p.m. | 82° F. | 20, 20, 19, 17 | 76 |
| 3a | June 28, 1911 | 10-30—12-30 p.m. | 84° F. | 24, 23, 22, 18 | 87 |
| 3b | „ 28, 1911 | 2—4 p.m. | 84° F. | 26, 24, 23, 20 | 93=91 inches |
| 3c | „ 28, 1911 | 2—4 p.m. | 84° F. | 25, 24, 24, 20 | 93 |

[1] 1911, vol. iv, pp. 301-306.

A further series of experiments were made, using a sheet of glass instead of the smooth paper. As the results were practically the same as those tabulated above, the actual figures are unnecessary.

Finally, three series in different temperatures were made on the laboratory bench. This has an oiled teak top, and the surface is, of course, considerably rougher than either the paper or glass.

The procedure adopted was similar to that recorded above, and the results obtained are interesting as the surface more nearly resembled the actual natural conditions than in the case of either the glass or the paper.

RATE OF TRAVEL ON TEAK BOARDS.

| Exp. No. | Date. | Time. | Temp. | Distance each ½ hour. | Total. |
|---|---|---|---|---|---|
| 4a | June 29, 1911 | 2—4 p.m. | 78·5° F. | 19, 18* | 37 |
| 4b | „ 29, 1911 | 2—4 p.m. | 78·5° F. | 20, 18, 16, 12 | 66 = 51 inches |
| 4c | „ 29, 1911 | 2—4 p.m. | 78·5° F. | 18, 18, 6, 8 | 50 |
| 5a | July 3, 1911 | 2-30—4-30 p.m. | 83° F. | 18, 17, 18, 10 | 63 |
| 5b | „ 3, 1911 | 2-30—4-30 p.m. | 83° F. | 18* | 18=44·1 inches |
| 5c | „ 3, 1911 | 2-30—4-30 p.m. | 83° F. | 16, 18, 18* | 52 |
| 6a | July 12, 1911 | 2-30—4-30 p.m. | 94° F. | 18, 18, 16, 14 | 66 |
| 6b | „ 12, 1911 | 2-30—4-30 p.m. | 94° F. | 19, 6, 12, 10 | 47=55·2 inches |
| 6c | „ 12, 1911 | 2-30—4-30 p.m. | 94° F. | 18, 5, 15, 16 | 54 |

* Specimens died.

In another case I placed some 60 to 70 newly-hatched Currant Scale on a sheet of white cardboard and exposed them to a temperature of 100° to 102° F.; they slowly dispersed over the board, and at the end of three and a half hours were fairly well scattered over an area of about two square feet. I then turned the board over. Examined four hours later nineteen of the scales had made their way on to the upper surface; sixteen hours later, quite fifty were on the upper surface exposed to a temperature of 102°, a few had fallen off the under surface and a few were dead.

Other experiments similar to those recorded by Mr. Quayle were tried, with very similar results, with this exception that I was unable to get a temperature any higher than 107° F.

Mr. Quayle[1] states that young examples of the Black Scale (*Saissetia oleae,* Bern.) died at a temperature of 84° F. "Experi-

[1] Journ. Econ. Entom., 1911, vol. iv, p. 305.

ments," he states, "relating to the effect of high temperature on young black scales showed that it is an important factor in the causes of death. Several hundred young black scales were liberated on white cardboard in the sun with a temperature of 94° to 100°; at the end of two hours they were unharmed by the heat. A similar experiment is recorded with a temperature of 106° to 110°. At 106° the scales were lively, but as the temperatures increased, they moved more slowly, and at 110° almost all movement ceased, although a two hours' exposure did not kill them.

Several hundred just emerged black scales liberated on soil with a temperature of 108° to 110° were active for about one hour, but at the end of that period some were dead, and at the end of one and a half hours nearly all had been killed. A check lot in the shade were not affected. A large number of young placed upon a board with a temperature of 118°, all died in five minutes. Scales exposed in sun on soil when temperature was 119° to 122° died within fifteen minutes. Under similar conditions, with the temperature of 130°, death resulted in five minutes. A check lot in the shade were not affected."

The distances travelled by *P. vitis* v. *ribesiae* are considerably shorter than those reported by Mr. Quayle, *e.g.*, on smooth paper; in two hours the Black Scale (*Saissetia oleae,* Bern.), at a temperature of 73.5° F., travelled a distance of 71.5 inches; at 80°, 76.5 inches; at 83°, 123.33 inches; and at 90°, 151.33 inches. The Red Scale (*Chrysomphalus aurantii,* Mask.) at 66° travelled 31.12 inches, and at 91°, 111 inches. The Purple Scale (*Lepidosaphes beckii,* Newm.) at 62°, 19.16 inches; at 68°, 32.87 inches; and at 89°, 111 inches.

Temperature undoubtedly plays a very important part in the rate and distance of travel.

On looking through a number of the leading works on the Coccidae I have been unable to find any reference as to the length of time the larvae will live when separated from their food plant. As the subject is one of considerable economic importance, the following observations may prove useful and interesting.

On July 6th I received a cutting from a Black Currant bush badly attacked with the White Woolly Currant Scale (*Pulvinaria vitis* var. *ribesiae,* Sign.). On the afternoon of the same day large numbers of the orange-red coloured larvae were noticed dispersing over the laboratory bench, some two hundred of which invaded a cardboard box.

On examining this box on July 15th quite half of the specimens were still alive and active. The dead specimens were taken out, and the living ones allowed to remain. Examined again on July 18th seventy were still alive. Further examinations on the 20th resulted in finding twenty alive, on the 22nd twelve, on the 24th ten, and seven on the 25th, three of which died on the 26th, having existed for practically three weeks without any food and in a temperature of nearly 105° F., being on a bench in the window which received the full sunlight from 9 a.m. to 6 p.m.

Whether the larvae of other species are capable of existing for so long a period without food I cannot say, but the fact that an appreciable percentage of the original two hundred existed for a fortnight suggests great possibilities in the way of distribution of this insect.

The results obtained may be summarised as follows:—

1. On smooth white paper or glass surface the larva travelled nearly 8 feet in a period of two hours in a temperature between 78°-84° F.

2. On a teak boarded surface in the same length of time, at a slightly higher temperature the rate of progress was just over four feet in two hours.

3. In all cases the insects travelled in the direction of the light, and when placed in semi-darkness, they made their way towards the light.

4. The larvae continued to live in a temperature of up to 105° F., but higher than that the rate of mortality was great.

5. Three larvae lived in a temperature of 105°, without any food, for a period of 20 days.

## REVIEWS.

**Calman, W. T.**—The Life of Crustacea. Pp. xvi + 289, 32 plts. and 85 figs. London: Methuen and Co., Ltd., 1911. Price 6s.

A work dealing in a semi-popular manner with the natural history of the Crustacea, fills a gap in such literature that has long been apparent.

All students of the Crustacea are now familiar with Dr. Calman's admirable volume on this Class in Lankester's *Treatise on Zoology*, but something less technical was desirable for another class of readers, that dwelt more particularly upon the habits, modes of life, and the various problems suggested by a study of these animals in relation to their environment.

Dr. Calman's volume fully meets this want, and the scope and method of treatment are both excellent. Treating first with the lobster as a type of the Class, the author passes on to a consideration of the classification and metamorphoses. This latter subject is very fully and clearly dealt with and well illustrated. Following this are chapters upon the crustacea of the seashore, of the deep sea, pelagic floating crustacea, the crustacea of fresh waters—an unusually interesting one. Subsequent chapters deal with the crustacea of the land, such as land crabs, land hermits, and wood-lice, crustacea as parasites and messmates, crustacea in relation to man, and crustacea of the past. A useful appendix on methods of collecting and preserving crustacea and some notes on books concludes a most fascinating volume.

Dr. Calman's work has none of the loose "popular" writing, common in so many recent natural history works, at the same time he avoids the more technical side, thereby making his book most interesting and readable.

The illustrations are all capital, the thirty-two half-tone plates being especially good.

The work is one we can heartily recommend, and we feel sure it will enlist a wide range of readers.

W. E. C.

**Howard, L. O.**—The House Fly—Disease Carrier. An account of its dangerous activities and of the means of destroying it. Pp. xix + 312, 1 plt. and 40 figs. New York: Frederick A. Stokes Company, 1911. Price $1.60 net.

Careful scientific investigations have now fully established the fact that the common house-fly is a dangerous pest which distributes the germs of typhoid and other diseases. In this book the Chief of the U.S. Bureau of Entomology sets forth complete information about the fly.

No one is better qualified than Dr. Howard for such a task. As he points out, within the last two years, articles relating to the so-called house-fly in connection with its disease-carrying possibilities have been published literally by the thousand, and this interest, perhaps having its origin in the United States, has spread to nearly all parts of the civilized world, and yet in no one of these published articles is the whole story told. No one can find in condensed and convenient shape the general information he desires in regard to this insect.

The present work is not intended to be a scientific monograph; it is simply an attempt to tell in a simple and lucid manner what is known about the subjects indicated in the title.

After describing the nature of the common house-fly, its habits and methods of breeding, he proves his case against it as a carrier of disease, and goes on to what will be the most interesting section to most readers—that on remedies and preventive measures. He considers screening, fly traps and various poisons, repellants, and the treatment of breeding places. A special point is made of the possibilities of action by communities, with suggestions as to organization, publicity, interesting the children, and the work of Boards of Health.

The extermination of the house-fly is much to be desired as a means to public health, but it can only be accomplished by the widest publicity and a full understanding of the subject.

Dr. Howard has produced an admirable little book, full of interest and wise counsel. We should like to see a copy in the hands of every Public Health Department in the country, and in the hands of all intelligent citizens.

W. E. C.

**Nuttall, G. H. F., and others.**—Ticks: A Monograph of the Ixodoided. Pt. II. Pp. xix + 244, plts. iv-vii, and 202 text figs. Bibliography of the Ixodoidea. Pp. vi + 68. Cambridge: University Press, 1911. Price 12s. and 6s. net.

We welcome the second part of this valuable monograph. Part i, issued in 1908, dealt with the *Argasidae,* and the present part treats of Superfamily *Ixodoidea* and the Family *Ixodidae.*

The part is divided into two sections, the first of which gives a historical review relating to classification, synonymy and literature, and a series of exceedingly useful descriptions of the different generic characters, illustrated by figures, together with an explanation of the terms and signs used.

Section II. deals with the genus *Ixodes,* Latr. Here are most useful keys for the determination of the males, females, nymphs and larvae of the different species, followed by specific descriptions of valid species of the genus, and of their varieties and sub-species. It would be impossible to speak too highly of the care and thoroughness that has been bestowed upon this portion of the work. Nothing seems to have been lost sight of, and throughout all structural details are fully illustrated.

A list of the condemned and doubtful species of *Ixodes,* including their synonymy and literature, follows, and must prove of the greatest value to all students. It has undoubtedly entailed an enormous amount of work, in which careful discrimination and sound judgment have played an important part, as also the notes on doubtful species of *Ixodes.*

Dr. Nuttall contributes a series of most interesting notes on the biology of *Ixodes,* and there are reprints of two papers from the pages of *Parasitology.* Finally we have an index to the valid species of *Ixodes,* together with a list of the collections in which the types are to be found.

Professor Nuttall and his helpers are to be heartily congratulated on this splendid piece of work, which must long remain the standard work of these important and interesting animals.

The bibliography, containing 2,004 references, includes all the more important papers, although many references of an economic nature are omitted.

W. E. C.

**Punnett, R. C.**—Mendelism. Third ed. Pp. xiii + 176, 7 plts. and 35 text figs. London: Macmillan and Co., Ltd., 1911. Price 5s. net.

There are now quite a number of introductory books on Mendelism, but none have attained the success reached by that of Mr. Punnett's unpretentious work which appeared in 1905. A revised second edition followed in 1907, which has been twice reprinted in this country, and we now have a third edition, entirely rewritten, and much enlarged.

Whilst making no attempt to treat of the subject in the detail given in Mr. Bateson's admirable and indispensable *Principles,* it is comprehensive, concise, and wonderfully clear in method and style.

A third edition scarcely calls for review, although there is here much new matter in illustration of the growth of our ideas on this subject.

It is a work which in its present form will serve both as an introduction to a vast and fascinating subject, and for the ordinary reader a sufficing exposition.

The illustrations are all excellent and carefully chosen.

W. E. C.

**Ross, E. H.**—The Reduction of Domestic Mosquitoes. Pp. x + 114, 18 illustrations. London: John Murray, 1911. Price 5s. net.

The sub-title of this interesting work informs us that it is a series of instructions for the use of municipalities, town councils, health officers, sanitary inspectors, and residents in warm climates, and to all such we can unhesitatingly recommend it as a thoroughly practical handbook, full of sound common sense.

Dr. Ross sets forth in a most lucid and informing manner the importance of domestic mosquitoes, their life and habits, and the most practical manner of eradicating such pests.

The reduction of these disease carriers presents no difficulties, the cost is not great, and if properly carried out, it prevents certain diseases and interests the inhabitants and encourages them to notify sickness and the return of mosquitoes to the local authority.

The author's previous experience in Egypt eminently fit him for writing such a book, in which nothing of practical importance has been overlooked. There is an atmosphere of enthusiasm about it, and will go far in making converts and helpers.

W. E. C.

**Spiller, G.**—Papers on Inter-Racial Problems. Pp. xlvi + 485. London: P. S. King and Son, 1911.

This work includes the papers communicated to the First Universal Congress recently held at the University of London. Many of the papers do not come within the scope of this Journal, but there are many that have a distinct interest for students of eugenics, genetics, and anthropology. Of these we would mention Prof. V. Luschan's "Anthropological View of Race," "The Instability of Human Types," by Prof. Franz Boas, "Climatic Control of Skin-Colour," by Prof. Lionel W. Lyde, "The Effect of Racial Miscegenation," by Prof. Earl Finch.

There are many others that have a less bearing upon such subjects, or relate to them only in particular sections; all are, however, most interesting reading, and cannot fail to appeal to a large reading public.

There is a concluding and useful bibliography.

**Theobald, Fred. V.**—Novae Culicidae. Pt. i, pp. 35, 21 figs. Wye, 1911. Price 3s. 6d.

This publication, so the author informs us, will appear at irregular intervals, and be mainly devoted to the description of new *Culicidae* from Africa, Australia, Asia and Europe. The object is to have the new species described in a uniform series, instead of being scattered in journals and periodicals.

The part before us deals with a collection from Uganda, and contains a new *Stegomyia,* a new *Megaculex,* four new *Chrysoconops,* a new *Mimomyia,* and an undescribed *Harpagomyia.* The previously unknown male of *Culex cumminsii,* Theob., and the undescribed male of *Uranstaenia bimaculata,* Theob., are also described.

The work is beautifully printed and well illustrated.

W. E. C.

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**Patch, Edith M.**—*Macrosiphum destructor* and *M. solanifolii.* Maine Agric. Exp. Stat., Bull. No. 190, 1911, pp. 81-92, 14 figs.

**Pethybridge, G. H.**—Investigations on Potato Diseases. Second Report. Journ. Dept. Agric. Ireland, 1911, vol. xi, pp. 1-34, 14 figs.

An excellent report, which should be in the hands of every grower.

**Van Dine, D. L.**—The Sugar-Cane Insects of Hawaii. U.S. Dept. Agric., Bur. of Entom., Bull. No. 93, 1911, pp. 1-54, 4 plts. and 5 figs.

**Weldon, G. P.**—Some Insects and Mites attacking the Peach in Colorado. Colorado Agric. Exp. Stat., Bull. 169, 1910, pp. 1-20, 6 figs.

**Wildermuth, V. L.**—The Alfalfa Caterpillar. (*Eurymus eurytheme,* Boisd.). U.S. Dept. Agric., Bur. of Entom., Circ. No. 133, 1911, pp. 1-14, 8 figs.

**Wilson, H. F.**—Notes on the Red " Spider " attacking Cotton in South Carolina. Journ. Econ. Entom., 1911, vol. 4, pp. 337-339.

**Woglum, R. S.**—Fumigation of Citrus Trees. U.S. Dept. Agric., Bur. of Entom., Bull. No. 90, pt. i, 1911, pp. 1-81, plts. i-viii, 12 figs.

**Woglum, R. S.**—The Value of Sodium Cyanid for Fumigation Purposes. Ibid., Bull. 90, pt. ii, pp. 82-90, plts. ix, x.

## V.—Forestry.

**Stebbing, E. P.**—On some important Insect Pests of the Coniferae of the Himalaya, with Notes on some Insects Predaceous and Parasitic upon them. For. Zool. Ser., 1911, vol. ii, pt. i, pp. 1-69, 15 plts.

## VI.—Fisheries.

## VII.—Medicine.

## VIII.—Animal Diseases, etc.

**Beuhne, F. R.**—Dysentery in Bees and *Nosema apis.* Journ. Agric. Victoria, 1911, vol. ix, pp. 550, 551.

**Cooley, R. A.**—Tick Control in relation to the Rocky Mountain Spotted Fever. Montana Agric. Exp. Stat., Bull. No. 85, 1911, pp. 1-29.

**Doane, R. W.**—An Annotated List of the Literature on Insects and Disease for the Year 1910. Journ. Econ. Entom., 1911, vol. 4, pp. 386-398.

**Gaiger, S. H.**—*Filaria osleri* in India. Indian Civil Vet. Dept. Mem., No. 2, 1911, pp. 58-60, plt. vii, and 1 fig.

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**Glover, G. H., and B. F. Kaupp.**—Rabies. Colorado Agric. Exp. Stat., Bull. 162, 1910, pp. 1-8, 4 figs.

**Gonder, R.**—The Life-cycle of *Theileria parva*—The Cause of East Coast Fever in Cattle in South Africa. Ann. Transvaal Mus., 1911, Bd. ii, pp. 241-247, 1 plt.

**Gonder, R.**—*Lamblia sanguinis,* nov. sp. Ibid., pp. 248-250, 1 fig.

**Howard, L. O.**—Remedies and Preventives against Mosquitoes. U.S. Dept. Agric., Far. Bull. No. 444, 1911, pp. 1-15.

**Leese, A. S.**—Experiments regarding the natural transmission of Surra carried out at Mohand in 1908. Indian Civil Vet. Dept. Mem. No. 2, 1911, pp. 1-26, plts. i-vi.

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**Martin, C. H., and M. Robertson.**—Further Observations on the Caecal Parasites of Fowls, with some reference to the Rectal Fauna of other Vertebrates. Pt. I. Q.J.M.S., 1911, Vol. 57, pp. 53-81, plts. 10-14, and 4 figs.

A valuable contribution to the subject, describing four new forms.

**Phillips, E. F.**—Bees. U.S. Dept. Agric., Far. Bull. 447, 1911, pp. 1-48, 25 figs.

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# PROCEEDINGS

OF THE

## ASSOCIATION OF ECONOMIC BIOLOGISTS.

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### TENTH GENERAL MEETING, April 6th and 7th, 1911.

Thursday, April 6th, 1911.

The Tenth General Meeting was held in the University of Birmingham.

The President, Professor Geo. H. Carpenter, occupied the chair, and there was a good attendance.

The minutes of the previous meeting were read, confirmed, and signed.

Mr. Richard S. Bagnall, F.E.S., was elected a member of the Association.

Prof. Geo. H. Carpenter communicated a paper on "Some Dipterous Larvae from the Turnip." Last year these caused considerable damage to crops near Dundalk, Ireland. They belonged to an apparently new species of gall-midge and to *Scaptomyza flaveola*. In connection with this species, several points of interest in the structure of the larvae were demonstrated by means of photographs and drawings shown in the lantern.

Mr. H. Maxwell-Lefroy, in a very interesting address, spoke on the training of economic entomologists. Not the least difficulty in making economic zoologists in England was the preponderance of the academic view, and the total absence of the economic view based on experience. He pointed out that, in addition to a training in zoology, botany, and chemistry, a course in agriculture should be taken, and a knowledge of field work in entomology was useful.

Mr. Walter E. Collinge read a paper on "House-flies and Public Health," in which it was pointed out that there was now no longer any doubt that cholera and typhoid fever were both spread by these insects, and that there was accumulating evidence that infantile diarrhœa, dysentery, and tuberculosis were also. Mr. Collinge contended that a proper system of control and prevention were essential on the part of every corporate body having anything to do with the health of the general public. After briefly referring to the ordinances and regulations in force in other countries, he commented upon the inadequate conditions for the keeping of food in the modern dwelling house, and the necessary regulations for the disposal and storage of manure, &c. In concluding, he pointed out that it remained with the general public to educate the authorities in these and like matters if we have to remove from our midst a danger full of potentialities to ourselves and our children, and detrimental to the public at large.

An interesting discussion on the standardization of economic nomenclature was opened by Mr. H. Maxwell-Lefroy, and a committee consisting of Prof. Geo. H. Carpenter, Richard S. Bagnall, Dr. R. S. MacDougall, H. Maxwell-Lefroy, Prof. R. Newstead, and Walter E. Collinge (Hon. Sec.), was appointed to deal with the matter.

Dr. G. H. Pethybridge gave an account of some recent work on diseases of the potato in Ireland, where the potato crop is peculiarly liable to suffer. Great advances have been made in recent years in checking the ravages of different diseases, but there are still many that have not yielded to treatment. A considerable amount of attention has been given by the author to these, and the results are fully described and illustrated.

Mr. W. B. Grove described four little known British fungi, viz., *Mucor spinosus, Monilia lupuli,* n.sp., long known to brewers as occurring on spent hops, but hitherto undescribed. *Rhopalocystis nigra* was a new name proposed for *Aspergillus niger,* and *Hormodendron cladosporoides,* a species often confounded with *Cladosporium herbarum.*

Mr. Walter E. Collinge directed attention to the extremely serious nature of the plague of eelworms and white worms which are at present attacking different crops throughout the country, and to the scanty nature of our knowledge of their life-histories and bionomics.

Dr. J. H. Priestley initiated a discussion on the systematic recording of diseases of economic plants.

The occurrence of the beetle *Necrobia rufipes* in cotton bales formed the subject of an interesting communication by Mr. Joseph Mangan.

Mr. G. E. Johnson demonstrated some stages in the life of the nematode living in the nephridia of the earthworm.

The Association accepted the invitation of Prof. Carpenter to meet in Dublin in 1912 at a date to be fixed later.

## ANNUAL MEETING, JULY 6th, 1911.

Held at the Rooms of the Linnean Society, London. Prof. Percy Groom occupied the chair.

The minutes of the previous meeting were read, confirmed, and signed.

In accordance with Law 12, the Council have nominated the following gentlemen as the Officers of the Association for the year 1911-12. No further nominations having been received, these were put to the meeting and declared elected.

*President:*

PROFESSOR GEO. H. CARPENTER, B.Sc., M.R.I.A., F.E.S.

*Vice-Presidents:*

PROFESSOR J. B. FARMER, M.A., D.Sc. (Oxon), F.R.S.
PROFESSOR SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
SIR PATRICK MANSON, K.C.M.G., LL.D., M.D., F.R.S.
PROFESSOR G. H. F. NUTTALL, M.A., M.D., Sc.D., F.R.S.
PROFESSOR E. B. POULTON, M.A., D.Sc., F.R.S.

*Council:*

PROFESSOR PERCY GROOM, M.A., D.Sc., F.L.S.
R. STEWART MACDOUGALL, M.A., D.Sc., F.R.S.E.
FRANCIS H. A. MARSHALL, M.A., D.Sc., F.R.S.E.
PROFESSOR ROBERT NEWSTEAD, M.Sc., A.L.S., F.E.S.
G. H. PETHYBRIDGE, B.Sc., Ph.D.
A. E. SHIPLEY, M.A., Hon. D.Sc., F.R.S.
FRASER STORY, F.R.S.E.
CECIL WARBURTON, M.A.

*Hon. Treasurer:*

R. T. LEIPER, D.Sc., M.B., Ch.B., F.Z.S.

*Hon. Secretaries:*

WALTER E. COLLINGE, M.Sc., F.L.S., F.E.S.
S. E. CHANDLER, D.Sc., F.L.S.

Mr. Collinge read the following Annual Report:—

## SIXTH ANNUAL REPORT.

In presenting their Sixth Annual Report (covering the period, July, 1910, to July, 1911), your Council are pleased to record a year's steady progress and prosperity.

The total number of members of all classes on June 30th, 1911, was 104, namely:—

| | |
|---|---|
| Honorary ... ... ... ... | 8 |
| Ordinary ... ... ... ... | 89 |
| Associate ... ... ... ... | 7 |
| | 104 |

A successful and largely attended meeting was held at the University of Birmingham on April 6th and 7th, 1911.

On the invitation of the President it was decided to meet in Dublin in 1912.

The total receipts up to December 31st, 1910, amounted to £192 14s. 5d., whilst the total expenditure for the same period amounted to £59 13s. 4d., leaving a balance in the hands of the Hon. Treasurer of £133 1s. 1d.

There is also a small balance due for outstanding subscriptions.

Dr. Leiper presented the Treasurer's Statement attached.

On the motion of Prof. Boulger, seconded by Mr. Chittenden, the Report and Statement were approved of and passed.

It was decided to hold the Dublin Meeting during the Easter Vacation.

The best thanks of the Association to the Council of the Linnean Society for their kindness in granting the use of their rooms was moved by Prof. Boulger, and seconded by Mr. Collinge.

# THE ASSOCIATION OF ECONOMIC BIOLOGISTS.

## CASH ACCOUNT, 1910.

### Receipts.

| | £ | s. | d. |
|---|---|---|---|
| To Balance in hand at Bankers, Dec. 31st, 1909 ... ... ... ... | 122 | 12 | 11 |
| ,, Receipts for 1910:— | | | |
| Members' Subscriptions (arrears) ... | 2 | 2 | 0 |
| ,, ,, for 1910 ... | 59 | 6 | 6 |
| ,, ,, in advance | 3 | 16 | 0 |
| ,, Entrance Fees ... | 2 | 2 | 0 |
| Associates' Subscriptions ... | 1 | 15 | 0 |
| Sale of Proceedings during 1909-10 | 1 | 0 | 0 |
| | £192 | 14 | 5 |

### Expenditure.

| | £ | s. | d. |
|---|---|---|---|
| By Journal of Economic Biology ... | 38 | 15 | 0 |
| ,, Clerical Assistance ... ... ... | 10 | 0 | 0 |
| ,, Printing, Stationery, Postages, etc. ... | 7 | 12 | 0 |
| ,, Bank Charges ... ... ... | | 1 | 2 |
| ,, Hire of Room ... ... ... | | 10 | 6 |
| ,, Secretarial Petty Expenses ... ... | 2 | 14 | 8 |
| | 59 | 13 | 4 |
| ,, Balance at Bank, Dec. 31st, 1910 ... | 133 | 1 | 1 |
| | £192 | 14 | 5 |

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Vol. 6. February 16th, 1911. No. 1.

# THE JOURNAL OF ECONOMIC BIOLOGY.

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# THE JOURNAL OF ECONOMIC BIOLOGY.

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The Journal of Economic Biology.

Vol. 6. OCTOBER 31st, 1911. No. 4.

# Contents.

# The Journal of Economic Biology.

Edited by

WALTER E. COLLINGE, 59, Newhall Street, Birmingham.

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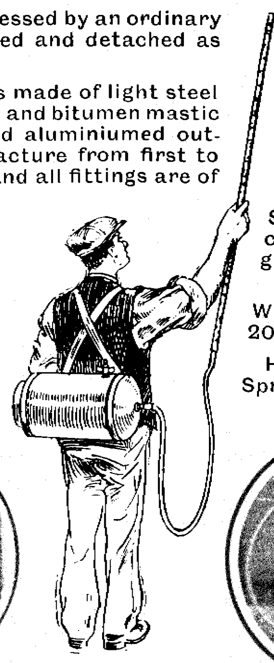

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