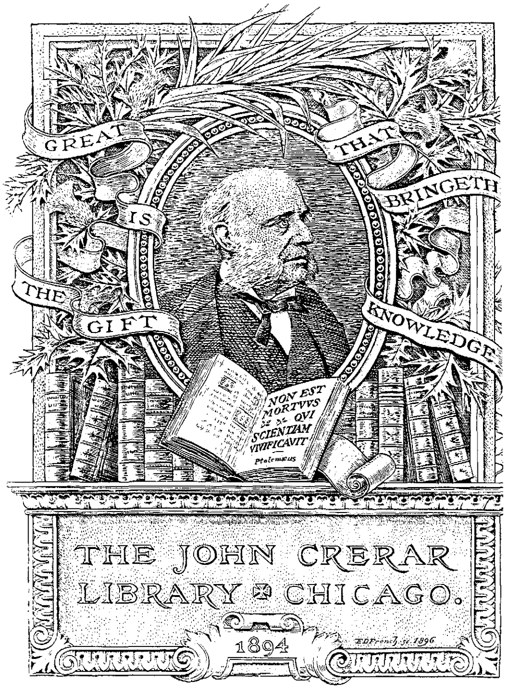
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THE JOURNAL OF ECONOMIC BIOLOGY.

EDITED BY

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

Foreign Member of the American Association of Economic Entomologists; Honorary Fellow of the Royal Horticultural Society; Honorary Consulting Biologist to the Land Agents' Society; the Midland Reafforesting Association, and the Warwickshire Agricultural Society; late Special Lecturer on Economic Zoology in the University of Birmingham.

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THE

JOURNAL OF ECONOMIC BIOLOGY.

CERATOTHRIPS BRITTENI, N. SP., A TYPE OF THYSANOPTERA NEW TO THE BRITISH FAUNA.

By RICHARD S. BAGNALL, F.L.S.

(WITH 1 TEXT-FIGURE).

IN 1899 the late Prof. O. M. Reuter described *Ceratothrips trybomi* from Sweden[1] forming the type of a new genus characterised by the unusual antennal features, and upon the strength of which I recently separated it from the Thripidae s. s.[2] To some these may seem small characteristics upon which to place such value, but in the classification of an Order one must study the relative values of the chief characteristics. Thus characters of value in separating genera and families in one Order may be of little or no value in another. For instance, a character often used in other insect Orders, the relative distances between the coxae, in the Thysanoptera persists unchanged throughout the two suborders Terebrantia and Tubulifera, whilst the structure of the tarsi are also subject to but little variation.

Again, taking the antennae, we see that the same general 8-jointed type[3] persists throughout the Tubulifera. In the Terebrantia, after setting aside the Aeolothripidae and the Heterothripidae, each with distinctive antennal characters, we get the large group generally known as Thripidae, and we find that of the numerous genera and species known from all parts of the world the same general type of antennae is common, *i.e.*, composed of 6 larger or main joints and a single or double-jointed style, and having joints 3 and 4 at least furnished with

[1] Acta Soc. Pro Fauna et Flora Fennica, 1899, xvii (Addenda, p. 65).

[2] Ann. & Mag. Nat. Hist., 1912, pp. 220-222.

[3] The few species bearing 7-jointed antennae being undoubtedly derived from an 8-jointed form, a joint being lost by the fusion of the two apical joints.

single or double trichomes. It is true that some species possess a 6-jointed antennae (*e.g., Aptinothrips rufa* and *Drepanothrips reuteri*), but in such cases the 6th joint is not styliform but pyriform, and caused, undoubtedly, by fusion with the style, as proved by the fact that *A. rufa* possesses a normal 8-jointed form as well as the 6-jointed form.

Therefore the very constancy of the general type of antenna gives a considerably higher taxonomical value to any deviation than would be otherwise the case, and such were the considerations that weighed with me when I proposed the family Ceratothripidae.

That (in the light of recent material) the classification of the Terebrantia requires considerable modification, cannot be gainsaid, and it seems to me that it should be divided into two main divisions, or tribes, the one Aeolothripides (for Aeolothripidae) and the other Thripides (for Heterothripidae, Thripidae (s.l.) and Ceratothripidae).

Tribe THRIPIDES.

Fam. **Ceratothripidae,** Bagn.

Genus **Ceratothrips,** Reut.

Easily recognised by the very distinctive type of antennae which have five main joints (six in the rest of the Thripide genera) and a single-jointed style. The third joint is pedicellate, very small and without trichome.

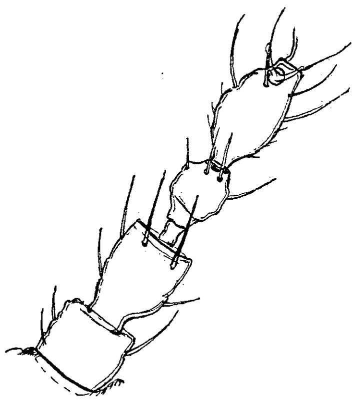
Ceratothrips britteni, n. sp.

Length 1.3 mm., breadth of pterothorax 0.27 mm.

Colour dark grey-brown, head and thorax somewhat deeper in colour than the rest of the body. Apex of 2nd antennal joint, and pedicel and base of third yellowish-white. Fore-tibiae lighter grey-brown, excepting basally and along upper and lower margins, and extreme tips of hind- and intermediate-tibiae inclined to be light. Tarsi light grey-brown. Fore-wings including ciliae light greyish- or smoky-brown, spines black

Head about 0.9 as long as broad, cheeks slightly swollen behind eyes and somewhat arcuate; surface irregularly and transversely striate. Eyes coarsely facetted occupying a little less than 0.5 the length of head, markedly pilose pigmentation black. Ocelli large, equidistant, posterior pair on a line drawn through posterior fourth of eyes; anterior ocellus protected by a pair of fairly long bristles. A series of setae on a line just behind eyes. Mouth-cone not quite reaching to base of prosternum. Maxillary palpi apparently 2-jointed, the second being long and slender. Antennae 6-jointed, including a single-jointed style. Relative lengths of joints 1-4 as follows:—10: 16: 10 (with pedicel): 19, and 5 and 6 together (distorted in the unique preparation) approximately 32; 3 much narrower than either 1, 2, 4, or 5, and 1 at least as broad as 2. 4 with a stout (and apparently double) trichome, and 5 with a transverse pale area; long dark bristles on inner side of 1 and encircling 2 to 4.

Prothorax about as long as head, transverse, 1.65 as broad as long, posterior margin depressed (as in *Thrips paludosus,* Bagn. and others); two long, stout bristles at each posterior angle which are about 0.7 the length of prothorax, and a series of 3 additional postero-marginal pairs, the inmost being the longest and about 0.4 the length of those at posterior angles. Surface somewhat sparingly furnished



Ceratothrips britteni, n. sp.
First four joints of left antenna, × c. 350.

with fine setae, mostly about 0.2 the length of the prothorax. Pterothorax broadest at juncture of meta- and mesothorax, where it is about as broad as long and 0.3 broader than the prothorax. Legs rather stout, hind pair longest; all femora and tibiae setose and hind tibiae in addition having the distal two-thirds within armed with a series of long, stout spines. Wings reaching to about the base of 9th abdominal segment. Fore-wing more than 12 times as long as broad through middle: costa with 22-23 setae; lower vein 11-12, the most distal being slightly remote; upper vein with a series of 3 near juncture with hind vein, and then a series in distal half, in one wing 7 (5+2) and in the other 8 (7+1).

Abdomen oblong-ovate, broader than pterothorax, broadening gently to 4, 4-6 sub-equal, thence narrowing gently to 9, and then more sharply to apex. Apical bristles long and strong, those on 9 (excepting inmost pair) about as long as segments 9 and 10 together; those on 10 only slightly shorter. Posterior margin of 8th tergite minutely fringed, 9 with a pair of dorsal bristles about 0.4 the length of the postero-marginal ones, 10 divided above almost to base. Lateral abdominal bristles moderately long.

This species is easily separated from *C. trybomi,* Reut., by the coloration of the body and antennae, the chaetotaxy of the forewings and larger and broader basal antennal joint.

Type.—In Hope Collections, University Museum, Oxford.

Habitat.—One female taken by Mr. Britten (after whom I find pleasure in naming the species) in the flowers of Devil's Bit Scabious *Scabiosa succisa*), Great Salkeld, Cumberland (Sept. 16th, 1913), with numerous examples of *Physothrips vulgatissimus,* Hal. (*pallipennis,* Uz.), *Ph. atratus,* Hal., etc.

THE BRITISH SPECIES OF THE GENUS *TETRACANTHELLA* (COLLEMBOLA).

By RICHARD S. BAGNALL, F.L.S.

(With 9 Text-figures).

In 1891 Schött[1] described *Tetracanthella pilosa,* the type of a new genus, and figured it in 1893 in his *Zur systematik und Verbreitung Palaearctischer Collembola.* In 1900 Wahlgren[2] in a paper, *Collembola der Bären-Insel,* records as *T. pilosa* a somewhat similar insect, differing chiefly in the shorter, incomplete spring, to which Axelson[3] later gave the name of *T. wahlgreni.* At this time the genus was placed in either the Lipuridae (Aphoruridae) or the Poduridae, but research has shown its affinities with *Isotoma,* and the genus is now placed with *Anurophorus* in the Entomobryidae at the beginning of the Isotominae.

Dr. W. M. (Axelson) Linnaniemi describes the two species, *pilosa* and *wahlgreni* in his *Die Apterygoten Finlands*, II., and it should be remarked that though Schött in diagnosing the genus says, "Pili clavati in segmentis apicalibus stipati, in ceteris dispersi," and figures the insect with very pronounced clubbed hairs on the abdominal segments, the *pilosa* of Axelson-Linnaniemi possesses simple hairs.

For some time I have observed a *Tetracanthella* which occurs not uncommonly in *Sphagnum* on our northern moors and hills, and which on account of Schött's misleading figure I could not reconcile with *pilosa.* However on the appearance of the second part of Axelson Linnaniemi's splendid work on the Finnish Apterygota the species was readily identified with *pilosa* as diagnosed and figured by him, my examples agreeing perfectly in every detail. More recently, whilst collecting Thysanoptera in the neighbourhood of Oxford, I had the good fortune of beating out a second species of *Tetracanthella* from old sallow stems, which, even on the field, I concluded to be referable to the genus. This latter insect

[1] Entom. Tidskr., pp. 191-192.

[2] Bih. till K. Sv. Vet.—Akad. Handl., 26.

[3] Die Apterygoten Finlands, I, 1907,

differs considerably from the two hill forms, thus necessitating some slight modifications in our present conception of the genus. It is quite possible that some future worker may erect a new genus for its reception, but, remembering the extraordinary variety in the number of anal horns in *Tullbergia*, and the fact that at least one species of *Aphorura* possesses a spring, I hesitate to take this step.

Genus **Tetracanthella**, Schött.

Lubbockia, Haller, 1880; *Deuterolubbockia*, v. Dalla Torre, 1895.

On the field species of this genus, though somewhat reminding one of *Anurophorus*, are very distinct little creatures, glossy, bluish-grey with lighter markings, and slow in their movements. *T. pilosa* occurs in numbers in *Sphagnum*, wet moss, etc., on our northern moors and hills to a height of 2,500 feet or more, whilst *wahlgreni*, which is more of an alpine form than *pilosa*, will almost certainly occur on some of our higher mountains.

The following key will enable workers to readily separate the species :—

1. Spring present, small. Anal horns large, 4. Inner claw of foot present Size 1.5-2.5 mm. . . . . :

   Spring absent. Anal horns small, 2. Inner claw of foot absent. Siz 1.3 mm. **T. oxoniensis**, n. sp

2. Spring longer, with mucro (2 teeth); Dens and mucro together abou 0.75 the length of manubrium. Inner claw not bristle-like, abou 0.25 the length of the outer claw. . . . **T. pilosa** (Schött), Axel

   Spring shorter, without mucro. Mucrodens not quite 0.50 the lengt of the manubrium. Inner claw produced to a bristle-like endin about 0.50 the length of the outer claw. . . **T. wahlgreni,** Axel

Tetracanthella pilosa (Schött), Axels.-Linnaniemi.

Figs. 1-4.

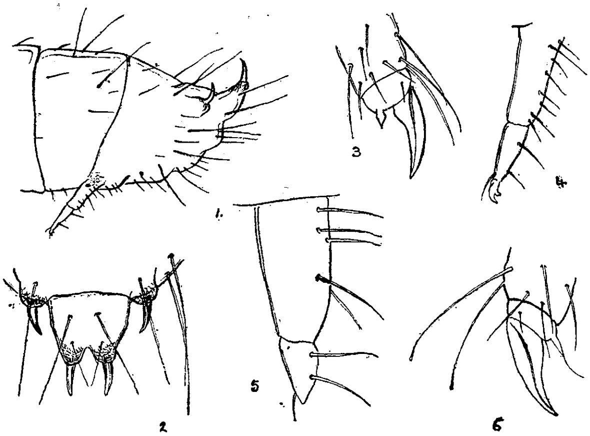
Syn. See Axels.-Linnaniemi, Die Apterygoten Finlands, II, p. 101.

Haller's *Lubbockia coerulea* (1880) is doubtfully referred to th species, whilst the *Tetracanthella alpina* (1901) of Carl is synonymou By a *lapsus calami* I referred to this insect in the *Entomological Reco* (xxv, p. 226) under the name of *Tetracanthella schötti*, Wahl., lamentable confusion of names caused by a too complete trust in memory.

The species is readily recognised by its completely develop spring, which is longer than in *wahlgreni*, and by the shape of empodium or inner claw of foot.

British Distribution.

I first took the species in numbers in *Sphagnum* on Chapel Fell near St. John's Chapel in Weardale, Co. Durham, in June, 1910, and later took a single example with *Isotoma* sp. in a nest of *Formica rufa* near Corbridge-on-Tyne, Northumberland (vii-1910). In September of the same year the species was met with in fair numbers at



Figs. 1-4. *Tetracanthella pilosa*, Schött. 1, Lateral view of end of abdomen, *i.e.* segments IV and V (+VI), × c. 90. 2, Dorsal view of anal horns, × c. 150. 3, End of tibio-tarsus and claw, × c. 360. 4, Lateral view of furca or spring, × c. 210.

Figs. 5-6. *T. wahlgreni*, Axels. (after Axelson-Linnaniemi). 5, End of tibio-tarsus and claw, × c. 360. 6, Lateral view of spring, × c. 360.

Ravenscar, Yorkshire, where it occurred in *Hypnum* on the cliffs at 600 feet, and in *Sphagnum* on the moors at about 700 feet,[1] whilst in May of this year I found it plentifully on Cheviot peak (Northumberland) at from 1,500 to 2,500 feet.

The *Tetracanthella* sp. recorded by Mr. Evans from Scotland are almost certainly referable to this species.

Previously known from Sweden, Norway, Finland, and the Swiss Alps.

Tetracanthella wahlgreni, Axels.-Linnaniemi.

Figs. 5 and 6.

Syn. See Axels.-Linnaniemi, Die Apterygoten Finlands, II, p. 103.

This species is closely allied to *pilosa,* but may be readily separated by the short spring which is without true mucrones, and has the apical

[1] Some of these Yorkshire examples were submitted to Dr. Axelson-Linnaniemi and returned as *T. pilosa*, Schött.

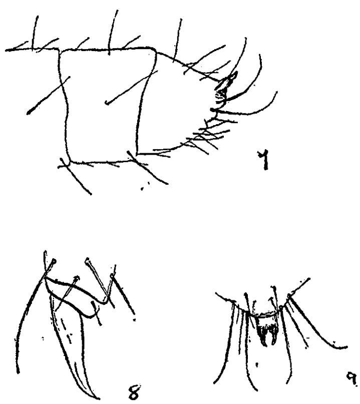
part (mucrodens) less than one-half the length of the manubrium, and by the bristle-like form of the inner claw.

It is an alpine species, rarer than *pilosa*, and is known from Sweden, Norway, Spitzbergen, and Finland. It will almost certainly occur on our Scottish mountains.

Tetracanthella oxoniensis, n. sp.

Figs. 7-9.

Form generally, and colour as in *pilosa*. Antennal joints 3 and 4 practically subequal. Upper claw without inner lateral teeth, inner claw absent, tibio-tarsus with one outer tenant hair. Spring apparently absent. Anal horns on elongated papilla, 2, approximate. Abdominal segment IV dorsally longer than either III or V (+VI). Length 1.3 mm.



Figs. 7-9. *Tetracanthella oxoniensis*, n. sp. 7, Lateral view of end of abdomen, *i.e.* segments IV and V (+ VI), × c 90. 8, End of tibio-tarsus and claw, × c. 360. 9, Dorsal view of anal horns, × c. 150.

Type.—In Hope Collections, University Museum, Oxford.

Habitat.—In moderate numbers by beating dead sallow branches, near Kirtlington Park (Oxon.), September 21, 1913.

This species differs sharply from both *pilosa* and *wahlgreni* by the absence of the spring, the single pair of small, approximate, anal horns and by the absence of the inner claw of foot. The relative lengths of the antennal joints are 9: 15: 15: 23,—2 and 3 being subequal, whilst in *pilosa* 3 is distinctly smaller than 2.

The fourth abdominal segment in *pilosa* is shorter than V (+ VI), whilst in *oxoniensis* it is longer than either III or V (+VI).

OBSERVATIONS ON THE LIFE-HISTORY OF *USTILAGO VAILLANTII*, TUL.

By IVY MASSEE.

(With Plate I.)

From a systematic standpoint this parasitic fungus has been known for some time. It was first described by Tulasne (1) in 1847; it has been recorded as occurring in the anthers or ovary of the following host-plants :—*Gagea fascicularis,* Salisb., *Scilla bifolia*, L., *Urginea scilla*, Steinh., *U. anthericoides*, Steinh., *Muscaria comosum,* Mill., *M. botryoides,* Tausch., *Hyacinthus romanus,* L., *H. trifoliatus*, Tenore.

Its known distribution is as follows: Britain, Italy, Germany, Austria, Hungary, and N. Africa. It is highly probable that in the case of cultivated plants, its distribution is much more extended than is indicated above; for instance, so far as is known it is only met with on *Scilla bifolia* in Britain, an introduced plant. The following observations are based on material parasitic on *Scilla bifolia*, growing in the Royal Botanic Gardens, Kew.

Mycelium.

The mycelium is colourless, slender, from 4-6μ in thickness, sparingly septate and irregularly branched. At first it is intercellular, dissolving the pectin compound of the middle lamella, and forcing apart the walls of adjoining cells. At a later stage the mycelium penetrates the cell-walls, which appear to be dissolved by the tip of the hypha as in the *Botrylis* described by Marshall Ward (1*), and by this means spreads through the tissues. The hyphae were never observed to pass through pits in the cell-walls. When a seedling is infected the germ-tube of the spore enters along the line of the middle lamella and forms mycelium which passes into the tiny "cushion" or flattened stem at the base of the bulb, and it continues to increase in quantity as the stem increases in size, being most abundant towards the periphery. Numerous haustoria, formed of short, inflated branchlets crowded together and forming a botryoid mass, are present in the cells, agreeing closely in structure with the haustoria of *Melanotaenium endogenum*, De Bary, and the haustoria of *Puccinia fusca,* Wint., and its aecidial condition (*Aecidium leucospermum*, DC.) as figured by Dowson. (2) When young and of functional value the haustoria are hyaline, very thin-walled, and stain very quickly with a watery solution of azol blue, before any other portion of the section has taken up the stain, thus becoming sharply differentiated. When old the walls of the haustoria become thicker, and tinged yellowish-brown, and are very conspicuous. At this stage they are of no functional value.

Hyphae from the perennial mycelium enter the flower-stalk immediately it is formed, and can be readily traced throughout its length, also in the pedicels, and the filaments of the stamens. On entering the anther the hyphae soon fill the cavities intended for pollen, and form numerous short branches, which in due course give rise to the spores. The course of development of the spores will be explained later. In rare cases the hyphae enter the ovary, and form spores in the ovules. The mycelium in the stem never passes into the roots, the substance of the bulb or the leaves. On the other hand, when a lateral bulb is formed the mycelium passes from the old stem into the young one, with which it is in organic contact. Tulasne (3) says that in *Muscari comosum* the spores are produced in the ovary and the anthers remain uninjured.

Formation and Germination of the Spores.

The vegetative mycelium is transversely septate, and each cell contains a single nucleus. Those portions of the mycelium which enter the anther-cells produce numerous short branches which are cut up into cuboid cells by transverse walls, each cell containing one nucleus: eventually alternate transverse septa deliquesce and disappear, thus leaving two nuclei in each cell. These nuclei fuse and form the single nucleus present in the mature spore. Soon after the fusion of the nuclei the wall of the mother hypha becomes swollen, and the protoplasm concentrates round the nuclei and forms the spores, which are fully grown while yet within the hyphal wall. Finally the deliquescent walls of the hyphae completely disappear, leaving a dry, dusty mass of spores. The epispore when first formed is perfectly continuous and slightly tinged with violet. It becomes darker in colour and rigid before the spore has attained its full size, and consequently is broken up into minute, irregularly polygonal portions, due to the continued increase in size of the spore which when mature averages $13\text{-}15\mu$.

When placed in a hanging drop in tap water the spores germinate, on the average, after two days, whether only one day old, or three months old, but to this general rule there are exceptions. Different cultures put up at the same time, from the same batch of spores, showed very marked differences in the time of germination. Sometimes practically all the spores in a culture germinated, and the hemibasidia became free from the promycelium, within twenty-four hours, while in another culture germination was delayed until the sixth day, and the hemibasidia were free on the seventh day. Again, in different cultures from the same batch of spores, under exactly similar conditions of treatment, some of the cultures produced only hemibasidia on germination, whilst in other cultures some spores produced hemibasidia while others bore chains of oidia as a direct continuation of the promycelium, which was often very much elongated. In these cases no hemibasidia were formed. The oidia became free and reproduced themselves copiously by budding, and large colonies of thousands of spores were produced in a culture. These budding spores were rarely observed to germinate; when this occurred the germ-tube again became broken up into oidia. (Pl. 1, fig. 24.)

Rarely a sterigma, instead of remaining short and bearing a normal spore, grows out into a long filiform branch which remains simple or becomes branched, and the tips of the branches break up into minute oidia. When the spores are put up in a decoction of prune juice the promycelia and hemibasidia are more robust than those produced in tap water.

On germination the promycelium varies very much in length, ranging between 80-200μ in the same culture. A terminal portion of the promycelium tube, of variable length, becomes swollen and narrowly fusiform, and is then cut off by a septum: this terminal portion, or hemibasidium, as a general rule breaks away from the promycelium at the septum, as previously pointed out by de Bary (4), and afterwards becomes 3-septate and constricted at the septa. Finally each cell gives origin to a short slender outgrowth or sterigma, bearing an elliptic-oblong spore, averaging 8-12 $\times$ 3-4μ. The apical cell of the hemibasidium usually bears the first spore, at or near the tip. As a rule a spore only gives origin to one promycelium tube: Brefeld (5) figures a spore producing two promycelium tubes, and in my cultures I have observed spores producing as many as four. Brefeld (5) has also figured cases where, after the first hemibasidium has separated from the promycelium, the latter has branched and produced a second hemibasidium; this was a common occurrence in my cultures, sometimes the promycelium sending out two or three branches each bearing a hemibasidium. The average size of a hemibasidium is $40\text{-}50 \times 5\text{-}8\mu$. It is not unusual for the hemibasidia to produce several spores in succession from the same sterigma: in fact, spores are produced until all the protoplasm contained in the cell is exhausted. No conjugation of the spores takes place in this species.

Infection Experiments.

Numerous attempts were made to infect the anthers, in some cases while they were quite young and in the unexpanded flower-bud, but always without success. The fact that infected plants produce flowers which are full of spores before the inflorescence appears above ground, proves infection of the flowers to have taken place underground.

My father who has been interested in this disease for many years, has already proved the presence of hibernating mycelium in the flattened stem of the bulb, and further observed that the same bulb produced smutted anthers annually.

This suggested the idea that the plant might possibly be infected in the seedling stage, as occurs in oats and certain other plants attacked by species of *Ustilago*. This idea proved to be correct. Very young seedlings of *Scilla*, planted in finely sifted soil, sterilised by steam, and afterwards intimately mixed with a copious supply of the *Ustilago* spores, were allowed to grow for three months. Examination of the stem or "cushion" of the bulb of these seedlings showed the presence of mycelium and the very characteristic haustoria. Seedlings grown under exactly similar conditions, except that no spores were mixed with the soil, showed no trace of mycelium in the stem. Seedlings placed in water in which germinating *Ustilago* spores were present also became infected. The germ-tubes of the promycelium spores appeared to be capable of entering the tissues through any colourless portion of the seedling, but not where chlorophyll was present. The entrance of the germ-tube was indicated by a minute yellowish spot on the surface, from which point the mycelium could be traced in the tissues, being clearly differentiated by a watery solution of nigrosin.

Bulbs which had produced flowers free from smut and were consequently free from the disease, did not become infected when grown in soil containing the *Ustilago* spores, thus proving that infection can only take place during the seedling stage. This explains why smutted flowers appear in the same bed as healthy flowers year after year, and the latter do not become infected. Infected plants are, as a rule, more robust and somewhat larger than normal ones; and, with the exception of the anthers, the flowers are unchanged. Seeds are usually formed, and when this is not the case it is due to the dense mass of spores preventing pollen from reaching the stigma.

This work was done in the Jodrell Laboratory, Royal Botanic Gardens, Kew.

SUMMARY.

All the host-plants of the fungus belong to the order Liliaceae.

The spores are only produced in the anthers or in the ovary.

Infection of the host-plant can only occur during the seedling stage. The mycelium hibernates in the flattened stem or "cushion," and grows up along with the flowering stem each year. Hence, when a seedling is infected, the resulting bulb is infected for all time. By the dispersion of infected bulbs, the spread of the disease has been effected in the case of cultivated plants.

The spores retain their vitality for at least three months, after being kept perfectly dry. The influences which respectively determine the production of a promycelium bearing a hemibasidium, or that of a slender germ-tube which becomes directly broken up into oidia, have not been determined.

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1.* Marshall Ward.—Ann. Bot., 1889, 2, p. 319.
2. Dowson.—Geitschr. für pflanzenkr., 1913, 23, tab. 3.
3. Tulasne.—Ann. Sci. Nat., series 3, 1847, p. 91.
4. De Bary.—Compar. Anat. and Physiol. Fungi. Eng. ed., p. 195.
5. Brefeld.—Unters., 1895, 12, tab. 6, figs. 32-38.

EXPLANATION OF PLATE I.

Illustrating Miss Ivy Massee's paper on the "Life-history of *Ustilago vaillantii*, Tul."

Fig. 1. *Scilla bifolia*, showing infected anthers; nat. size.
Fig. 2. Flower of same, with infected anthers; slightly mag.
Fig. 3. Fragment of vegetable mycelium; highly mag.
Fig. 4-5. Terminal branches of mycelium from the anthers, showing various stages of spore-formation; highly mag.
Fig. 6. Haustoria in cells of flattened stem or cushion of bulb; highly mag.
Fig. 7. Haustorium in a cell of the pedicel of a flower; highly mag.

Fig. 8. Portion of mature epispore, broken up into irregularly polygonal patches; highly mag.

Fig. 9. Mature spore; highly mag.

Figs. 10-12. Spores germinating and producing hemibasidia; highly mag.

Figs. 13-19. Spores producing secondary hemibasidia after the first hemibasidia have become free; highly mag.

Figs. 20-21. Hemibasidia, which have become free, in various stages of development, some producing spores; highly mag.

Fig. 22. Spores free from the hemibasidia; highly mag.

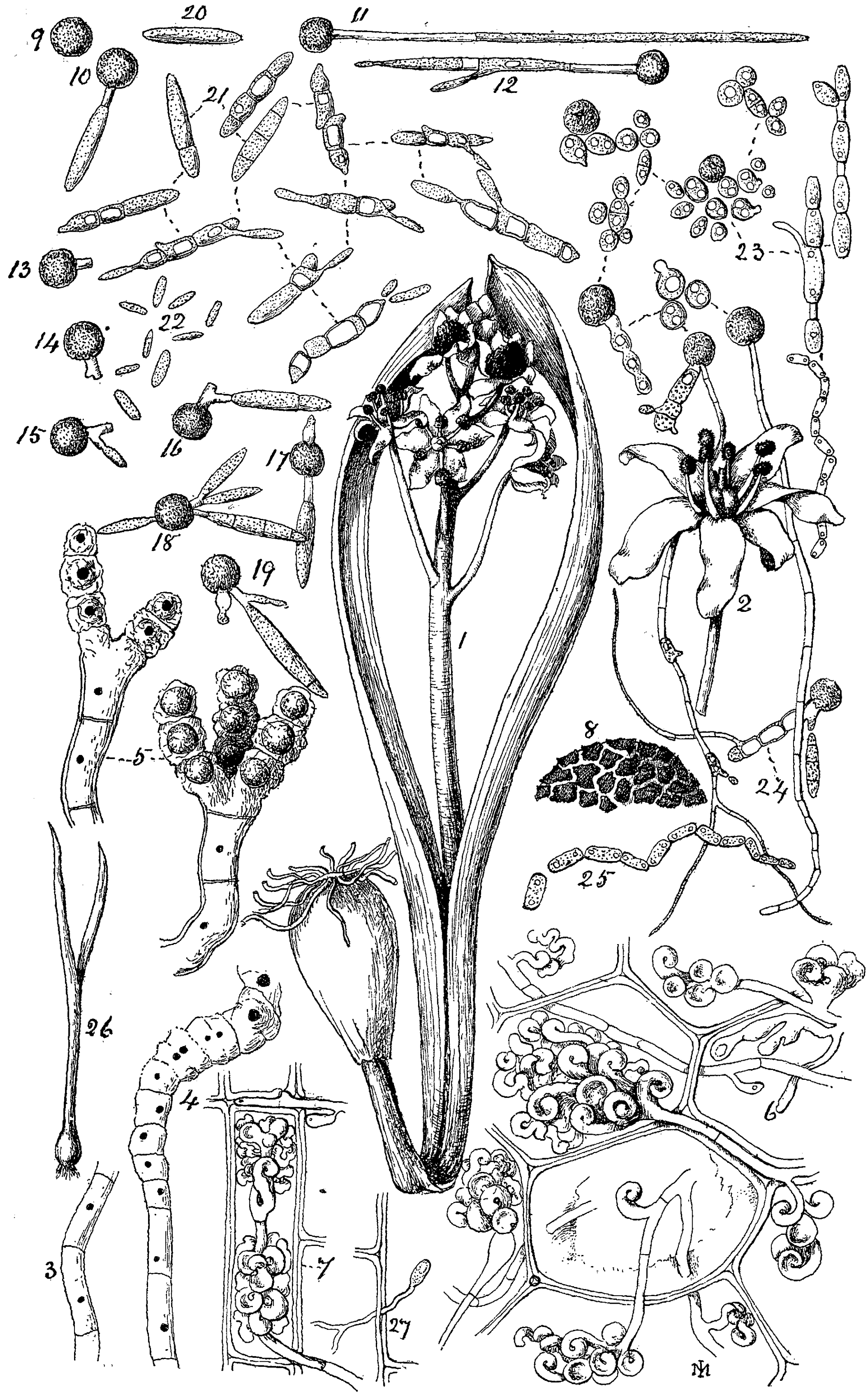
Fig. 23. Spores germinating and producing oidia directly instead of bearing hemibasidia; highly mag.

Fig. 24. Spore bearing a short chain of oidia, the terminal one of which has produced a slender hypha; the basal oidium has given origin to a hemibasidium; highly mag.

Fig. 25. A typical chain of oidia which has become free; highly mag.

Fig. 26. Seedling of *Scilla bifolia* at about the stage when infection occurs.

Fig. 27. A germinating spore entering the tissues of a seedling; highly mag.



USTILAGO VAILLANTII, Tul.

SOME NOTES ON THE TERRESTRIAL ISOPODA.

By P. A. AUBIN, F.R.M.S.

(WITH 2 TEXT-FIGURES).

THE following notes which, so far as I am aware, are original, record, I believe, some hitherto unnoticed points in connection with this interesting family.

Though the observations have been made principally on *Porcellio scaber*, Latr., and *P. laevis*, Latr., they apply equally to *P. dilatatus*, Brandt, *Porcellionides pruinosus*, Brandt, *Trichoniscus roseus*, Koch and *Oniscus asellus*, L. No other species have been observed up to the present.

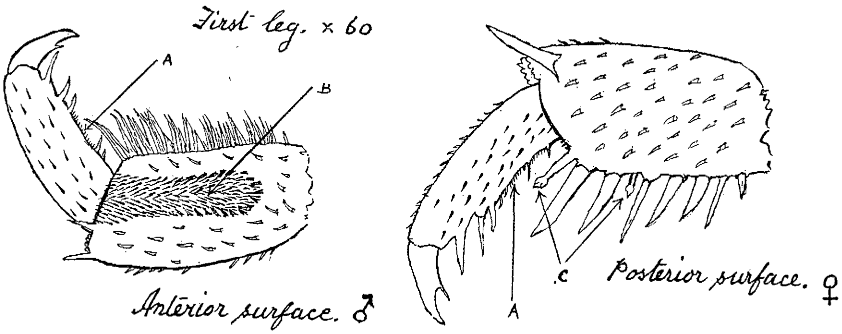
Antennae. In addition to being the bearers of sense organs, the antennae are also used as weapons; thus specimens of *Porcellio* may be seen with their frontal lobes in contact striking each other with their antennae. For this purpose the flagellum is bent at right angles to the peduncle, and the blow is struck with the point of the terminal spine. The action is quite distinctive, and cannot be mistaken for the ordinary movements of the antennae.

A further action has been observed on several occasions which tends to show not only that the antennae are modified legs, but, also, that the modification has not proceeded sufficiently far to obliterate entirely the ambulatory function. Oniscus, if confined in a Petri dish with sides of such a height that whilst the specimen cannot reach the top with its feet, it can do so with its antennae, will hook the flagellae over the edge and attempt to pull itself up.

Legs. There is a marked difference between the sexes in the arrangement and nature of the spines on the posterior edge of the legs. The accompanying sketch of the three distal joints of the first leg of *P. laevis* shows this clearly. In the upper figure, from a male specimen, the spines are very numerous, fine and closely set, and may be described as brush-like; in the lower figure, from a female, they are coarse, set far apart and comb-like. Further, the bulbous spines shown at C. are always present in females, but their situation does not appear to be very definite. This sexual difference applies to all the legs.

A definite portion of the first pair of legs, shown in A. and B., is highly specialised to provide for the cleaning of the antennae. This consists of (A) a fine comb-like arrangement of spines on the inferior edge of the propodite, and (B) a groove of varying depth on the anterior surface of the carpopodite. This groove is bounded over most of its periphery by a row of slighly recurved spines, whilst the whole area of the groove itself is closely beset with fine hair-like spines. It is somewhat difficult to make out this structure in unprepared material, but it is easily demonstrated by treating a fresh specimen with one of the intra-vitam stains, possibly best of all a very dilute aqueous solution of neutral red.

This cleaning apparatus is used in three different ways: (1) the



Porcellio laevis, Latr

flagellum is grasped between the comb A. and the long spines at the distal end of the carpopodite and drawn between the two; (2) the front leg is held forward, the flagellum is laid in the groove and the leg is thrust forward so as to stroke the flagellum; (3) the leg is held forward, the flagellum is bent to an acute angle with the peducle, it is then laid in the groove and the stroke made with the antenna, the leg remaining rigid. It will be seen that (2) and (3) clean opposite sides of the flagellum.

The first pair of legs are also used for other than locomotive purposes; thus, small particles of food are held down, or the particle may be clasped between the claws and held up to the mouth; food is carried by being grasped between the carpopodites, where it is apparently held by the spines on the periphery of the above-mentioned grooves. They are used, in conjunction with the second pair, to disintegrate large pieces of food, the claws of first pair being hooked into a particle, the second pair of feet are placed against the mass and the particle is torn off by a combined retraction of the first pair and an extension of the second pair.

All the legs are cleaned by stroking them with the spined edge of an adjacent pair.

The long, stiff spines (D) at the distal end of the propodite, and the fact that the dactylopodite can be brought into apposition with them or between them, is very suggestive of a grasping organ like that of *Palinurus*. I have, however, been unable to detect such use.

Ecdysis. From such literature as I have been able to consult, this interesting process appears to have been dealt with very inadequately, and the following record of observations on *Porcellio laevis* and *P. dilatatus*, whilst not professing to be complete, gives some additional details.

Ecdysis is extremely common in early Spring, and it is quite an easy matter to observe the process in detail with captive specimens.

The process commences with a general listlessness, and the animal may in some cases, but not the majority, try to hide; some 20 to 24 hours later the posterior tergal joints are distinctly gaping, and the connecting integument is of glass-like brilliancy, a faint white line is visible at the extreme edge of pleura and along the posterior edge of terga; five hours later the three posterior thoracic and all the abdominal segments have become quite white, the last three pairs of legs are not used but are dragged uselessly along the ground; the front of the fifth segment is just showing at the fracture of the old shell; droplets of liquid exude at the fracture, and close examination shows that there is a film of liquid interposed between the old shell and the underlying cuticle; the animal makes constant efforts to free itself, manifested by a rhythmical elongation and contraction of the body, noticeable more especially between the fourth and fifth segments; these contractions continue throughout the process of ecdysis and for some time after. An hour later the whole of the fifth segment is exposed, except the points of the pleura, which are folded back and still held by the edge of the old shell; ten minutes later half of the sixth tergum is showing, and the points of the fifth pleura are free; the tail-appendages are entirely withdrawn from their old shell, and the legs are so far withdrawn that the extremities occupy the centre of the carpopodite of the old shell. The ecdysed portions participate in the contractions, and the worm-like undulations distinctly show that the new cuticle is soft; five minutes later the whole thorax is free as well as the pleura of the third abdominal segment, and in a further five minutes the animal crawls free. At this time the posterior segments are still narrower than the anterior ones; but the contractions continue at the rate of about two per minute, and in the course of about half an hour the soft posterior half of the body has become wider than the anterior half (except in the case of full-grown specimens) and the animal crawls about, slowly using the anterior legs only. The new cuticle has now lost its glossy appearance and become smoky. It may therefore be said that the increase in size of the animal takes place gradually in the short period between the moment of ecdysis and the solidification of the new shell.

The animal remains quiescent for two or three hours, when it will begin to use the posterior legs; at first it appears to try their strength by supporting the body on them and raising the four anterior pairs of feet from the ground, and at the same time curving the anterior segments upwards.

The tail-appendages play a distinct part in ecdysis; when the process is sufficiently advanced, it can be observed, through the shell, that with each contraction of the body they move forward with their upturned points resting against the interior surface of the old shell, and with the following elongation they retain their position and the shell is moved backward.

Specimens frequently examine the cast shell, but make no attempt to eat it, though it is often eaten by other individuals.

Some two to four days after the moult of the posterior half is completed, the animal becomes inactive and begins to show the same preliminary whitening of parts of the anterior portion of the body, the first part to whiten being the flagellum; the joints of the carapace begin to gape, showing the glossy connecting integument; the legs of the anterior segments as well as the antennae are directed forwards.

Twenty-four hours later, expansion and contraction of the body begins, each contraction being accompanied by a strong downward bending of the posterior half of the body. Shortly after the commencement of these contractions the eyes and lobes lose their colour and become semi-transparent; the limbs and antennae become useless and do not respond if touched.

If, after the contractions of the body have continued for about an hour, the specimen be examined under a strong light, it will be found that although there is as yet no sign of the terga having moved within the old shell, the antennae have been withdrawn to such an extent that the flagellae occupy the distal two-thirds of the first joint of the peduncle, and that the legs have been withdrawn nearly three joints within the old shell. The flagellae gradually become more visible within the peduncle owing to a gradual resumption of colour.

After a variable period of effort the edge of the fourth tergum appears from beneath the old shell, and the same phases are gone through as in the case of the posterior half of the body; all the legs are freed practically simultaneously when the free edge of the old shell reaches the level of the eyes, but as soon as the proximal joints are clear they are used to push the shell forward; the spines along the legs engaging with the free edge of the old shell of the fourth sternum for this purpose.

After the feet are free the shell is still pushed forward with the antennae; the first joints of the peduncle being in contact along their whole length and resting against the inside of the old shell in the median line, the more proximal joints are used after the fashion of lazy-tongs; as soon as the peduncles are entirely clear of the cast shell the flagellae are freed by a sudden separation of the antennae, which are at once folded back so that the flagellae rest, along their whole length, against the head and first tergum with the points directed upwards. Except for the contractions of the body, the animal remains motionless for some minutes, and then begins to walk with a peculiar gait—the anterior four pairs of legs being still soft it uses only the fifth, sixth and seventh pairs, with the result that it overbalances at every step and falls forward so that the metastoma strikes the ground.

The point I would emphasize is that throughout the whole ecdysis there is no such thing as *crawling out of the shell*; with the exception of the moment when the last abdominal pleura are freed and a slight forward movement is made to free the tail-appendages, the animal remains stationary, and the shell being cast is pushed forward or backward as the case may be; this even applies to the clearing of the greater portion of the antennae as described above.

At the moment of ecdysis there are no joints properly so-called between the terga, the connecting integument being continuous from the posterior edge of one tergum to the anterior edge of the succeeding one; the infolding of the integument to form the normal joint is not complete until half an hour after complete ecdysis, and the joints appear to infold in the order of their emergence from the old shell.

In some cases, at the period when the legs and antennae are withdrawn within the old shell before the terga have moved, the extremities are eaten by other woodlice and the individual so attacked dies, being unable to complete ecdysis. This is due to the soft extremities being injured, and the coagulation of the exuded blood, by fastening the limb to the shell, prevents further withdrawal.

Though such is stated by several writers to be the case, I have never observed any attempt on the part of other individuals to eat the soft parts of a newly ecdysed specimen; the latter, however, objects to such parts being touched.

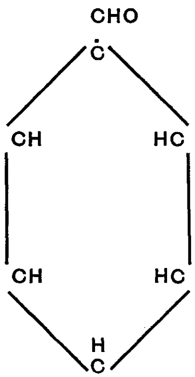
Intelligence. The following observation appears to indicate a process of reasoning which can hardly be attributed to instinct. For ease of observation I keep specimens in shallow, glass-topped boxes; when a fresh batch are introduced it is almost impossible to prevent their escaping in all directions if the cover is lifted; after a few days, however, the cover may be removed for quite an appreciable time, and hardly a single specimen will crawl up the side of the box; they appear to have realized that there is no escape in that direction.

A TRAP FOR THRIPS.

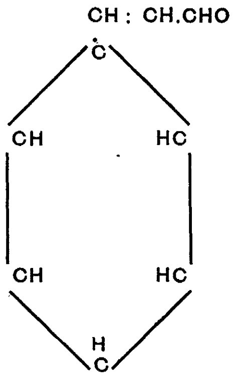
By F. M. HOWLETT, B.A., F.E.S.,

Imperial Pathological Entomologist, India.

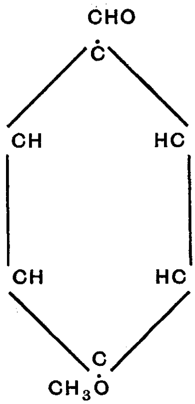
In the course of some experiments on the degree of attraction of some chemical substances for flower-haunting insects, I recently observed that three of these substances have a very marked attraction for Thrips. The attraction is indeed strong enough to suggest that the observation may be of value as providing a simple means of destroying the insects in quantity. The three substances are all Aldehydes of similar composition, *Benzaldehyde*, *Cinnamylaldehyde*, and *Anisaldehyde*, with the following structural formulae :—



Benzaldehyde.



Cinnamylaldehyde.



Anisaldehyde.

Another aldehyde, Salicylaldehyde, was found also to be not unattractive.

The experiments have been tried in November and December, and Thrips is at this season far from abundant. It seems not improbable that much larger catches of the insects will be made when the weather becomes warmer and more favourable, and I have for this reason thought it worth while to publish the not very imposing record to date, in the hope that it may perhaps prove of some utility to horti-

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culturists and others interested in the destruction of Thrips. Anisaldehyde and Cinnamylaldehyde can be bought for eight or ten shillings a pound, but Benzaldehyde (pure) costs under two shillings: taking the same quantity as was used in my experiments (about 2 grammes), a pound would be enough for about 200 traps, which would probably retain their efficiency for at least a week, and possibly much longer if a better form of trap is devised. To prevent possible oxidation of the aldehyde it might be well to add a trace of Formaldehyde, which is likely to have little effect on the efficiency of the trap, but it is now too late in the season for testing the effect of this addition here.

Two varieties of Thrips were caught, one with a fulvous head and thorax and blackish abdomen (A), and the other palish yellow (B); neither are identified. They appeared to be all females, but of this I cannot be quite certain. The method adopted was to expose small bowls, each containing about half-a-pint of water with 2 cc. of the aldehyde stirred up in it. The insects attracted are drowned in the water. Better methods of trapping could probably be easily devised.

The first experiment was as follows:—

(1) 1.ix.13. 6.0. a.m. Exposed bowl of Cinnamylaldehyde Merck.
1.0. p.m. Between 100 and 150 Thrips *A*.
2.ix.13. 1.0. p.m. Over 300 Thrips *A*.

After this date I was unable to continue the observations until November, when Thrips was getting scarce.

(2) 9.xi.13. 1.0. p.m. Exposed following aldehydes, and inspected for Thrips

Number of Thrips seen at

	11 a.m. 10.xi.13,	9 a.m. 12.xi.13,	& 10 a.m. 20.xi.13.
Isobutylaldehyde	2 A 2 B	2 A 2 B	(smell gone).
Salicylaldehyde	10 A 8 B	20 A 8 B	(smell faint).
Anisaldehyde	5 A 30 B		(a crow upset the bowl).
Cinnamylaldehyde	10 A 4 B	60-80 A 30-40 B	100 A 40 B
Benzaldehyde	15 A 2 B	60 A 8 B	80 A (6) B

(3) 10 a.m. 12.xi.13. Mixed 1 cc. *Benzaldehyde* with 1 cc. *Cinnamylaldehyde* in 10 cc. alcohol, and exposed in a pint of water in bowl.

After	5 minutes	exposure,	0	Thrips.	
,,	25 ,,	,,	1	,,	*(A)*
,,	50 ,,	,,	5	,,	,,
,,	2 hours	,,	13	,,	,,
,,	8 days	,,	290-300	,,	,,

(4) 10 a.m. 10.xii.13. Exposed following bowls: inspected at

	6 p.m. 10th.	10-30 a.m. 11th.
(a) *Benzaldehyde* and water	0	0
(b) *Benzaldehyde* and dil. formalin.	0	0
(c) Dilute Formalin.	0	0

It seems probable from this last experiment that Thrips is now (December) absent or inactive, and that the November catches were made at the end of the season of activity, and were thus naturally small. I propose to resume operations at the beginning of the warm weather, and to experiment with Nitro-benzene, a substance which does not contain the aldehyde-group (CHO), but has a smell closely resembling that of Benzaldehyde. It should be then possible not only to obtain more evidence as to the practical economic value of the method, but by employing Nitro-benzene to ascertain also whether the attractiveness is bound up with the presence of the aldehyde-group, or whether the insect's olfactory sense is, like our own, similarly affected by Nitro-benzene and Benzaldehyde.

PRELIMINARY STUDIES ON THE BIOLOGY OF THE BED-BUG, *CIMEX LECTULARIUS*, LINN.

III. FACTS OBTAINED CONCERNING THE HABITS OF THE ADULT.*

By A. A. GIRAULT,

The University of Illinois.

Introduction.

In this concluding paper of the series of three upon this insect, I shall give a narrative account of pairs mating in confinement, adding occasional comments.

Narrative Account of Mating Pairs Kept in Confinement.

1. *A First Generation.* This generation has already been noticed in the first and second parts. It originated from a single female partly fed, captured from a berth in a stateroom of a steamboat plying between Cincinnati, Ohio, and Louisville, Kentucky, near midnight, August 7th, 1907. This female was confined at once in an ordinary physician's pillbox and left without food. On August 26th it died after laying ten eggs. These latter hatched at noon, August 27th, and were reared to maturity as described in Part I. The following matings were effected between the mature bugs :

(1) *Pair No. 1.* After a full meal[1] on human blood at 8 p.m.,[2] at 9.30 p.m., December 19th, 1907, adults No. 2 (larger) and No. 4 (smaller) were confined together in a flat cardboard box, three inches long, three quarters of an inch high and two inches wide, containing a few strips of coarse paper. They had been fed previously on the same kind of blood, No. 2 on November 24th (15 minutes);[3] No. 4 on November 1st

*Part II appeared in this Journal, 1912, vol. vii, pp. 163-188.

[1] All of these pairs were fed on human blood, usually at night near an electric light, feeding was usually accomplished by baring the arm, placing the fore arm across a clean sheet of paper and tilting the box confining that pair against the naked flesh at a place (lower fore arm) where there is little or no hair. Upon responding to the stimulus, the bugs would run up the sides of the containing box and insert the setae.

[2] Five and a half minutes of actual; one and a half minutes for insertion.

[3] Plus four and a half minutes for insertion of the setae.

and 24th for ten and eleven minutes,[1] respectively. The two bugs were not observed to mate, though they remained near each other. Consequently, on December 22nd, No. 4 was removed (it proved to be a female) and adult No. 3 added (9.30 p.m.). After a few minutes the latter approached the larger No. 2 and climbed upon its back, acting as though desirous of mating. No. 3 had been fed previously on November 24th (6 minutes) and December 19th (6 minutes). They were not further observed until 12.45 a.m., December 31st, when both were offered food; No. 2 gorged itself,[2] but No. 3 obtained only part of a full meal; after feeding, No. 3, a male, was again observed to climb upon the back of No. 2, a female. After several minutes the latter dislodged her mate. Food was again offered at eight o'clock, January 9th, 1908, but the meal was interrupted. At 7 a.m., January 10th, ten freshly deposited eggs were found; they proved to be fertile, and mating had doubtless occurred. Thereafter, oviposition with this pair occurred as follows, all the eggs being fertile.

Jan.	10	7 a.m.	10 eggs	Jan.	22-24		18 eggs
,,	10	noon	1 ,,	,,	24-25	night	3 ,,
,,	10	4 p.m.	1 ,,	,,	25	3 p.m.	2 ,,
,,	11	6 a.m.	3 ,,	,,	25	10 p.m.	2 ,,
,,	12	,,	2 ,,	,,	25-26	night	1 ,,
,,	12-13	night	6 ,,	,,	27	a.m	1 ,,
,,	13-14	,,	6 ,,	,,	27-28		3 ,,
,,	14	9-30 a.m.	2 ,,	,,	28	late p.m.	1 ,,
,,	14	7 p.m.	2 ,,	,,	29-30	night	5 ,,
,,	15	3 a.m.	1 ,,	,,	31	3 a.m.	1 ,,
,,	15-16	night	2 ,,	Feb.	1	by 6 a.m.	8 ,,
,,	17	4 p.m.	2 ,,	,,	1	6 p.m.	3 ,,
,,	18	4 a.m.	3 ,,	,,	2-3	night	3 ,,
,,	18-19	night	2 ,,	,,	4	2 a.m.	3 ,,
,,	19	7 p.m.	1 ,,	,,	6	4 a.m.	1 ,,
,,	19-20	night	4 ,,	,,	7-15		1 ,,
,,	20	noon	1 ,,				
,,	20-21	night	4 ,,			Total	109 eggs

The pair were offered food by tilting the edge of the box containing them against the fore arm at 10 a.m., January 10, 1908. The male was then on the side of the box opposite to the female which was nearest to the food, but after the latter commenced to feed, the male crossed over, climbed on her back and took food from that position. The female fed for ten and a half minutes,[3] the male for about six. When repleted, the female left, necessarily disturbing the male, which was

[1] Nine minutes actual feeding, two for insertion.

[2] Nine and a half minutes feeding, one minute for insertion.

[3] Plus two more minutes for insertion of the setae.

probably not fully fed. Immediately after leaving food, the female voided two drops of excrement (each drop about 1.5 mm. diameter), and after several minutes another about the same size. This excreted matter was of the colour and consistency of watery black ink, and when voiding it the female makes a characteristic movement described later. On January 12th it was noted that the pair were constantly together, the male on the back of the female. Mating had not been observed. The female was fed at 4.30 p.m., January 14th until nearly glutted,[1] and again at 9 p.m. the same day; at neither time did the male approach the host. Again at 7.20 p.m., January 18th, the female fed until satisfied,[2] and at the same hour the following day[3]; on this occasion the male partly fed itself.[3]

When both sexes were full fed, the female was twice as large as her mate. On January 19th the female fed for six minutes, though within twenty-four hours of a previous meal; she did not, however, respond as quickly as usual to the food stimulus. At the same time the male succeeded in obtaining part of a meal; he was disturbed by the female. At 9.15 p.m., January 25th, the female remained at food for ten and a half minutes, including insertion, becoming glutted; and the male for five minutes at 10 p.m. The latter was shy and induced to take food only when in almost complete darkness. At 10.30 p.m., January 27th, upon lifting the lid from the confining box, the pair were found apparently mating, end to end. Before this could be determined with certainty, however, they separated (presumably because of the sudden exposure to the bright light). The female died on February 15th. The male was fed and confined with adult No. 9 at 8 p.m., February 18th, constituting pair No. 3.

The female of this pair hatched at noon, August 27th, 1907, reached maturity at noon, October 30th of the same year, after having been given eight full meals. She was fed for the first time, after maturity, nearly a month later (November 24th), and was mated on December 22nd, after having been fed once more. About twenty days after being mated she began to lay fertile eggs, continuing nearly regularly to do so until her death on February 15th. A hundred and nine eggs were deposited in a period of thirty-six days, or about three per day. The history of the male is summed up in connection with pair No. 3.

(2) *Pair No. 2.* Adults Nos. 1 and 4 were placed together on

[1] Nine and a half minutes of actual feeding.

[2] For seven minutes, including insertion.

[3] For six minutes including insertion.

strips of paper laid side by side in a circular wooden box (about twice the depth of an ordinary pill-box) at 6.30 p.m., January 19th. No. 4 being small was supposed to be a male, and had been confined with adult No. 2 of the first pair (which see); subsequently, it had been isolated and was fed on January 12th at 2 p.m. Adult No. 1 had been isolated from maturity; it had fed previously on November 1st (10 p.m., 6 minutes), November 24th (11.30 a.m., $5\frac{1}{2}$ minutes), and December 19th (9 p.m., $5\frac{1}{2}$ minutes feeding, 3 minutes insertion). As soon as placed together the two females were shaded from the electric light; after remaining quiet for two minutes No. 1 moved over to No. 4, and climbed upon its back and then off again; No. 4 then crawled upon No. 1. These movements were continued for several minutes, No. 4 generally climbing on to No. 2. From these actions, which are known not to have any sexual significance, since both were females, it would seem that bedbugs recognize each other and are not adverse to company.

On January 25th, 9.40 p.m., under equal chances, the adult No. 1 fed until satisfied for five minutes, including insertion, but No. 4 refused food. However, at 10.20 p.m., No. 4 fed for six minutes, when placed in nearly complete darkness and exposed to the stimulus for some time (compare the actions of the male in pair No. 1), No. 1 also went back to food for one minute. At 7 p.m., February 18th, food was again offered, and No. 1 immediately accepted, becoming gorged after some minutes; No. 4 after several minutes rapidly ran to the food (fore arm placed over the edge of the box), disturbed No. 1, ran back to bottom of box and after remaining perfectly quiet for about a minute, again rapidly ascended and began to feed (before No. 1 had finished); it gorged itself. Again at 8 p.m., February 23rd, food was offered and No. 4 soon accepted and gorged itself, reversing its former behaviour, which was taken by No. 4 this time; for the latter did not respond positively to the stimulus at all, appearing to be very shy. However, at first, No. 4 also hesitated; both, in fact, at first ran nervously backwards and forwards. Thirty minutes later food was again offered upon which No. 1 cautiously[1] approached, remained a minute inserting its setae, but suddenly left.

Being convinced that both of these adults were females, at 8.30 p.m., February 23rd, 1908, adult No. 6, a male, was added to the box. Fifteen minutes later it was found (apparently) mating with No. 1, and five minutes later it attempted (apparently) to mate with No. 4; the latter was immediately removed and isolated in a vial. Both

[1] Certainly cautiously is the word; bedbugs are negatively phototropic.

females began to deposit fertile eggs on February 27th; adult No. 4 was therefore fertilised by adult No. 6. Nos. 1 and 6 constitute this pair, the female of which deposited eggs at the following times:

Feb. 27	early a.m. - -	3 eggs	Mar. 26-27	night - - -	3 eggs
,, 27	11 a.m. - -	1 ,,	,, 27-28	24 hours from 8 a.m.	1 ,,
,, 28	4 a.m. - -	2 ,,	,, 29	3-8 a.m. - -	1 ,,
,, 28	5 30 p.m. - -	1 ,,	,, 29-30	24 hours from 8 a m.	2 ,,
,, 29	6.30 a.m. - -	3 ,,	April 2-3	night - - -	1 ,,
,, 29	2.30 p.m. - -	2 ,,	,, 3-4	24 hours from p.m.	5 ,,
Mar 1	early a.m. - -	3 ,,	,, 4	10 30 p m. - -	3 ,,
,, 1-2	night - -	1 ,,	,, 5	4 a.m. - - -	1 ,,
,, 4	early a.m. - -	1 ,,	,, 5-6	night - - -	3 ,,
,, 4	4 p.m. - -	1 ,,	,, 6-7	,, - - -	3 ,,
,, 6	early a.m. - -	3 ,,	,, 7-8	,, - - -	4 ,,
,, 6	noon - -	1 ,,	,, 8	p.m - - -	1 ,,
,, 7	2 p.m. - -	1 ,,	,, 8-9	night - - -	2 ,,
,, 7	11 p.m. - -	2 ,,	,, 9	p.m. - - -	1 ,,
,, 8	4-30 a.m. - -	4 ,,	,, 9-10	- - -	2 ,,
,, 8-10	- -	6 ,,	,, 13	4-9 p.m. - -	1 ,,
,, 11	- -	1 ,,	,, 16	2-5 a.m. - -	1 ,,
,, 11-12	night - -	2 ,,	,, 16	p.m.-April 18 p.m.	6 ,,
,, 12	- -	1 ,,	,, 18-20	p.m. to p m. -	2 ,,
,, 13	- -	3 ,,	,, 20-21	24 hours from p.m.	4 ,,
,, 14-15	24 hours from a.m.	11 ,,	,, 21-22	,, ,, ,,	1 ,,
,, 15-16	p.m. to p.m., 24 hours	4 ,,	,, 23-25	- - -	4 ,,
,, 16	10 p.m. - -	1 ,,	,, 25-26	24 hours from p.m.	3 ,,
,, 16-17	p.m. to p.m., 24 hours	2 ,,	,, 26-27	,, ,, ,,	3 ,,
,, 19	8 9 p.m. - -	3 ,,	,, 27-28	,, ,, ,,	3 ,,
,, 20	3 a.m. - -	4 ,,	,, 29-30	,, ,, ,,	2 ,,
,, 20	p.m. - -	1 ,,	,, 30-May 4	- - -	7 ,,
,, 20-21	night - -	3 ,,	May 4-12	- - -	11 ,,
,, 21-22	24 hours from a.m.	3 ,,	,, 23-27	- - -	10 ,,
,, 23	- -	1 ,,	June 20-24	- - -	13 ,,
,, 24	- -	2 ,,			
,, 24-25	24 hours from 9 p.m.	4 ,,		Total	190 eggs
,, 25-26	night - -	5 ,,			

Of these hundred and ninety eggs all were fertile, except the last thirteen (June 20-24th), which failed to hatch. This fact is surprising, but the male had died two months previously and the final infertility of the female may be the more easily understood by reading the paragraphs concerning adult No. 4, added as a supplement to this pair.

The female of this pair was gorged with food at 8 p.m., March 7th, the male then refusing; however, at midnight, it finally accepted food after some hesitancy, the female leading the way for the second time and feeding again for about one and a half minutes; the male then quickly gorged itself. The male was also fed at 6 p.m., March 1st. Again the female gorged itself on March 15th at 8.10 p.m., the male then refusing until food was again offered at 8.30 p.m., when, after some minutes, it responded to the stimulus and gorged itself. Upon leaving the host, it went immediately to the female and mated (in the dorso-lateral position upon the female's back). Both were fed until glutted at 8.35 p.m., March 20th, the male as usual responding positively to the stimulus about twenty seconds later than the female, and occupying less time for engorgement and leaving sooner. At 2 a.m., March 29th, the female again fed for over twelve minutes, its mate not responding to the stimulus. The next day at 8 p.m. the male was again exposed to food, but again did not respond; the female, however, seemed eager to feed, but was prohibited. There appears to be quite a difference between the sexes in regard to appetite (compare pair No. 3 this date; but also compare the two females in No. 1). April 4th at 9.55 p.m., the female gorged itself, feeding for five minutes; at the same time, the male responded to the stimulus but did not approach the host. At 9.15 p.m., April 12th, the female fed for seven and a half minutes, in full glare of the electric light; the male for ten minutes, but feebly, not appearing to be able to extract much food, its body remaining flat but becoming tinged, slightly reddish. The body of the female was flat before feeding. The male died on April 18th, still coloured. It had not had a full meal since March 20th. This male hatched at noon, August 27th, 1907, came to maturity January 9th, 1908, after having been fed (not at any time to repletion) nineteen times; after maturity it was fed, in addition to the times recorded above, at noon, January 12th (engorged); 6 p.m. January 29th; 7 p.m. February 18th; 7.30 p.m. February 23rd, just before mated, and at 6 p.m. March 1st.

On April 20th, 10 p.m., the female, now alone, responded almost immediately to food and fed for ten minutes; afterwards, she at once expelled excrement. And again at 10.20 p.m., April 28th, it accepted food after forty seconds, glutting itself, feeding for seven and a half minutes. It was necessarily neglected after May 6th on account of illness, but at 8.45 p.m., May 16th, it was still alive though obviously rather weak yet still active and full coloured. It accepted food at once, feeding until satisfied (engorgement), and for eight and a half minutes, having no difficulty in inserting the setae. Oviposition was checked, and no eggs were deposited during the four or five days, since all progeny present in the box with her were all nymphs. Not until June 11th was another meal given. Then at 10.50 p.m., it responded to the host, feeding to engorgement and for eight minutes, plus five minutes for various attempts to insert the setae, there being much difficulty in this respect; the female was still normally dark but sluggish in movement, and no eggs had been deposited since May

27th. Nearly a month later, June 20th, a few *infertile* eggs were deposited, and on June 24th thirteen of these were removed.

At 12.21 a.m., July 4th, the female still full coloured was exposed to food by tilting the box containing it against the under portion of the fore arm; it responded (by a quick, short movement) at 12.24, going to the food at 12.25 and feeding for fifteen and a quarter minutes until enormously swollen; apparently there was no difficulty with insertion. At 12.55 a.m. the same day, the very small adult No. 10 (a male) was placed with her after having been fed (see pair No. 4); after three minutes, the two were together, the male upon the back of the female but not mating. However, later, at 1.45 a.m., they were evidently mating, as the extremity of the abdomen of the male stretched when separating from the female when the box was opened (at least, attempting to mate). The male was removed at 10 p.m., July 4th, to its original box. I did not observe it to have any further relations with this female, though such may have occurred.

The female deposited no more eggs. It was allowed to engorge at 8.45 p.m., July 20th, and without receiving more food, died on August 10th, 1908. Like the others, this female hatched at noon, August 27th, 1907, came to maturity at noon, October 30th of the same year, after having received eight full meals, was fed for the first time two and a half days after reaching maturity, but not mated until February 23rd, 1908, or over three and a half months after reaching maturity. It then deposited a hundred and ninety eggs in a period of nearly four months, or on the average about 1.6 eggs per day; fertile eggs were deposited for slightly over three weeks after the death of the male. Oviposition commenced four days after mating.

Supplement to Pair No. 2.—Adult No. 4. The history of this female is given in connection with the first two pairs. Its small size was the cause of its being mistaken for a male. It was fertilised by adult No. 6 on February 23rd, 1908, then depositing eggs as follows. No male present.

Feb. 27	early a.m.	6 eggs	Mar. 7	early a.m.	2 eggs
,, 27	11 a.m.	1 ,,	,, 7	3 p.m.	1 ,,
,, 28	4 a.m.	6 ,,	,, 7	10 p.m.	1 ,,
,, 28	7 p.m.	1 ,,	,, 8	4.30 p.m.	1 ,,
,, 29	early a m.	4 ,,	,, 12		1 ,,
,, 29	3 p.m.	4 ,,	,, 13		2 ,,
,, 29-Mar. 1	night	1 ,,	,, 14-15	24 hours from a m.	7 ,,
Mar. 1-2	night	1 ,,	,, 15-16	,, ,, ,, p m	2 ,,
,, 4	early a.m.	1 ,,	,, 19		4 ,,
,, 4	3 p.m., average	4 ,,	,, 19	8-9 p.m.	1 ,,
,, 6	early a.m.	6 ,,	,, 19-20	night	1 ,,

Mar. 20	p.m.	1 eggs	April 8-9	night	2 eggs
,, 20-21	night	3 ,,	,, 9	3 p.m.	1 ,,
,, 21-22	24 hours from a.m.	1 ,,	,, 9-10	night	1 ,,
,, 22-23	,, ,, ,, p.m.	4 ,,	,, 11		1 ,,
,, 24-25	,, ,, ,, ,,	3 ,,	,, 11-12	night	1 ,,
,, 25-26	night	2 ,,	,, 13-15		1 ,,
,, 26	3 p.m.	2 ,,	,, 15-18		3 ,,
,, 26-27	night	2 ,,	,, 18-20	p.m. to p.m.	5 ,,
,, 27-28	24 hours from a.m.	2 ,,	,, 20	9 p.m.	1 ,,
,, 29-30	,, ,, ,, ,,	1 ,,	,, 23-25	p.m. to p.m.	5 ,,
April 2-3	night	1 ,,	,, 25-26		4 ,,
,, 4	2 p.m.	5 ,,	,, 26-27		2 ,,
,, 4	9.40 p.m.	2 ,,	,, 27-28		2 ,,
,, 5	3 a.m.	1 ,,	,, 29-30		1 ,,
,, 5-6	night	2 ,,	May 3-4		5 ,,
,, 6-7	,,	1 ,,	,, 4-12		7 ,,
,, 7-8	,,	4 ,,			
,, 8	3 p.m.	2 ,,		Total	139 eggs

Of these eggs all were fertile, excepting the five deposited April 18th-20th, four of the five—deposited between April 23rd and 25th, and all the others after that date excepting the last seven, nymphs from which were found on May 15th; these eggs, with the exceptions noted, shrivelled.

The female was allowed to engorge at 7 p.m., March 7th, responding to the stimulus after but a few seconds; an egg was deposited within the next few hours. And at 8.20 p.m., March 15th, the female engorged, responding at once; also at 8.40 p.m., March 20th, feeding to engorgement for nine and a half minutes; at 1.15 p.m., March 29th, 12 minutes (including three and a half minutes for insertion of the mouth setae), and again for seven and a half minutes at 9.15 p.m., April 4th, responding to the stimulus after a minute and a half, and approaching food after two minutes of exposure to it. Exposed to food at 9 a.m., April 12th, in full glare of an electric lamp, the female responded and went to food after forty seconds and fed for six and a half minutes, until glutted; its body was flat before feeding. On April 20th, 1908, it fed for fourteen minutes until glutted—during this period it was accidentally disturbed and left the food for a minute and a half. Immediately after feeding, on the way from the host, the bug suddenly turned around, backed quickly, then ran forward a short distance, at the same time expelling a streamlet of dilute inky excrementitious matter. This appears to be a characteristic action when expelling excrement. April 28th, at 10.10 p.m., the bug fed for ten minutes until glutted, going to the host after a minute of exposure. Since it had by this date become infertile, a male (No. 2 of generation II) was added at 9.35

p.m., April 30th. Mating did not occur within the next ten minutes, though the two recognised each other. The male was removed at 8 a.m., May 1st. Mating must have occurred since the last seven eggs deposited (May 4th-12th) hatched; but five eggs deposited May 3rd-4th did not.

In order to prevent actual starvation the female was fed for one and a half minutes at 8.30 p.m., May 16th (plus three minutes for insertion). She died, however, on May 19th, 1908.

(3) *Pair No. 3.*—Adult No. 3, a male, was partly fed at 7.30 p.m., February 18th, and adult No. 9 gorged itself at 8 p.m. the same day; the two were then confined together. They remained perfectly motionless some distance apart until covered. Fifteen minutes later they were discovered mating; the male was upon the dorso-lateral aspect of the female's back with the abdomen curved under that of the female. They separted after four minutes, probably because of the disturbance. The female had fed previously since maturity at 6 p.m., January 29th; the male as recorded under pair No. 1. Both gorged themselves at 6.45 p.m., February 23rd, the male not approaching the host until five minutes after the female; but at 6 p.m., February 29th, both went to the host at once and gorged, the female feeding for one and a half minutes longer than the male. Again at 7.30 p.m., March 7th, both sexes gorged themselves, the female going to the food first, followed by the male several minutes later. Both sexes engorged at 7.30 p.m., March 13th, the female as usual approaching the host first, running to it, but the male cautiously; the former fed for at least two minutes longer than the male. Oviposition commenced a few days following pairing, and as follows :—

Feb.	22-23	night	4 eggs	Mar.	7	day	2 eggs
,,	23	7.30 p.m.	3 ,,	,,	7	10 p.m.	1 ,,
,,	23-24	night	2 ,,	,,	8-10		3 ,,
,,	25	early a.m.	6 ,,	,,	11-12		1 ,,
,,	25-26		2 ,,	,,	13	p.m.	3 ,,
,,	27	early a.m.	3 ,,	,,	14-15		5 ,,
,,	27	7 p.m.	2 ,,	,,	15	day	3 ,,
,,	27-28		2 ,,	,,	16	10 p.m.	1 ,,
,,	28	noon	1 ,,	,,	16-17	p.m. to p.m.	2 ,,
,,	28	5-6 p.m.	3 ,,	,,	19		4 ,,
,,	29	early a.m.	1 ,,	,,	19	8-9 p.m.	2 ,,
,,	29	3 p.m.	2 ,,	,,	20	p.m.	1 ,,
,,	29	7 p.m.	1 ,,	,,	20-21	night	3 ,,
,,	29-Mar. 1		1 ,,	,,	21-22		3 ,,
Mar.	1-2		1 ,,	,,	22-23		2 ,,
,,	4	day	6 ,,	,,	24	p.m.	2 ,,
,,	6	early a.m.	5 ,,	,,	24-25		4 ,,
,,	7	,, ,,	1 ,,	,,	25-26	night	2 ,,

Mar. 26	day	2 eggs	April 11		3 eggs
,, 26-27	night	2 ,,	,, 15-16	night	3 ,,
,, 27-28	a.m. to a.m.	3 ,,	,, 16-18	p.m. to p m	8 ,,
,, 28	late p.m.	1 ,,	,, 18-20	,, ,, ,,	3 ,,
April 3-4	p.m. to p.m.	6 ,,	,, 20	9 30 p.m.	1 ,,
,, 5	early a.m.	1 ,,	,, 23-25		6 ,,
,, 5-6	night	5 ,,	,, 25-26	p.m. to p.m.	3 ,,
,, 6-7	night	2 ,,	,, 26-27	,, ,, ,,	1 ,,
,, 7	day	2 ,,	,, 27-28	,, ,, ,,	1 ,,
,, 7-8	night	5 ,,	May 1-4		1 ,,
,, 8-9	night	1 ,,	,, 4-15		15 ,,
,, 9	day	3 ,,			
,, 9-10	night	1 ,,		Total	168 eggs

All of these hundred and sixty-nine eggs were fertile, excepting the one deposited between May 1st-4th, which shrivelled. At 8 p.m., March 20th, the pair were offered food and responded, the male last; they glutted themselves and then mated. At 1 a.m., March 29th, the female responded to the food stimulus and fed for nine and a half minutes, the male not responding. The latter was offered food several times at 8 p.m., March 30th, but did not go to it; the female, however, responded readily, but was prevented from feeding; her response was slower than usual. The male was active. On April 4th, at 8.45 p.m., the female responded to food after a minute and a half, the male a minute afterward, crawling upon the back of the female and apparently mating; the female fed this time for seven and a half minutes until glutted and then left, carrying the male with her; after a minute, the latter left the female and went to food, sucking for seven minutes; it had not fed while with the female. April 12th, at 9.30 p.m., the female responded and approached the food immediately, sucking for eighteen and a half minutes; but much of this time was occupied in attempts to piece the skin with the setae; at the same time the male responded to the stimulus with a slight movement, but did not approach. At 8.20 p.m., April 20th, both sexes responded at once, the female immediately approaching thereafter, and feeding for fourteen minutes until greatly distended; the male approached two minutes later and left two minutes earlier, also much distended. Upon leaving the food, the female crawled down near to the quiet male and then both rested for two minutes; then the female approached the male and rested her forebody across his, then deliberately turned around in her tracks. After several seconds the latter mated with her (dorso-lateral position); this act lasted for sixty-five seconds, and terminated with a few sudden spasmodic jerks of the male's body. The latter then crawled off the female. An egg was deposited at 9.30 p.m.

On April 29th at 9.55 p.m. the female fed for ten and a quarter minutes the male for nine and a quarter, the former responding at once, the latter following after one and a half minutes. After feeding, both immediately voided excrement, as is usual after a meal. The female died on May 10th, the male May 18th, 1908, both apparently from starvation.

This female hatched at noon, August 27th, 1907, and came to maturity on January 16th, 1908, at 11 p.m., after having been fed twenty times (but not to engorgement), and after moulting six times. It was fed for the first time after reaching maturity on January 29th, was mated on February 18th, and then deposited a hundred and sixty-nine eggs (February 22nd-May 15th) at the rate of two eggs per day.

The male hatched at the same time, and came to maturity on November 9th of the same year at 4 p.m., after having been supplied with eleven full meals. After maturity it was fed the first time on November 24th, and subsequently on December 19th; on December 22nd it was mated with adult No. 2 (see pair No. 1), with which it was confined until the death of that female on February 15th. It was then confined and mated with adult No. 9 of this pair as detailed above. It mated with two females.

(4) *Pair No. 4.*—On February 18th, 9 p.m. (1908), adults No. 10 and 8 were allowed to engorge, and were then confined together in a round wooden box. No. 8, the female, had fed previously at 6 p.m., January 29th; No. 10, the male, at noon, January 12th, and 6 p.m., January 29th. The first eggs were found at 7 a.m., February 23rd, the deposition being as follows :—

Feb. 22-23	night	3 eggs	Mar. 16	9.30 p.m.	1 eggs
,, 23	7.40 p.m.	1 ,,	,, 19		1 ,,
,, 23-24	night	2 ,,	,, 19	8-30 p.m.	1 ,,
,, 25	noon	1 ,,	,, 19-20	night	1 ,,
,, 25-26	night	4 ,,	,, 20	p.m.	2 ,,
,, 27	early a.m.	3 ,,	,, 20-21	night	3 ,,
,, 27-28		2 ,,	,, 21-22	a.m. to a.m.	3 ,,
,, 28	10 a.m.	1 ,,	,, 23-24	p.m. to p.m.	2 ,,
,, 28	6 p.m.	1 ,,	,, 24-25	,, ,, ,,	4 ,,
,, 29	7 a.m.	4 ,,	,, 25-26	night	1 ,,
,, 29	4 p.m.	1 ,,	,, 26	4 p.m.	3 ,,
Mar. 4	4 p.m.	5 ,,	,, 26-27	night	1 ,,
,, 6	early a.m.	3 ,,	,, 27-28	,,	2 ,,
,, 6	11 a.m.	1 ,,	April 3-4	p m. to p.m.	5 ,,
,, 7	5 p.m.	4 ,,	,, 4	9.50 p m.	1 ,,
,, 13	p.m.	4 ,,	,, 4	10.30 p.m.	1 ,,
,, 14-15	a.m to a.m.	6 ,,	,, 4-5	night	1 ,,
,, 15	4 p.m.	1 ,,	,, 5	day	1 ,,
,, 15-16	p.m. to p.m.	1 ,,	,, 5-6	night	2 ,,

April 6	day	1 eggs	April 18-19		1 eggs
,, 7		1 ,,	,, 19-20		1 ,,
,, 7-8		3 ,,	,, 23-25		6 ,,
,, 8	day	1 ,,	,, 25-26		2 ,,
,, 8-9	night	3 ,,	,, 26-27		1 ,,
,, 9-10	night	1 ,,	,, 27-28		3 ,,
,, 11		3 ,,	May 4-11		9 ,,
,, 13-15	p.m. to p.m.	1 ,,			
,, 15-18		9 ,,		Total	130 eggs

All of these eggs were fertile. Both sexes were fed until gorged at 7 p.m., February 23rd, both going directly to the food. An egg was deposited thirty minutes later. Both were again allowed to engorge at 6.30 p.m., February 29th, both responding after a few seconds; at 7.30 p.m., they were found mating (end to end position). On March 7th, at 8 p.m., the response to the food stimulus was almost immediate, both running quickly to the host a second or two after exposure; also on March 15th, at 7.45 p.m., they were allowed to engorge, the male responding positively forty-five seconds slower than the female, and leaving the food a minute and a half earlier. At 8.20 p.m., March 20th, the female actually ran to the food immediately following exposure, the male following a quarter of a minute later, both engorging. The female approached the food just a few seconds before the male at 1.30 p.m., March 29th, and fed for seven and a half minutes until glutted; this time the male fed for five and a half minutes, and then left the food, ran "excitedly" to the female and mated (or at least attempted to) for five times in succession, each act lasting only one or two seconds, and done while the female still fed. The latter responded and after three quarters of a minute went to food at 9.25 p.m., April 4th, feeding for seven minutes; the male followed a minute after the female, and fed for four minutes. Both were glutted. On April 12th, at 8.40 p.m., in the presence of a bright light, the female went to food, at once feeding for twelve minutes, taking some time for insertion of the setae; the male this time ran rapidly to the host after about thirty seconds, and during the eleven and a half minutes ensuing tried "desperately" to feed, but was unable to insert the mouth-parts. It was flat from lack of food; the female was also flat before feeding

Both sexes ran to the food immediately after exposure at 8.45 p.m., April 20th, the male leading. Both began to feed at once, the female for six and a half minutes, the male for ten; the latter was not repleted for the mouth-parts were inserted with difficulty. After feeding, as usual, both voided ecrement. This was done by rapidly backing, stopping, expelling the excrementitious matter, and as it came forth running rapidly ahead; sometimes, at the commencement, a rapid turn about occurs, followed by the other movements. This is characteristic. At 10.5 p.m., April 29th, the female responded positively to the food stimulus at once, the male following after thirty seconds, pushing the female out of its place. Both then fed, the male for four and a half minutes, the female for eight minutes. Three minutes later mating occurred. The female died on May 11th, from necessary neglect, its body still fully coloured. After four attempts the male succeeded with the insertion at 8.30 p.m., May 19th, and fed to repletion. And again after two and a half minutes of insertion at 11.5 p.m., June 11th, feeding to repletion and for four minutes; before this meal it was still normal in colour and active. In the same condition, at 11.48 a.m., July 4th, the male fed for six minutes, including the time taken for insertion of the mouth-parts; at 12.55 a.m. it was placed with adult No. 1 (pair No. 2) in order to fertilize that female again; it was isolated again at 10 p.m. the same day. It died August 8th, 1908, fully coloured but thin, not having been fed since.

Thus, the female of this pair hatched at noon, August 27th, 1907, reached maturity at 6 p.m., January 17th, 1908, after having been fed twenty times (but never to repletion), was fed for the first time following maturity at 6 p.m., January 29th, and mated at 9 p.m., February 18th, after a second engorgement. Oviposition commenced four days later, and continued without break until death (May 11th), a hundred and thirty eggs being deposited at the rate of 1.5 per day.

The male had a history nearly similar to that of the female, hatching at the same time and similarly fed (*i.e.*, never to repletion), reaching maturity at 7 p.m., January 9th, 1908, after feeding sixteen times. It was mated on February 18th, and lived continually with the female until her death on May 11th; it was again mated on July 4th, but isolated after about twenty hours, dying shortly afterwards (August 8th, 1908).

2. *A Second Generation.* Direct descendants of the first generation, the following pairs originated from pair No. 1, which deposited eight eggs about 6 a.m., February 1st, 1908, these eggs hatching at about 4 p.m., February 10th, following (average time). All of the nymphs were fed to repletion at each meal, and were kept isolated. After reaching maturity they were paired off as narrated herewith.

(1) *Pair No. 1.* Adults No. 1 and 7, the former the female, were confined together in a small glass tube at 7 p.m., March 18th, 1908;

neither had fed since maturity. After several minutes they mated, the act lasting but two or three minutes (in bright light). Both went simultaneously to food at 7.30 p.m., March 19th, and they were then transferred to a coverglass box. Oviposition was as follows:

Mar. 25	6 p.m.	3 eggs	April 8	day	2 eggs
,, 25-26	night	1 ,,	,, 9	,,	1 ,,
,, 26	day	1 ,,	,, 11-12	night	3 ,,
,, 26-27	night	2 ,,	,, 12	day	2 ,,
,, 27-28	,,	1 ,,	,, 12 13	night	4 ,,
,, 29-30	,,	1 ,,	,, 13-15	p.m. to p.m	8 ,,
,, 30-31	,,	1 ,,	,, 18-19		1 ,,
,, 31	noon	2 ,,	,, 22-23		2 ,,
April 1		2 ,,	,, 23-25		11 ,,
,, 2	early a.m.	2 ,,	,, 25-26		2 ,,
,, 2	11 a.m.	1 ,,	,, 26-27		1 ,,
,, 2	midnight	1 ,,	,, 28-29		1 ,,
,, 4	9 p.m.	1 ,,	,, 29-30		1 ,,
,, 4	10.30 p.m.	2 ,,	,, 30-May 4		12 ,,
,, 5-6	night	3 ,,	May 4-11		3 ,,
,, 6	day	2 ,,			
,, 6-7		4 ,,		Total	86 eggs
,, 7	day	2 ,,			

At 8 p.m., March 26th, the female went to food immediately, and as usual the male followed after about twenty seconds, leaving much earlier. Both were again glutted at 7.50 p.m., April 1st, the male approaching the food as soon as the female and feeding for ten minutes; the female fed for nine and a half minutes. On April 7th, at 8.50 p.m., the female responded to the stimulus after a half minute, and fed for nine and a half minutes; her mate responded after a minute and a half, then went slowly to food, changed position because of disturbance, approached the female and leaped upon her back, clung to her and fed while in that position, leaving the food after four minutes and a half, fully gorged. Apparently, mating did not occur and the female continued feeding steadily after the male left. The female fed for nineteen minutes until glutted at 9.30 p.m., April 18th, approaching the food a minute before the male; the latter fed for seven minutes (including four minutes for insertion of the mouthparts) and then left, approaching again after several seconds, fed for four minutes (plus insertion), then leaving, but returning again after several minutes, but this last time retreating before reaching the host. At 8.30 p.m., April 26th, the male preceded the female to food by one and a half minutes and fed for eight minutes until glutted; the female fed for twelve minutes until glutted. The female died between May 8th and 14th, 1908, not having been fed again. The male was fed to repletion at 7.30 p.m., May 18th, and again at 11.20 p.m., June 15th. At 1.39 p.m., July 4th, it fed (until satisfied) for eleven minutes, having difficulty with insertion of the mouth-parts. It was not fed subsequently and died of starvation on November 4th, 1908, still fully coloured.

The female of this pair came to maturity at 9 a.m., March 18th, and was mated ten hours later, obtaining its first meal on March 19th. It commenced to lay fertile eggs at 6 p.m., March 25th, continuing until May 11th or until its death, depositing them at the rate of about a little less than two per day. The female obtained seven full meals before reaching maturity. The male became adult at 2 p.m., March 17th, 1908, after six full meals.

(2) *Pair No. 2.* Adult No. 2 was added to the vial containing adult No. 3 (large) at 7 p.m., March 18th, 1908, neither having been fed since maturity; they apparently mated soon afterwards Both went to food simultaneously at 7.45 p.m., March 19th, after a few seconds of exposure to the host. They again glutted themselves at 8.30 p.m., March 26th, the larger (mistaken for a female) as usual approaching food first, a slight delay following exposure to the stimulus; about ten minutes later, the smaller followed, crawling upon the back of the larger male and feeding from that position. (*Note.* These actions were first taken for mating until it became known that both the adults were males). At 8.45 p.m., April 1st, food being offered the smaller responded after a minute, the larger after two minutes, feeding for three and a quarter, and three and three quarter minutes, respectively. Again at 9.20 p.m., April 7th, response to the stimulus occurred after one and a half minutes, and a half minute later the smaller male went to food, feeding until glutted (three minutes); three and a half minutes after the first response the larger male went to the host, meeting the smaller leaving; the latter pounced upon the larger's back and then off; after seven minutes the larger male stopped feeding and moved over about a quarter inch, commencing again and feeding for four and a half minutes longer (total of eleven and a half minutes). Once, during the meal, adult No. 2 approached the larger adult, mounted upon its back and then off again, but made no movements like those of mating.

On April 18th, at 10.15 p.m., the larger male approached the food a minute before the smaller; both fed to engorgement, the former for four and a half minutes, the other a minute less. But on April 26th, at 9.10 p.m., the smaller male responded and went to the host at once, becoming engorged after four minutes and a half. A minute afterward adult No. 2 went to the host and fed for six minutes. During the interval and while feeding No. 2 often crawled upon the back of No. 3, acting as if to mate, even bending the top of the abdomen around beneath the other. At 9.35 p.m., April 30th, No. 2 was mated with female. No. 4 of the first generation (which see). May 18th, 8 p.m., No. 2 preceded No. 3 to food by thirty-five seconds, and both fed to repletion; and again at 11.30 p.m., June 15th, 1908. July 4th, 1.12 a.m., No. 3 preceded No. 2 to the host by one minute, feeding for seventeen minutes, having great difficulty in puncturing the skin; it engorged, however. Adult No. 2 fed for seven minutes, and after finishing went over at once to No. 3, crawled upon its back, bending the tip of the abdomen under in the exact position of mating pairs; this occupied about a second of time, and was repeated twice hereafter in quick rushes to and from No. 3.

Both died about September 20th, 1908, without receiving further attention. Both adults hatched about 4 p.m., February 10th, 1908, and came to maturity at about 9 a.m., March 18th (No. 2), and 6 a.m., March 17th (No. 3) of the same year after receiving (No. 2) five and seven (No. 3) full meals, respectively. The further history is as above.

(3) *Pair No. 3*. Adults Nos. 5 and 6, the former the female, were placed together in a wooden cover-glass box at 7.30 p.m., March 22nd, 1908. They did not approach each other. Food being offered, the male went to it and gorged, after remaining quiet for several minutes. Upon leaving food it went at once to the female, but was evidently repulsed. The female then went to the host, glutted itself, left, and then actually ran to the male, which mated with her (dorso-lateral position); the act only occupied two or three seconds, but to all appearances was completed. Oviposition was as follows:—

Mar.	27	3 p.m.	1 eggs	April	9	day	3 eggs
,,	27-28	night	2 ,,	,,	11-12		6 ,,
,,	28	day	2 ,,	,,	12	afternoon	1 ,,
,,	29	3 to 8 a.m.	3 ,,	,,	13	10 a.m.	2 ,,
,,	29	day	1 ,,	,,	13	4-5 p.m.	3 ,,
,,	29-30	night	2 ,,	,,	13-15	p.m. to p.m.	4 ,,
,,	30-31	,,	4 ,,	,,	15	10 p.m.	1 ,,
April	1		3 ,,	,,	15-18	p.m. to p.m.	1 ,,
,,	2	early a.m.	2 ,,	,,	22-23	,, ,, ,,	2 ,,
,,	2	forenoon	1 ,,	,,	23-25	,, ,, ,,	7 ,,
,,	2	midnight	1 ,,	,,	25-26		3 ,,
,,	4	,,	1 ,,	,,	27-28		3 ,,
,,	4-5	night	2 ,,	,,	29-30		1 ,,
,,	6	day	5 ,,	,,	30-May 4		11 ,,
,,	6-7		3 ,,	May	4-15		4 ,,
,,	7	day	2 ,,				
,,	7-8	night	1 ,,			Total	89 eggs
,,	8-9	,,	1 ,,				

All these eggs were fertile. The pair glutted themselves from the host at 8.45 p.m., March 26th, both responding positively to the food stimulus at about the same time; at 7.50 p.m. they had been observed to mate (to appearances), the act lasting but several seconds, and occurring under a bright light. At 8.10 p.m., April 1st, the female after responding at once to the stimulus, fed for seven minutes and to repletion. Just as it turned to leave the host the male ran forward and upon meeting the other pounced upon its back and mated. After half a minute the two parted, and some seconds afterward the male went to the host and fed for three and a half minutes to repletion. On April 7th, at 10 p.m., the female responded to the food stimulus a half minute after exposure, the male immediately following it to the host, crawling on to the female's back; both commenced to feed, but the male left before insertion of the setae and took another feeding position. The female fed for seven minutes, the male a half minute less.

April 18th, at 10 p.m., the female went to food a minute before the other, and fed for seven minutes to repletion. The male fed for four and a half minutes. At 8.50 p.m., April 26th, the female fed for twelve and a half minutes, becoming enormously swollen; the male held back, but eight minutes after the female commenced to feed it ran suddenly forward and jumped upon the female's back, feeding from that vantage for four minutes and a half. Both left at the same time, and immediately thereafter voided excrement.

The female died on May 15th, apparently from starvation. The male engorged at 8 p.m., May 18th, and again at 11.50 a.m., June 15th. At 2.2 a.m., July 4th, the male again accepted food and fed for nine and three quarter minutes. It died on September 24th, 1908, without other meals. The female of this pair hatched at about 4 p.m., February 10th, 1908, and came to maturity at 6 a.m., March 22nd, after seven full meals; the male hatching at the same time matured at 7 a.m., March 19th, after the same number of meals.

(3) *A Third Generation.* A third generation was directly descended from the second generation, pair No. 3. The eggs hatched at the average time of 2 a.m., April 20th, 1908 (see part II). The following matings were made, but not very carefully watched.

(1) *Pair No. 1.*—Adults No. 1 and 2, the former the female. Confined together at 10 p.m., July 19th, 1908. But few eggs resulted, as follows :—

July 26	6 a.m.	2 eggs	Aug. 10	4 a.m.		10 eggs
,, 26	7 p.m.	3 ,,				
,, 27	6 a.m.	5 ,,			Total	20 eggs

All of these eggs were fertile. On July 31st, at 9 p.m., the pair were glutted and again at 4.30 p.m., August 10th. The female died September 1st; the male, October 2nd, 1908. Neither were fed until after they had been mated.

(2) *Pair No. 2.*—Adults No. 4 and 6, both females, hence no eggs. Fed on June 19th, 1.50 a.m., after mated, July 31st, 9 p.m. and 7.30 p.m., October 9th, 1908. They died about January 15th, 1909.

(3) *Pair No. 3.*—Adults No. 3 and 5, both females. Confined at 10 p.m., July 19th, 1908, died on September 18th, 1908, after receiving but one meal (at 9 p.m., July 31st).

Supplementary Notes.

An adult male captured in a bed in a hotel at Normal, Illinois (U.S.A.), 10 p.m., March 18th, 1910, coloured but not recently fed, was kept in a tin box and fed at 1.10 p.m., March 20th; responded positively to the stimulus after two minutes of exposure; after three minutes the setae had been inserted and engorgement resulted after five minutes. On March 26th, a larger adult male was captured at 2.20 a.m., on my leg immediately after getting out of a bed in a hotel in Chicago; at 2 p.m., March 30th, it was placed in with the first one; this second male when captured was coloured and partly fed. First, however, it was fed for seven minutes and a half (plus a minute and a half more for insertion). When the meal was completed, the first male immediately climbed upon its back and assumed the position of mating, riding thus for ten minutes; no actual mating, of course, but these actions could be easily mistaken for such. During the time that the Chicago specimen fed, the Normal male, unfed since March 20th, and hiding under the loose paper in the box, responded several times to the stimulus, but gave a negative reaction upon reaching full daylight. It responded positively after seven minutes' exposure at 8 p.m., March 30th (in shadow), feeding to repletion for four and a half minutes (plus three minutes more for insertion). Upon engorgement it backed off, turned round, stopped, backed again, and then while voiding a drop of excrement, walked forward. The other male responded sooner, but did not feed. Both died, fully coloured, April 20th, 1910, without other meals.

Tropisms.

Bedbugs react to certain physical stimuli characteristically. The reactions to light and food are those most strongly marked, while the individuals also react to contact. In regard to light, the nocturnal habit of the species is well known. Nevertheless, although this reaction normally is markedly negative, its strength is weakened by the stimulus of hunger. Thus, while the species is normally nocturnal and feeds nearly always at night in the presence of a constant host, yet when the presence of the latter is unconstant and hunger supervenes the latter becomes dominant, and the insect will overcome its negative reaction. Hence, bedbugs will visit a host in daylight or in bright, artificial lights (electricity, coal gas) when hungry. However, the food stimulus may cause them to enter a light field gradually, indicating that they soon become accustomed to light; as soon as the food stimulus is neutralized by engorgement, however, the negativeness to light becomes dominant again, and the insect runs off to hide itself. The greatest dominance of the food stimulus over negative phototropism appears to occur when a hungry individual has actually commenced to suck blood.

The reaction to food is characteristic and marked; thus, when confined in a small pillbox, as noticed already, and the latter is opened and its edge tilted against the naked arm, the insect first makes no movement. It shows no immediate indicative response to the stimulus. After a varying interval, maybe of not more than several seconds, it makes a (or several) short, sudden, jerky movements, immediately relapsing into immobility; this is what may be taken to be the actual response to the stimulus, the unconscious recognition of the presence of the food. After this, advance to the food is made, directly after some seconds or else indirectly, a number of indirect movements in the general direction of the food being made. Food is then taken to engorgement, excretion follows, and the bug then hides itself.

Reaction to contact is evidenced by the fact that these insects nearly always insert themselves into crevices, so that both sides of the body are in contact with an object. When hiding in holes, such as vacant screw-holes in wooden bedsteads, a number are usually piled one upon the other. Their flat bodies as well as their habits tend to show that the reaction is a real one. Thus they are gregarious (but not cannibalistic, at least in confinement), and as noticed, the pairs, or two males, seemed to like contact, frequently crawling over each other.

These three reactions seem to be the dominant ones in the life of the Cimex.

Food.

Cimex lectularius has never been known in nature to feed upon any other host than man. Experimentally, myself and others have shown that it will readily feed upon mice (Girault and Strauss, 1905) young and old; later, I have seen hungry individuals feed readily upon the blood of the English Sparrow, the North American Mole, and the Guinea Pig. Many individuals subsisted for several months on the blood of the latter, and oviposition occurred. The same individuals will feed upon two different hosts (in confinement), as the guinea pig and man, or the sparrow and mice, after having lived upon man. Bedbugs have been observed feeding at as low a temperature as 56° Fahrenheit.

Miscellaneous and Concluding Notes.

The following observation was made upon an isolated individual now in the ultimate larval stage, but captured five months previously and fed irregularly. It was inverted over the under surface of the forearm at 7.55½ a.m., March 31st, 1906, and immediately attempted to feed, the labium bending in three places, the setae straight; it had not fed previously since the fifteenth of November preceding. The first blood entered the body not until after four minutes, and the abdomen was much distended two minutes later; feeding ceased after six and a half more minutes. While feeding the pulsations in the head, near the base of the nostrum were at the rate of three per second; the insect was immensely swollen after this meal. On November 15th, preceding, it fed for eight minutes; on May 9th, 1906, it engorged from the cold body of a dying mole, and twelve days later fed on human blood for four minutes and a half; and on June 2nd following, for seven and a half minutes, both times to engorgement. Reaching maturity after moults on September 28th, 1905, and April 13th, 1908, a few infertile eggs were deposited. This individual was captured from a human bed, fed once from the blood of a common house mouse, twice on human blood, once on that of the mole, and then twice more on human blood.

Upon hatching the bedbug is perfectly white, becoming after several hours a light straw yellow. After the first full meal all of the body is coloured red excepting the extreme tip of abdomen, the head, thorax and legs.

I have captured bedbugs in large numbers from the common types of iron bedsteads, so that it is a fallacy to think that they are adverse to hiding in them. These captures were made from single beds in hotels and boarding houses, and also from beds ranged side by side in numbers in the large rooms of cheap lodging-houses in cities; in the former cases the insects were hiding in the walls of the rooms, but in the latter in the beds themselves.

When feeding bedbugs have an "alert" attitude, and while puncturing the skin a slow, back and forward motion is made; after actual feeding commences, slow, gradual movements do not greatly disturb them as the movement is followed up. The movements of a sleeping host would not greatly disturb them, at least not so much as to deter them from obtaining satisfaction; they readily return to the host if disturbed sufficiently to cause temporary retreat.

A fertile egg shrivels as the embryo develops, and several longitudinal sunken areas appear about the time the body of the embryo becomes visible. Two young and pale bugs of the first stage captured while hiding in the crease at the edge of a mattress in a berth on an excursion steamer at about eleven o'clock, August 7th, 1907, were at once place together in an ordinary pillbox and left unfed. One died on the fourth of September following, the second seven days later. This observation was overlooked, and should have been included in part II.

LITERATURE REFERRED TO.

1905. Girault, A. A. and J. F. Strauss. Psyche, Boston, pp. 117-123.

REFERENCES TO PREVIOUS PAPERS ON THE BEDBUG.

In order to bring together all of my published data on this insect, I append the following list of articles:—

1905. Psyche, Boston, pp. 61-74.
1906. Ibidem, pp. 42-58.
1906. Journ. American Medical Assoc., Chicago, xlvii, pp. 85-87.
1907. Science, New York, new series, vol. xxv, p. 1,004.
1907. Zoologische Annalen, Wurzburg, pp. 143-201.
1908. Psyche, Boston, pp. 85-87.
1908. Zoologische Annalen, Wurzburg.

CORRECTIONS.

The following errors occurred in printing part II of this series:—

Page 165, line 7, for maxim *read* maximum ; line 17 for 10=liniata *read* 10=lineata.

Page 168, first footnote, line 1, for plant *read* planting.

Page 172, line 25, for where *read* when.

Pages 178-181, Tables III and IV, line 1, sex names should be in the singular.

ON SOME COCCID PESTS FROM THE SEYCHELLES.

By E. ERNEST GREEN, F.Z.S., F.E.S.

A SMALL collection of insect pests, received from Mr. R. Dupont, Superintendent of Botanic Gardens, Seychelles, contains the following species of Coccidae :—

1. *Aspidiotus ficus,* Ashm.; on leaves of *Zamia* sp.

Zamia is an ornamental Cycad largely cultivated in tropical gardens. It is subject to numerous insect pests, of various orders, and the present species adds one more to the recorded number.

2. *Aspidiotus bromeliae,* Newst.; on leaves of Pineapple.

The discovery of this species, in the Seychelles, is of peculiar interest, as, hitherto, it has been recognized only from examples found on pineapples purchased in the English fruit markets, and said to have been imported from the Canary Islands. (Vide "A Monograph of the British Coccidae," Newstead, Vol. i., p. 87). The question arises, Is the species indigenous in the Seychelles? Or is it, there also an introduction? Judging from the extensive infestation of the single leaf submitted to me, *A. bromeliae* promises to be a somewhat serious pest to the cultivator of pineapples in the tropics. Its introduction to other countries should be guarded against by careful quarantine regulations. Serious pests are usually introductions, and, *vice versa,* imported insects are more likely to develop into serious pests. In view of the possible importance of this particular pest, it is desirable to ascertain the real headquarters of the species. It has not been recorded from the West Indies or the American continents. Mr. Newstead's evidence points to the Canary Islands. If it should be found to occur on indigenous Bromeliads, in those islands, the presumption would be stronger.

3. *Lecanium hesperidum,* auct., and 4. *Lecanium tessellatum,* Sign.; on leaves of the "Water Hyacinth."

The Water Hyacinth, though of considerable beauty, has proved itself to be an unmitigated plague in many countries where, by its excessive and rapid growth, it has blocked the waterways. These insects, therefore, may be considered beneficial in their relation to this particular plant.

5. *Lecanium hemisphaericum,* Targ.; on leaves of *Justicia gendarussa.*

Many of the Justicias are ornamental flowering shrubs. They appear to be particularly liable to Coccid infestation. In Ceylon, most of the cultivated species of *Justicia* fall victims to *Orthezia insignis.* *Lecanium hemisphaericum* is a cosmopolitan pest, and no plants (except, perhaps, those of the orders *Coniferae* and *Gramineae*) appear to be immune to its attacks.

Bearsted, Kent, 20 Oct., 1913.

REVIEWS.

THE FUNGI WHICH CAUSE PLANT DISEASES. By F. L. Stevens. Pp. ix + 754, 449 figs. New York: The Macmillan Company, 1913. Price 17s. net.

Mycologists and students of mycology have long required a concise and handy text-book of the more important cryptogamic parasites affecting economic plants, with sufficient keys and descriptions to enable their identification, and Professor Stevens' latest work goes far to provide this.

With the works of Saccardo, Engler and Prantl and others to draw upon, we should have liked to have seen better Keys, for most of them are too brief for the student, indeed brevity might be said to be the chief fault in this work, in spite of its seven hundred printed pages. Many genera embracing a large number of species are dismissed with a description of two or three lines. Much space might have been saved by a different arrangement of the various bibliographies (some of the titles and references are very bewildering) which occupy upwards of forty pages. Finally, in a work of this kind, it is hardly necessary to reproduce figures of the fruit-bodies of the larger Basidiomycetes.

All the above are, of course, matters of individual opinion, and our questioning of their value does not in any sense mean that we fail in our appreciation of a very excellent work which must prove of great value to all students.

OUR COMMON SEA-BIRDS. By Percy R. Lowe. Pp. xvi + 310 and 239 figs. London: "Country Life" Ltd. [1914]. Price 15s. net.

Of the numerous illustrated books on birds, and there is no dearth of them, few have anything to recommend them beyond the illustrations. The details as to life-history, habits, migration, etc., are most meagre and not always correct. Mr. Lowe's beautifully illustrated work is of a very different character. The illustrations throughout are charming, but there is in addition a wealth of information on the habits, migration, nesting sites, methods of feeding the young, food, distribution, etc., all described in simple and clear English. Further, we have special chapters by Mr. W. P. Pycraft on the natural history of the Cormorant and on the Guillemot's eggs, by Mr. Bentley Beetham on the flight of birds, by Mr. W. R. Ogilvie-Grant on the changes of plumage in the Cormorant and another on the Little Auk, by Mr. A. J. R. Roberts on the home of the Skuas, and one by Dr. Francis Heatherley on the Puffin at home, all of which add to the interest of the work.

It is some time since we have been so interested in a "bird-book," and look forward with much interest to the appearance of the second volume. In this we hope the author will give a detailed bibliography of the numerous works quoted from.

No one interested in the natural history of birds should fail to secure a copy of this enchanting work, which reflects the greatest credit on author and publishers, and the numerous naturalist-photographers who have assisted.

THE BRITISH RUST FUNGI (Uredinales) their Biology and Classification. By W. B. Grove. Pp. xii + 412, 290 figs. Cambridge: The University Press. Price 14s. net.

During the past twenty years very rapid strides have been made in our knowledge of the physiology and morphology of the different groups of fungi. Since Plowright wrote his justly eminent Monograph on the Uredineae, the works of the brothers Sydow, Ed. Fischer, and McAlpine have been issued, and a host of other workers have contributed to the advancement of our knowledge of the Uredinales or Rust Fungi.

In the work before us much of this knowledge has been summarised, together with many original observations and a distinctly refreshing method of treatment.

Mr. Grove divides his book into two parts, the first treating of the life-histories and reproduction, with chapters on immunity and classification and phylogeny; whilst the second is devoted to the purely systematic part. Here closely allied forms have been grouped, in a few cases, under a common name, and we welcome this stand against the excessive multiplication of species. The inclusion of the figures in the text is also very helpful.

This volume gives evidence of really careful and patient work, and must for some time to come be regarded as the leading text-book on the subject.

THE DISEASES OF TROPICAL PLANTS. By M. T. Cook. Pp. xi + 317, 85 figs. London: Macmillan & Co., Ltd., 1913. Price 8s. 6d. net.

This is a work intended primarily for the planter, and Dr. Cook is to be congratulated on its production. As most students of the pathology of tropical plants are aware, the literature on the subject is scattered, frequently very indefinite in character and generally inaccessible.

The author has fully grasped the kind of work that will prove of value to the planter, and the descriptions and information given under the different plants is always concise, clear, and practical. This is seen again in the chapter on prevention and control.

To the student the work forms a most useful introduction to the diseases of tropical plants, whilst a very full bibliography to the general literature on the subject and the special monographs and writings on the diseases of particular plants will prove most helpful.

We look forward to further and much enlarged editions of this excellent work.

THE DISEASES OF ANIMALS. By N. S. Mayo. Eighth edition, pp. xvi +459, 59 figs. New York: The Macmillan Company. 1913. Price 6s. 6d. net.

The fact that Professor Mayo's book has now reached its eighth edition may be taken as an indication that such a work was needed, and that this particular one has met the demand.

The present edition differs little from previous ones. The different diseases are clearly and concisely described, and illustrated by carefully selected figures. There is a distinctly "common-sense" flavour about many of the methods of treatment, which will recommend the work to the farmer and all who have the care of domestic animals. Special attention has been given to the use of domestic and simple remedies, whilst complicated medicinal treatment, frequently dangerous in unskilled hands, has been purposely omitted.

Special emphasis is laid upon prevention, sanitation and careful handling, and generally upon a more rational treatment of animal diseases.

MILDEWS, RUSTS AND SMUTS. By George Massee, assisted by Ivy Massee. Pp. iii + 229. London: Dulau & Co., Ltd. 1913. Price 7s. 6d. net.

Mr. Massee's useful and compact synopsis of the families Peronosporaceae, Erysiphaceae, Uredinaceae and Ustilaginaceae will prove most useful to those mycologists interested in these families, but the value of the work, would, we think, have been considerably increased had the 64 figures, given on the four plates at the end of the volume, been introduced in the text

Apart from excellent descriptions throughout, there is a very full index of genera and species and one of host plants. The book cannot fail but prove a most useful handbook.

THE LIFE-STORY OF INSECTS. By Geo. H. Carpenter. Pp. iv + 134 and 23 figs. Cambridge: The University Press. 1913. Price 1s. net.

Professor Carpenter set himself no easy task when he decided to portray the story of the transformations of insects in a little over a hundred pages of these delightful Cambridge Manuals. He has succeeded, however, in presenting a most interesting account of the adaptations and modifications of larvae and pupae and of the general metamorphoses of insect life, in spite of the limitations of space.

THE

JOURNAL OF ECONOMIC BIOLOGY.

RECENT ADVANCES IN OUR KNOWLEDGE OF THE GENUS *PHYTOPHTHORA*.*

BY G. H. PETHYBRIDGE, PH.D., B.SC.,

Economic Botanist to the Department of Agriculture and Technical Instruction for Ireland.

(WITH PLATES II AND III).

As usually understood the genus *Phytophthora* comprises a considerable number of species of fungi, all of which are parasitic on living plants, while many of them have been cultivated saprophytically with success.

Several of them are of great economic importance, since the diseases which they cause in cultivated crops often result in very serious losses. In this connection it is sufficient to mention the ordinary potato blight to indicate the extent to which such losses may frequently run.

When de Bary, in 1866, described[1] the details of the development of the conidiophores and conidia of the potato blight fungus, then known as *Peronospora infestans*, Mont., he showed that whereas in species of *Peronospora* such as *P. parasitica, P. effusa*, etc., only one conidium is formed at the tip of each branch of the conidiophore, in *Peronospora infestans* two, three, or even many conidia may be developed successively on each branch, their positions being indicated

* Read at the Liverpool Meeting of the Association of Economic Biologists, December 31st, 1913. The spelling of many of the specific names is in accordance with the custom of this Journal, for which the Editor, and not the Author, is solely responsible.

[1] de Bary, A. Zur Kenntniss der Peronosporeen. I. Die Conidienbildung von Peronospora infestans. Abhandl. d. Senckenb. naturf. Gesellschaft. Bd. 5, also, Beitr. 2. Morph. u. Phys. der Pilze (de Bary and Woronin). Bd. 1, Reihe ii, 1866, p. 35.

by the presence of characteristic swellings on the branches which, up to that time, had not been accounted for satisfactorily.

At the close of this short paper de Bary suggested that on account of this characteristic mode of development of its conidia the potato blight fungus might perhaps form the type of a special genus amongst the Peronosporaceae.

Ten years later, in 1876, he acted on this suggestion,[1] and created the genus *Phytophthora*, *P. infestans* becoming the first member of it.

In 1879 Hartig[2] gave the name *Phytophthora fagi* to the fungus discovered by him in 1875, and then named *Peronospora fagi*, which causes a disease in seedling beech trees; and this species was incorporated by de Bary[3] two years later, together with *Peronospora sempervivi*, Schenk and *Per. cactorum*, Lebert and Cohn in his species *Phytophthora omnivora*.

Recent investigations by Himmelbaur,[4] however, have shown that *Ph. fagi* and *Per. cactorum* must be regarded as distinct species; and this author suggests that de Bary's specific name *omnivora* should be dropped. Presumably on grounds of priority, Schroeter[5] adopted the combination *Phytophthora cactorum* in place of *P. omnivora*, de Bary, and this is the name adopted by Saccardo.[6]

We should thus have *Phytophthora cactorum* (Lebert and Cohn) and *Ph. fagi*, Hartig, as distinct and independent species, the former including as a synonym *Peronospora sempervivi*, Schenk.

With regard to Coleman's *Phytophthora omnivora* var. *Arecae*, I have elsewhere suggested[7] that this species is probably quite distinct from de Bary's *P. omnivora* and deserving of the name *P. arecae*.

Excluding *P. omnivora*, therefore, and including *Per. sempervivi*, Schenk, under *Ph. cactorum*, Schroet., the following is as complete a list of the species of *Phytophthora* described up to the present as I am able to furnish.

---

[1] de Bary, A.—Researches into the Nature of the Potato Fungus. Journ. Roy. Agric. Soc. of England, 1876, 12, S.S.

[2] Hartig, R.—Die Buchenkeimkrankheit erzeugt durch *Phytophthora Fagi*. Forstwissenschaft. Centralblatt, 1897, p. 171.

[3] de Bary, A.—Zur Kenntniss der Peronosporeen. Botanische Zeitung, 1881, 39, p. 521.

[4] Himmelbaur, W.—Zur Kenntniss der Phytophthoreen. Jahrb. d. Hamburg. Wiss., Anstalten, 1910, 28, p. 39.

[5] Krypt. Flr. Schles. p. 236.

[6] Saccardo, P.—Sylloge Fungorum, 1888, vol. 7, pars. I, p. 238.

[7] Sci. Proc. Roy. Dublin Soc., 1913, 13. (N.S.), p. 554.

1. *P. cactorum*, Schroet.[1]
2. *P. infestans*, de Bary.[2]
3. *P. fagi*, Hartig.[3]
4. *P. phaseoli*, Thaxter.[4]
5. *P. nicotianae*, Breda de Haan.[5]
6. *P. coloeasiae*, Raciborski.[6]
7. *P. thalictri*, Wilson and Davis.[7]
8. *P. agaves*, ? Gandara.[8]
9. *P. syringae*, Klebahn.[9]
10. *P. faberi*, Maublanc.[10]
11. *P. theobromae*, Coleman.[11]
12. *P. omnivora* var. *arecae*, Coleman.[11]
13. *P. erythroseptica*, Pethybridge.[12]
14. *P. parasitica*, Dastur.[13]

In addition to these, cultures of a *P. jatrophae*, Jensen have been sent out by the *Bureau pour la distribution de cultures de moisissures* of the International Association of Botanists in Amsterdam, but I am not aware of the publication as yet of any description of this species, and have been informed by the Bureau that it is probably identical with *P. nicotianae*, de Haan.

In the case of several of the species enumerated in the above list the details of the life-histories are fairly completely known, whereas in regard to others this is not so. It is particularly in regard to the mode of development of the sexual organs of these fungi that our interests are at present concerned.

It is chiefly to de Bary[14, 15] that we owe our knowledge of the development of these organs in those species which have been longest known. In these cases, to take *P. cactorum* as an example, the antheridia and oogonia arise close together usually on short but distinct branches of the same main hypha, and more or less coincidently as to time. Fertilisation takes place by the lateral penetration of the oogonium, which contains an oosphere, by a beak-like outgrowth from the antheridium and by the passage into the oosphere through this beak of a portion of the protoplasmic contents of the antheridium. As a result of fertilisation the oosphere becomes an oospore, around which a thick wall becomes deposited. This method of development of the sexual organs is shared by the members of the genus *Peronospora*.

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[1] Cohn's Beiträge z. Biologie, 1875.
[2] Journ. Roy. Agric. Soc. England, 1876.
[3] Forstwiss. Centralblatt, 1879.
[4] Botanical Gazette, 1889.
[5] Med. uit's Lands Plantentuin, 1896.
[6] Parasit. Algen u. Pilze Javas, 1900,
[7] Bull. Torrey Bot. Club, 1907.
[8] Mem. y Rev. Soc. Cient. Ant. Alzate, 1908-9.
[9] Krankheiten des Flieders, 1909.
[10] L'Agric. Pract. d. Pays Chauds, 1909.
[11] Diseases of the Areca Palm, 1910.
[12] Sci. Proc. Roy. Dublin Soc., 1913.
[13] Mem. Dept. Agric. India, Bot. Ser., 1913.
[14] Abhandl. d. Senckenb. naturf. Gesellsch, Bd. 12.
[15] Botanische Zeitung, 1881, Bd. 39.

The sexual organs of some of the species of *Phytophthora* remained for a long time unknown in spite of repeated search for them (this applies particularly to *P. infestans*), and even at present there are some species in which they are either not known at all or only imperfectly known.

The investigations carried on in recent years, however, have added very greatly to our knowledge of the mode of development of these organs, and some rather surprising and highly important results have come to light. These results are in no small degree due to the fact that the fungi in question have been grown successfully as saprophytes in pure cultures on suitable media, and their study has thus been much facilitated.

The starting point of the most recent work was the discovery by Clinton of the long sought for oospores of *Phytophthora infestans,* when the fungus was grown in pure culture on a medium composed chiefly of crushed oats. It is not necessary to go into the history of this matter here, as I have quite recently dealt with it in two papers,[1, 2] in which full references to the literature will also be found.

From these two papers it will be seen that Clinton's discovery has been amply confirmed, and new light has been thrown on the mode of development of the sexual organs in this as well as in some other species of Phytophthora.

P. erythroseptica, Pethyb., which is described in the first of the two papers just referred to, causes a specific disease of the potato plant as a whole, of the "wilt" type, the outward symptoms of which rather closely resemble those of the so-called "Black Stalk Rot" or "Black Leg" disease due to bacteria. From the economic point of view the most serious aspect of the fungus is its capacity for producing a characteristic rot ("Pink Rot") in potato tubers, which, under certain conditions, results in heavy losses.

This fungus can be cultivated with ease as a saprophyte on several media, on which it produces its sexual organs in abundance. By such means it was found possible to follow under the microscope the various phases of the development of these organs from start to finish.

In this species the antheridia and oogonia arise on separate hyphae. At an early stage the young oogonium, or oogonial incept, as I have termed it, penetrates into the interior of the antheridium at or near

[1] Pethybridge, G. H.—On the rotting of potato tubers by a new species of *Phytophthora*, having a method of sexual reproduction hitherto undescribed. Sci. Proc. Roy. Dublin Soc., 1913, 13, (N.S.), no. 35.

[2] Pethybridge, G. H., and P. A. Murphy.—On pure cultures of *Phytophthora infestans*, de Bary, and the development of oospores. Ib., 1913, no. 36.

the base, grows up through the latter, and emerges at the summit, when it swells out rather rapidly, forming a spherical portion, in which subsequently an oosphere and then a thick-walled oospore develops.

The ripe sexual organs therefore consist of a pear- or balloon-shaped oogonium, having an oospore in its upper spherical portion, situated above the antheridium, and its conical or funnel-shaped base within and surrounded by the antheridium. The funnel-shaped base is closed off from the hypha bearing the oogonium by a thick plug of cellulose.

Whether an actual process of fertilisation takes place or not is not yet known, but the cytology of the whole series of phases is at present being worked out. If it does it would appear that it must take place while the thin-walled oogonial incept is still within the antheridium, and therefore some considerable time before the formation of the oosphere.[1]

In the case of *P. infestans* the actual phases of development have not directly been observed. This fungus develops its sexual organs much less readily and more irregularly that *P. erythroseptica* does, and further, it only does so satisfactorily on a rather opaque medium. The final state of affairs, however, is identical in the two species, and there is no reason to suppose that there is any important difference in the mode of development of the sexual organs in the two cases. The same holds good also for *P. phaseoli*.

Very soon after the publication of the two papers mentioned further confirmation of the existence of such a novel mode of development of the sexual organs in species of *Phytophthora* was forthcoming from India.

In studying a disease of the Castor Oil Plant, Dastur[2] obtained a new species of *Phytophthora*, which he named *P. parasitica*. His description of the development of the antheridia, oogonia and oospore in this species agrees in all essentials with that described by me for *P. erythroseptica*.

In two respects, however, there are minor differences. In *P. parasitica* it appears that in some cases the antheridium and the oogonium may arise on the same stalk, and when this is so the

[1] Cytological work carried out by my former assistant, Mr. P. A. Murphy, since the above was written and not yet published, shows, however, that this surmise is not correct. The contents of the antheridium and the oogonium follow a normal course of development up to the stage when a uninucleate oosphere is formed. It is extremely probable that fertilisation occurs subsequently, but this point has not been determined as yet with absolute certainty.

[2] Dastur, J F.—On *Phytophthora parasitica*, nov. spec. A New Disease of the Castor Oil Plant. Mem. Dept. Agric. in India, Botanical Series, 1913, vol, 5, No. 4.

oogonial hypha arises from the base of the antheridium as an outgrowth. This has not been observed in *P. erythroseptica*. In *P. parasitica* the exit of the swollen head of the oogonial hypha (oogonial incept) through the summit of the antheridium is described as taking place by solution of the antheridial wall. In *P. erythroseptica* on the other hand, in the cases where this process was followed under the microscope, the emergence was apparently due to a mechanical bursting of the wall at the summit of the antheridium, and the finely serrated ragged edges of the aperture in the wall through which the oogonium made its exit were clearly visible for some little time afterwards.

In an account of the blight of *Colocasia esculenta,* for which Raciborski had assigned *Phytophthora colocasiae* as a cause in 1900, Butler and Kulkarni[1] provide a description of this parasite based largely on results obtained from pure cultures. The development of the sexual organs in this species is practically identical with that followed in *P. parasitica* and in *P. erythroseptica*. As in the latter species so also in *P. colocasiae* the antheridium and oogonium always arise on separate hyphae. The oogonial origin penetrates the antheridium after indenting its wall, pursues generally a straight course to the opposite wall which it again pierces, to emerge on the further side, where it swells out to form the oogonial cell in which ultimately the oospore develops.

Hence five species of *Phytophthora* have now been described which have this curious intra-antheridial mode of development of the oogonium. These are *P. erythroseptica, P. infestans, P. phaseoli, P. parasitica* and *P. colocasiae,* while, for reasons given in my previous paper, I surmise that Coleman's *P. omnivora* var. *arecae* will be found to resemble these five species in this respect.

In only one of these species, viz., *P. erythroseptica*, has the germination of the oospore as yet been described.[2] In pure cultures of this species the oospore remains within the oogonium to which the antheridium continues to be attached. Germination takes place by the production of a germ tube, which penetrates the oogonium wall and which may soon develop a conidium (zoosporangium) at its apex, or may branch and produce ordinary mycelium.

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[1] Butler, E. J., and Kulkarni, O. S.—Studies in Peronosporeacae. Colocasiae Blight caused by *Phytophthora Colocasiae*, Rac. Mem. Dept. Agric. in India, Bot. Series, 1913, vol. 5, No. 5.

[2] Pethybridge, G. H.—Further observations on *Phytophthora erythroseptica*, Pethyb., and on the disease produced by it in the potato plant. Sci. Proc. Roy. Dublin Soc. 1914, vol. 14 (N.S.), No. 10, p. 177.

Before this germ tube arises, however, the thick inner portion of the oospore wall, which consists of a kind of cellulose giving a bright blue colour with the ordinary iodine reagents for cellulose, becomes dissolved, leaving this wall extremely thin in most cases, and thus serves as a supply of reserve carbohydrate food material analagous to that deposited on the walls of the cells of the endosperm of certain seeds and elsewhere.

Butler and Kulkarni suggest, from a study of Hartig's figures of *P. fagi,* that intra-antheridial development of the oogonium may sometimes occur in this species. The same idea had also occurred to me not only with regard to *P. fagi,* but also *P. cactorum* and *P. syringae.*

These three species were therefore cultivated, and the development of the sexual organs and process of fertilisation was followed in the first two of them, but no case of such intra-antheridial growth of the incipient oogonium could be found. In the case of *P. syringae* the phases of development could not actually be followed, as it was only found possible to get the sexual organs to develop in the interior of pieces of sterilised carrot. The final stage of development, however, in this case is similar to that seen in *P. fagi* and *P. cactorum,* namely, an oogonium having an antheridium attached to it laterally by a kind of beak through which fertilisation has occurred.

From what has been said it will be seen that the genus *Phytophthora,* as usually understood, contains species which differ from one another fundamentally in the way in which the development of the sexual organs takes place. On the one hand the oogonium is developed extra-antheridially, and fertilisation occurs after the formation of the oosphere, while on the other hand the development of the oogonium is intra-antheridial, and fertilisation—if it occurs at all, which it probably does—would seem to take place before the formation of the oosphere.[1]

This important difference practically compels the splitting of the old genus *Phytophthora* into two, or at any rate demands the exclusion from it of all the species with one of the above types of oospore formation. The intra-antheridial mode of development of the oogonium was first discovered in *P. erythroseptica,* then in *P. infestans.* Since *P. infestans* was the original type of the genus *Phytophthora,* I have suggested that this generic name should be retained for those species, and those alone, which develop their sexual organs by the intra-antheridial growth of the oogonial incept. The genus *Phytophthora* as thus limited would therefore comprise the five species *erythroseptica,*

[1] See footnote on p. 57.

infestans, phaseoli, colocasiae and *parasitica,* with *arecae* a possible sixth.

Although the development of the sexual organs in the species *sempervivi, cactorum, fagi, syringae* and *theobromae* is similar to that occurring in *Peronospora,* the mode of formation of the conidia differs from that which obtains in this genus, hence it is necessary to place these species and others similar to them in a new genus, for which I have suggested the name *Nozemia.*

With regard to the few remaining species in which the sexual organs are imperfectly known, it remains for further research to decide as to whether they shall be retained in the genus *Phytophthora* or transferred to *Nozemia.*

EXPLANATION OF PLATES II AND III.

Illustrating Dr. G. H. Pethybridge's paper on "Recent Advances in our Knowledge of the Genus *Phytophthora.*"

(The blocks used for the accompanying plates have kindly been lent by the Royal Dublin Society).

Plate II.

Phytophthora infestans—All figures × 486.

Figs. 1, 2, 3. Abnormalities or deformities seen in mycelium growing submerged in potato-juice sterilized by filtration through a Berkefeld candle. They are probably to be regarded as abortive conidial growths.

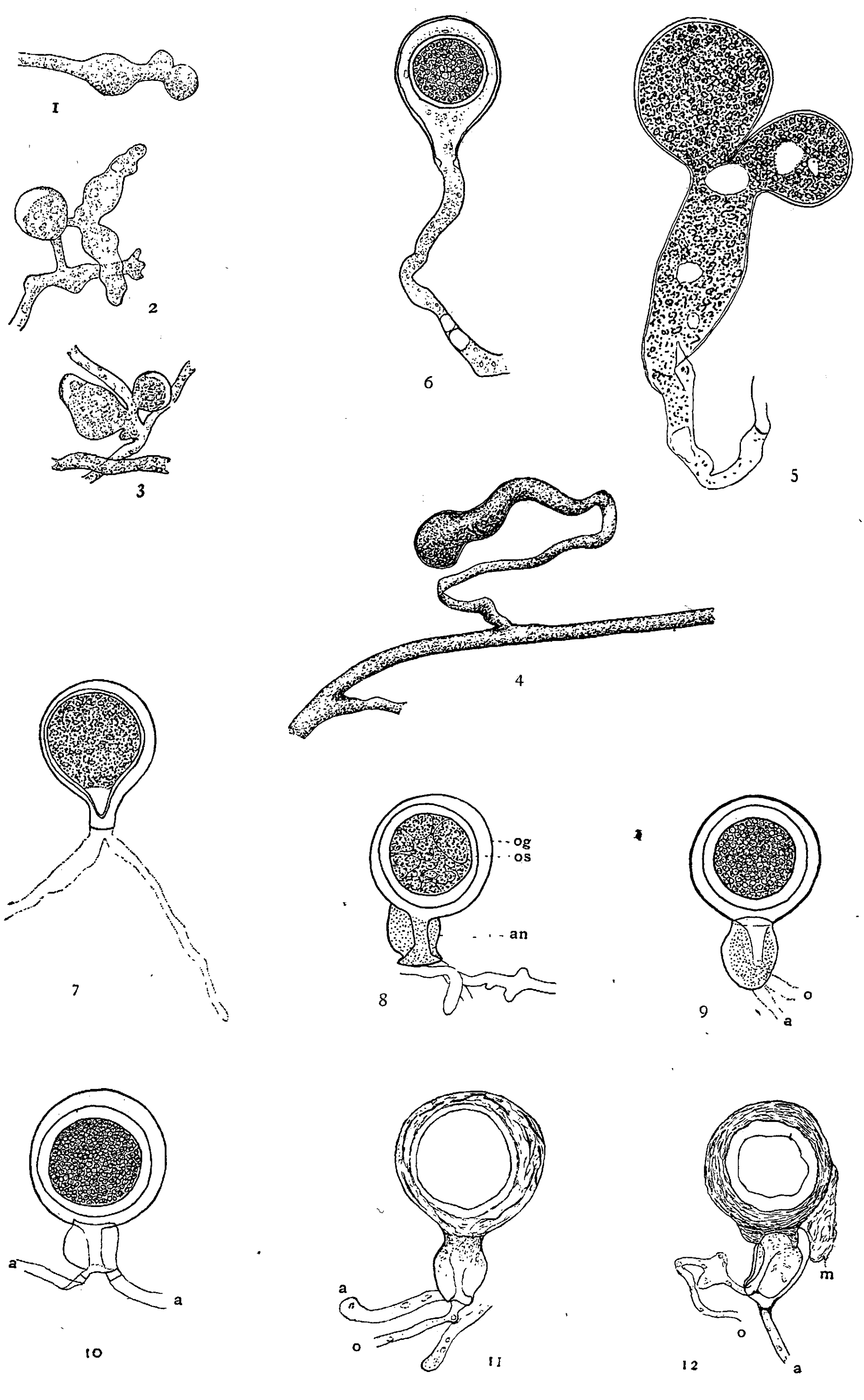
Fig. 4. An early stage in the development of an oogonium, no antheridium is present. (Quaker Oat Agar.)

Fig. 5. A "twin" oogonium in which two oospores would probably have been formed. A distinct wall separating the oogonium from the hypha which bears it is present. (Quaker Oat Agar.)

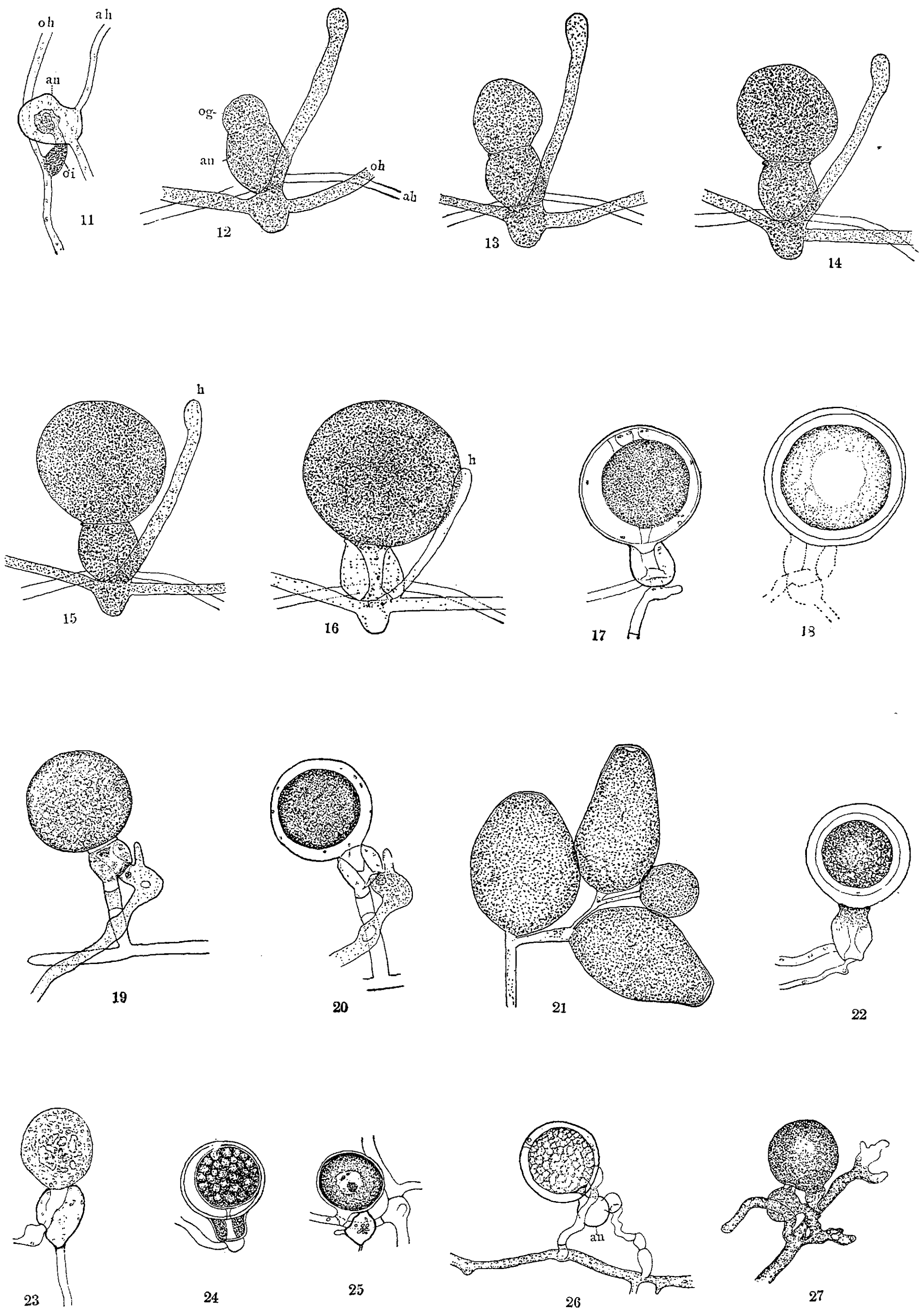
Fig. 6. An oogonium containing a young, parthenogentically formed oospore. The lower limit of the wall of the oogonium is clearly seen, but there is no septum closing the oogonium from the hypha which bears it. (Quaker Oat Agar.)

Fig. 7. An oogonium borne laterally on a hypha and containing a young pear-shaped oospore, formed parthenogenetically. (Quaker Oat Agar.)

Fig. 8. An oogonium (containing a practically ripe oospore) with its lower portion within an antheridium. The hyphae at the base of the antheridium are probably the oogonial and antheridial hyphae; but it was impossible in the preparation to determine this point with absolute certainty. (Quaker Oat Agar.) *og* = oogonium, *os* = oospore, *an* = antheridium.



PHYTOPHTHORA INFESTANS, de Bary.



PHYTOPHTHORA ERYTHROSEPTICA, Pethybridge, etc.

Fig. 9. An oogonium (with practically ripe oospore) with its antheridium. The antheridium is probably a terminal structure borne on the hypha *a*, the funnel-shaped lower portion of the oogonium within the antheridium is probably continuous with the hypha *o* (at the back); but the connexion could not be made out with certainty. (Quaker Oat Agar.)

Fig. 10. An oogonium (with a practically ripe oospore) with its lower portion within the antheridium, which is a sessile structure on the hypha *aa*. The hypha bearing the oogonium was probably broken off during the removal of the adhering medium. (Quaker Oat Agar.)

Figs 11 and 12. Oogonium, oospore, and antheridium. The irregularities in the oogonium wall are indicated by shading (except over the oospore). In fig. 11 the antheridium is probably a lateral outgrowth of a hypha, the end of which is seen at *a*, the other portion of it being absent. *O* is the hypha which bears the oogonium, and it was definitely traced into the antheridium and seen to be continuous with the funnel-shaped base of the oogonium. In fig. 12 the antheridium is a terminal structure, borne on the hypha *a*; and its contents are represented somewhat contracted away from its walls. *O* is the hypha bearing the oogonium; its passage into the antheridium and continuation as the funnel-shaped base of the oogonium was clearly discernible. *M* is a small portion of adhering medium. (Quaker Oat Agar.)

PLATE III.

Figs. 11 to 21. *P. erythroseptica.*

Fig. 11. An antheridium into which the oogonial incept has penetrated. After treatment with weak caustic soda and staining with Loeffler's methylene blue,—*oh* = oogonial hypha, *ah* = antheridial hypha, *an* = antheridium, *oi* = oogonial incept. × 625.

Fig. 12. Sexual organs drawn about ten minutes after the developing oogonium had burst out through the top of the antheridium. The antheridium *an* is sessile on the now empty antheridial hypha *ah*, the point of origin being at the back, and not shown in the drawing. The oogonial incept is sessile on the oogonial hypha *oh*, which is considerably swollen at the point of origin of the former. The funnel-shaped base of the developing oogonium *og* is only very faintly seen within the antheridium, the broken wall of which at the point of exit is somewhat jagged in outline. At this stage there was rather rapid movement of protoplasm from the oogonial hypha into the developing oogonium. Living material. × 625.

Fig. 13. The same organs as in fig. 12 after the lapse of a period of thirty minutes. The developing oogonium has increased considerably in size. × 625.

Fig. 14. The same after a further period of 2 hours 20 minutes. The broken wall of the antheridium is no longer jagged, but the "beaded" edge is becoming defined. × 625.

Fig. 15. The same after a further period of 2 hours 10 minutes. The oogonium is rapidly attaining its full size, and the contents of the hypha *h* are diminishing in quantity, being drawn upon to fill the oogonium. The funnel-shaped base of the developing oogonium is rather more distinct in this figure than in figs. 12, 13, and 14. × 625.

Fig. 16. The same, 17 hours 20 minutes later than fig. 12. The oogonium has attained its full size, the oogonial hypha has lost most of its contents. Protoplasmic streaming into the oogonium had ceased some time before this. The contents of the antheridium have largely disappeared, revealing clearly the funnel-shaped base of the oogonium within it, the hypha *h* has lost its contents and become reduced in size. × 625.

Fig. 17. Another set of the sexual organs, oosphere stage. Part of the contents of the upper portion of the oogonium have become rounded off, in preparation for the development of the oospore, the remainder forms trabecular structures which subsequently disappear or exists as isolated granules round the periphery. A "plug" in the funnel-shaped base of the oogonium is present. The thickness of the oogonium wall is somewhat exaggerated in this figure. Living material. × 425.

Fig. 18. A ripe oospore within the oogonium. The details of the base of the oogonium, antheridium and hyphae are only approximately indicated. Living material. × 625.

Fig. 19. The sexual organs showing a terminal antheridium and an oogonium derived from a terminal incept. The beaded edge of the broken top of the antheridium is well marked. Living material. × 425.

Fig. 20. The same as fig. 19, two days later, showing an early stage in the formation of the spore. Living material. × 425.

Fig. 21. Conidia showing sympodial development. Drawn after treatment with I in KI. × 625.

Fig. 22. *P. infestans,* showing the funnel-shaped base of the oogonium within the antheridium. The upper part of the funnel is obscured by the presence of portions of the browned oat-agar-medium adhering to the antheridium. These also adhered to some extent to the spherical part of the oogonium but did not obscure it, and have been omitted in the drawing. Living material. × 365.

Fig. 23. Sexual organs of *P. phaseoli* from living material in Lima Bean Agar, showing clearly the course followed by the developing oogonial incept. × 365.

Fig. 24. Sexual organs of Coleman's *P. omnivora* var. *arecae*, from his plate 18, fig. 3. × 335.

Fig. 25. *P. syringae*, Kleb. Sexual organs developed within the tissues of sterile carrot. The base or stalk of the oogonium is *not* within the antheridium. Living material. × 365.

Fig. 26. *P. cactorum*, Schroet. Sexual organs developed in a cover-glass film of carrot extract gelatine. The antheridium *an* is partially overlain by a portion of the hypha bearing the oogonium. The contents of the antheridium at this stage had become very reduced in amount and degenerated, and for the sake of clearness are omitted from the drawing. Living material. × 365.

Fig. 27. Sexual organs of *P. fagi* developing in cover-glass film of carrot extract gelatine, drawn just before fertilization occurs, and showing the lateral penetration of the oogonium by an outgrowth from the antheridium. Living material. × 365.

CLOVER AND LUCERNE LEAF-SPOT.

By IVY MASSEE.

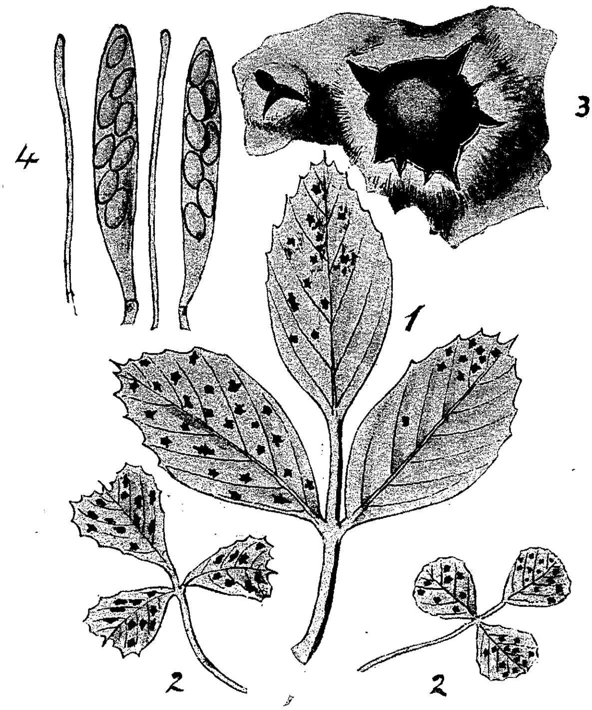
(With 4 Figures).

This disease is far more prevalent and more injurious to clover and lucerne crops in this country than is generally suspected. In the United States it often completely destroys lucerne, or alfalfa, as it is called there, and it is considered as the only important fungus disease attacking this crop. The first symptom of disease to the casual observer is a slight yellowing of the leaves commencing at the base of the plant and gradually creeping upwards. As the disease progresses the leaves assume a decided yellow tinge throughout, commence to wilt, and fall to the ground. When the disease is severe almost complete defoliation takes place, the naked stems alone remaining. Newly-sown clover-fields are frequently ruined by the disease; older stands also suffer to a considerable extent, but are not often killed outright. In the case of lucerne and crimson clover the disease often appears after the first cutting, and succeeding crops are very frequently severely injured.

The fungus causing this disease is called *Pseudopeziza trifolii*. During the period when the host determined the species, different names were given to the various fungi growing on allied leguminous plants. These, however, have been proved by cross-infection experiments to belong in reality to but one species, as named above. There are slight differences in the size of the ascophore, asci and spores, in the various supposed species, but these differences come well within the limits of variation, as observed in any one of the included forms. Furthermore, ascospores from the form growing on clover gave origin to a slightly different form of ascophore, when sown on leaves of lucerne, proving that such variations in form and size are not of specific value, but depend on the texture and mode of venation of the leaf on which they are growing. The fruit of the fungus is formed in the tissue of the leaf, and when approaching maturity bursts through to the surface, under the form of a minute, circular, more or less convex wart of a dark colour, surrounded by the torn epidermis. The fungus is sometimes developed on the stem, sepals, and less frequently on the seed.

[Journ. Econ. Biol., June, 1914, vol. ix, No. 2].

The dissemination of the disease may be effected in various different ways. Where an infected crop has grown, the diseased fallen leaves would prove a source of danger to future crops. In the United States it has been noted that where fields intended for alfalfa have been strewn with soil from another alfalfa field which had been affected with leaf-spot, for the purpose of inoculation with the nodule bacteria, infection often follows, as the result of spores of the fungus having been conveyed along with the soil. The dispersal of the fungus spores by wind is also considered as a factor in spreading the disease;



Pseudopeziza trifolii, Fckl.

Fig. 1. Fungus on lucerne leaf, nat. size.
Fig. 2. Fungus on clover leaves, nat. size.
Fig. 3. Fungus somewhat enlarged.
Fig. 4. Asci and paraphyses. × 400.

but so far as this country is concerned I am inclined to believe that the spread of disease is mainly due to the use of badly cleaned and infected seed. I have recently examined a sample of commercial seed, and found the fungus present in abundance on minute fragments of leaves, on calyces, and rarely on the seed itself.

SYNONYMY.

The following is the synonymy of *Pseudopeziza trifolii,* given in chronological order :—

Pseudopeziza trifolii, Fckl. (1869.)
Ascobolus trifolii, Bernhardt. (1813.)
Phacidium medicaginis, Desmaz. (1840.)
Peziza dehnii, Rabenh. (1842.)
Phacidium divergens, Roberge. (1864.)
Pyrenopeziza medicaginis, Fckl. (1869.)
Pseudopeziza medicaginis, Sacc. (1893.)

HOST-PLANTS.

The fungus has been recorded on the following host-plants :—*Trifolium pratense,* L., *T. repens,* L., *T. medium,* L., *T. arvense,* L., *T. incarnatum,* L., *T. fragiferum,* L., *T. hybridum,* L., *T. pallescens,* Schreb., *T. resupinatum,* L., *Medicago lupulina,* L., *M. sativa,* L., *M. falcata,* L., *M. denticulata,* Willd., *Trigonella faenum-graecum,* L.

DISTRIBUTION.

This fungus is widely distributed in a state of nature, and probably occurs wherever lucerne and clover are cultivated Europe, N. and S. America, Australia, New Zealand.

PREVENTIVE MEASURES.

Cleanliness, as usual, is a most important factor in arresting disease, and as the fungus is fairly abundant on many of our wild clovers, also on species of *Medicago,* all such weeds should be kept down in the vicinity of cultivated clover or lucerne.

It should be practicable, without incurring much additional expenditure, to remove all fragments of leaves, etc., from admixture with the seed, thus checking to a great extent the chances of infection. If, on examination, the seed itself is found to be infected, it should be treated by the hydrogen peroxide method I have described in the "Kew Bulletin."

SOME FURTHER OBSERVATIONS ON THE DISPERSAL OF WEED SEEDS BY WILD BIRDS.

By WALTER E. COLLINGE, M.Sc., F.L.S., F.E.S.

THAT a certain proportion of the seeds of various weeds which are eaten by wild birds pass through the intestinal canal uninjured and become dispersed in their droppings is now well known, and has been commented upon by Kerner,[1] Darwin,[2] Judd,[3] Beal,[4] Pycraft,[5] myself,[6] and other writers. Kerner (*op. cit.*) has shown that of fruit and seed which passed through the intestinal canal, so much as 75 per cent. germinated in the case of the blackbird, 85 per cent. in the case of the thrush, and 88 per cent. in the case of the rock-thrush. The same writer has also given many interesting details as to the interval of time between ingestion and evacuation, and the effect of ingestion on the seeds.

In a previous paper[6] I have shown that in the case of the house sparrow, bullfinch, and greenfinch large numbers of weed seeds are evacuated, and are capable of germinating and growing into healthy and normal plants.

In analysing and comparing my records for the past three years, viz., 1911, 1912 and 1913, a very interesting fact is brought out, which has an important bearing upon the subject of the distribution of weed seeds by wild birds.

During the dry summer of 1911 (June, July, August and September) the grit and soil content of the gizzard of thirty-six rooks was carefully weighed, the average amount being 108 grains, of which not more than one-sixth was grit. The same number of birds was examined during the wet summer of 1912 (June to September), and the average amount was 214 grains, of which nearly one-third was grit. During 1913 the test was repeated. The climatic conditions were similar to those of 1911, excepting in the early part of June and the

[1] Kerner and Oliver.—Nat. Hist. of Plants, 1895, vol. 2, pp. 862-866.
[2] Darwin, C.—Origin of Species, 6th ed., 1902, p. 510.
[3] Judd, S. D.—U.S. Dept. Agric., Div. Biol. Surv., Bull. No. 17, 1902.
[4] Beal, F. E. L.—*Ibid.*, Bull. No. 30, 1907.
[5] Pycraft, W. P.—A History of Birds, 1910.
[6] Collinge, W. E.—Journ. Bd. Agric., 1913, vol. 20, pp. 15-26.

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latter end of September. For this year the average amount of grit and soil was 129 grains, one-quarter being grit.

Unfortunately, with the rook no experiments could be made with the faeces, but with the house sparrow and starling it has been comparatively easy to show that during the dry summer of 1911 these birds distributed large quantities of weed seeds, but during the wet summer of 1912 they were considerably less, and rather more during that of 1913.

Thus in thirty-eight starlings examined from June to September, 1911, the average soil and grit content was forty-two grains, and the faecal contents, when placed on sterilised soil in the manner I have elsewhere described,[1] resulted in the cultivation of fifty-seven plants referable to six species. A similar number examined during 1912 gave an average soil and grit content of sixty-eight grains, and from the faecal contents only twenty-three plants were cultivated referable to four species. The figures for 1913 were thirty-two plants referable to five species.

Of the house sparrow, during 1911, the soil and grit content was weighed from sixty birds, and averaged twenty-seven and a half grains, from the faecal contents of twenty-four birds fifty-nine plants were cultivated referable to four species. From the same number of specimens examined during 1912, an average soil and grit content of fifty-three grains was obtained, and from the faecal contents of twenty-four of these only eighteen plants were cultivated referable to two species.

From the above observations it would appear that, in dry years, such birds as the rook, starling, house sparrow (and probably many other species) take in a much smaller quantity of grit and soil than in wet years, in consequence of which a larger percentage of weed seeds pass through the intestinal canal in an uninjured condition.

Whilst engaged upon recording these results it occurred to me that it would be interesting and important to endeavour to obtain some corroborative evidence from those actually engaged upon weed investigations as well as from practical farmers, and the following replies to my queries show that there is a very general view amongst the farmers that weeds on arable land are much more in evidence after a dry summer than after a wet one.

A number of farmers were appealed to, and their replies may be summarised as follows:—

1. Twenty per cent. had not observed any difference after a dry or wet summer.

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[1] Collinge, W. E.—Journ. Bd. Agric., 1913, vol. 20, pp. 15-26.

2. Sixty-five per cent. were of opinion that there are always more weeds on arable land after a dry summer than after a wet one.

3. Fifteen per cent. were of the same opinion as stated in par. 2, but also added that, from general observations made over a number of years, they were of opinion that the seeds were largely distributed by birds.

A number of investigators on weed problems were written to, but none were able to contribute any evidence to the subject. The matter is one, however, which I believe is worthy of further attention from an economic standpoint, apart from its interest otherwise.

ÜBER DAS VORKOMMEN UND DIE HEIMAT VON *PSEUDISCHNASPIS* (*ASPIDIOTUS*) *BROMELIAE*.

VON DR. LEONHARD LINDINGER.

IN einer kurzen Mitteilung über einige Schildläuse von den Seychellen kommt Green auf die Verbreitung und die noch unbekannte Heimat der genannten Schildlaus zu sprechen.[1] Der Angabe, dass die Laus aus Westindien oder vom amerikanischen Festland noch nicht gemeldet ist, pflichte ich (Station für Pflanzenschutz zu Hamburg. Sonderbruct 26) unumwunden bei, möchte mir aber zu den weiteren Ausführungen Greens einige Bemerkungen gestatten. Green nimmt an, dass die Art nur von englischen Märkten her bekannt sei (Newstead nennt Chester), wo die Laus auf Ananas gefunden wurde, die als von kanarischer Herkunft bezeichnet wurden.[2] Schon im Jahr 1911 habe ich aber in einer Bearbeitung der kanarischen Cocciden[3] darauf hingewiesen, dass die von Newstead gemeldeten Tiere in Wirklichkeit von den Azoren stammen dürften. Seit einer Reihe von Jahren wird nämlich die Art regelmässig auf Ananas von den Azoren, meist von Sâo Miguel, beobachtet.[4] Auch in meinem Schildlausbuch wird die Art von den Azoren angegeben.[5]

Wenn ich nun Green recht verstehe, so neigt er der Meinung zu, *Pseudischnaspis bromeliae* könne afrikanischen Ursprungs sein, soweit wenigstens die Inseln in Betracht kommen; er schreibt nämlich einmal: "The question arises, Is the species indigenous in the Seychelles?" Und etwas später: "Mr. Newstead's evidence points to the Canary Islands. If it should be found to occur on indigenous Bromeliads, in those islands, the presumption would be stronger."

[1] Green.—On some Coccid pests from the Seychelles. Journ. Econ. Biol., 1914, vol. 9, p. 47.

[2] Newstead.—Monograph of the Coccidae of the British Isles. 1903, vol. 1, p. 87.

[3] Lindinger, Afrikanische Schildläuse. IV. Kanarische Cocciden, ein Beitrag zur Fauna der Kanarischen Inseln. Jahrb. Hamb. Wiss. Anst. XXVIII. 3, Beiheft.

[4] Bericht der Station für Pflanzenschutz zu Hamburg: VII, p. 8; VIII, p. 7; X, p. 10. (In neuerer Zeit nicht mehr aufgeführt, weil fast immer vorhanden).

[5] Lindinger, Die Schildläuse (Coccidae) Europas, Nordafrikas und Vorderasiens, einschliesslich der Azoren, der Kanaren und Madeiras, 1912.

[JOURN. ECON. BIOL., June, 1914, vol. ix, No. 2.]

Die strenge Beschränkung auf eine Bromeliacee schliesst eine andere als die amerikanische Herkunft der Laus vollständig aus, denn Bromeliaceen kommen nur in Amerika vor. Auch die Ananas ist amerikanischer Herkunft.

Die Gefahr, dass sich das Insekt zu einem ernsthaften Ananasschädling entwickeln könne, wie Green andeutet, halte ich nicht für gross, denn nach meinen Befunden ist die Entwicklung des Tieres eine vergleichsweise sehr langsame.

Hamburg, den 12 März, 1914.

NOTE ON *ASPIDIOTUS BROMELIAE.*

By E. ERNEST GREEN, F.Z.S., F.E.S.

In my recent paper "On Some Coccid Pests from the Seychelles," I suggested that *Aspidiotus bromeliae* may have its home in the Canary Islands. Dr. Lindinger, writing under date 12th March, disputes this suggestion, and remarks that, so far back as 1911, he had shown that for many years the species has been observed on pineapples imported from the Azores, more particularly from Sâo Miguel. He concludes from this that the insect really originated in the Azores. Dr. Lindinger remarks that, if the species is actually confined to plants of the Order *Bromeliaceae,* its original home should be looked for in America, where these plants (and the pineapple itself) had their origin. So far as it goes, this reasoning may be sound; but our knowledge of the species is still too incomplete to permit of any definite conclusions. We do not even know that it is confined to Bromeliads. And is Dr. Lindinger correct in assigning to America the sole home of the *Bromeliaceae?* I do not profess to any extensive knowledge of Botany, but I was under the impression that India, Ceylon, Java, and some other eastern countries provide many indigenous Bromeliads.

Dr. Lindinger (in contradiction of my further remarks) does not think that the species is at all likely to become a serious pest, as—in his experience—the development of the insect is comparatively slow. I can only reply that the material from the Seychelles showed such a dense infestation that the health of those particular plants must have been seriously affected. The rate of development of any Coccid depends so much upon the presence or absence of natural enemies (*e.g.,* Coccinellid beetles and Hymenopterous parasites) that conclusions based upon its activity in one country may be completely upset by its behaviour in another.

30th March, 1914.

[Journ. Econ. Biol., June, 1914, vol. ix, No. 2.]

RECENT PUBLICATIONS ON ECONOMIC ORNITHOLOGY.

By WALTER E. COLLINGE, M.Sc., F.L.S , F.E.S.

THE FEEDING HABITS OF GULLS.[1]—We welcome this report of a sub-committee appointed by the Suffolk and Essex Fishery Board to investigate the feeding habits of Gulls, although it is more in the nature of an interim report. Application is being made to the Board of Agriculture and Fisheries for a grant of £100 towards the continuance of the inquiry, and we trust that it has ere now been granted, for this is a really useful piece of work which the Board might well assist. Writing in 1908[2] a writer stated : " In the matter of economic ornithology we in England are disgracefully behind the times; the Board of Agriculture seemingly prefers to leave this matter to private enterprise, or to deal with the matter in such a perfunctory manner as to be positively ridiculous, making us the laughing-stock of the nations." Since 1908 a considerable amount of private work has been done, so that little remains for the Board to assist; we therefore trust the opportunity that now presents itself will be taken advantage of.

Four hundred and fifty-six birds have been examined, viz., 167 black-headed gulls, 92 common gulls, 86 herring gulls, 13 great black-backed gulls, 10 lesser black-backed gulls, 2 little gulls, 30 kittiwakes, 25 common terns, 4 lesser terns, and 27 divers, including guillimots, razor-bills, red-throated divers, great crested grebe, etc.

So far as the investigation has proceeded it shows that fish of all varieties were present in 28 per cent. of black-headed gulls, 24.5 per cent. of the common gull, and 18.2 of the herring gull. Sixty per cent. of great black-backed gulls contained food fishes, 30 per cent. of lesser black-backed gulls, and 83.5 of kittawakes. Of the remaining species examined the numbers are as yet too small to be of value.

Incidentally it is pointed out that the great black-backed gull, in confinement, digests fish at the rate of 4 oz. per hour, and smaller gulls at a somewhat slower rate. Further experiments are being conducted in order to arrive at the rate of digestion in the former species in its wild state.

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[1] Suffolk and Essex Fishery Board. Report of Sub-Committee appointed to make arrangements for and to investigate the Feeding Habits of Gulls during the year 1913. 1914, pp. 15.

[2] Ann. Mag. N. H., 1908 (s. 8), vol. 2, p. 132.

[JOURN. ECON. BIOL., June, 1914, vol. ix, No. 2.]

We are somewhat surprised at the small percentage of "land food" (earthworms, insects, etc.) eaten; apart from earthworms it is very small. Cereals were found 2.9, 11.0 and 19.5 per cent. in the black-headed gull, common gull, and herring gull respectively, but it is pointed out that "the black-headed gulls were not examined in the district during the Spring and early Summer, as there are no breeding stations in the immediate vicinity." Common gulls and herring gulls, however, examined from various outside districts, contained a considerable amount of grain. "The destruction of cereals by the herring gull certainly seems a matter for further investigation, when 19.5 per cent., shot mostly at sea, contained cereals."

"The destruction of cereals in Suffolk would appear to be negligible, owing to the fact that no gulls breed in the district, and only a few immature birds are left during the Spring and early Summer, and that in the Autumn, when seed is being sown, there appears to be an abundance of food in the estuaries of our rivers. However, examination of the birds shot on the land might show that they took cereals, for a common gull shot flying over the Orwell on September 26th contained 40 grains of wheat and the gizzard was full of husks, and on December 15th a gull shot at Whitton contained growing Winter wheat."

"Twenty-two nestlings of the black-headed gull were examined. These were obtained from a gullery 150 to 300 yards from high-water mark, and 1¼ miles from several small artificial lochs stocked with trout. An analysis of the food contained shows that the material destroyed was distinctly in favour of the agriculturist. There were present, remains of two small fish, 33 useful beetles, and 6 earthworms. On the other hand, 51 harmful beetles and insects and 31 wireworms were destroyed."

This very interesting and valuable report concludes by stating "that it would be manifestly unfair to draw any definite conclusions from it as to the feeding habits of gulls in general. But since gulls have taken to feeding on grain, the balance would appear to be against the gull; and from an economic point of view we consider an exhaustive enquiry is indicated in consequence of the enormous rate at which these birds are increasing throughout the land."

WILD DUCK FOODS.[1]—The wise foresight of the U.S. Department of Agriculture has seldom been better exemplified than in the present instance, and no more able investigator in economic ornithology could have been allotted the task than Mr. W. L. McAtee.

[1] McAtee, W. L.—Five Important Wild-Duck Foods. U. S. Dept. of Agric., Bull. No. 58, 1914, pp. 1-19, 16 figs.

Some little time ago the Department published a Circular containing information on the value, appearance, distribution, and propagation of three important wild-duck foods, and the information there provided has been widely used by the State game commissions, game protective associations, and individuals interested in the protection, preservation, and propagation of the native species of ducks and geese.

The present Bulletin deals with five other plants of great intrinsic value, viz., the Delta Duck Potato (*Sagittaria platyphylla*), the Wapato (*S. latifolia* and *S. arifolia*), the Chufa (*Cyperus esculentus*), the Wild Millet (*Echinochloa crus-galli*), and the Banana Water Lily (*Nymphaea mexicana*). All of these are described and figured, and particulars given of their distribution and propagation.

THE ECONOMIC STATUS OF THE WESTERN MEADOW-LARK.[1]—In this memoir Mr. H. C. Bryant reviews in great detail his work on the Western Meadow-Lark (*Sturnella neglecta*) in the State of California. It is a very valuable and most interesting piece of work. The investigation has included field investigations, experimentation on the amounts of food consumed and the times of digestion, and stomach examinations of nearly two thousand specimens, obtained from twenty different parts of the State, during each month of the year.

Field investigation shows that this species destroys sprouting grain to a varying degree, but no other crops are seriously damaged. The young birds feed exclusively on insects, and experimentation on captive birds proves that nestlings consume very nearly their own weight of food daily.

The stomach examination indicates that about 63 per cent. of the total volume of food for the year consists of animal matter, of which a very large proportion consists of injurious insects, and nearly 73 per cent. of vegetable matter.

Mr. Bryant touches upon various other problems indirectly related to the problem in hand, and concludes that this species should be a protected non-game bird. The whole paper forms another valuable contribution to the literature on economic ornithology.

RELATION OF BIRDS TO GRAIN APHIDES.[2]—An outbreak of grain aphides in North Carolina led the writer to examine the stomach contents of a number of Goldfinch (*Astragalinus tristis*), Pine Siskin (*Spinus pinus*), Vesper Sparrow (*Pooecetes gramineus*), Savanna Sparrow (*Passerculus sandwichensis savanna*), Chipping Sparrow

[1] Bryant, H. C.—A Determination of the Economic Status of the Western Meadow-Lark (*Sturnella neglecta*) in California. Univ. of Calif. Publ. in Zool., 1914, vol. 11, pp. 377-510, pls. 21-24, and 5 text figs.

[2] McAtee, W. L.—Relation of Birds to Grain Aphides. Year-book U. S. Dept. Agric., 1912, pp. 395-404, 3 figs.

(*Spizella passerina*), Field Sparrow (*S. pusilla*), Snowbird (*Junco hyemalis*), Song Sparrow (*Melospiza melodia*), Titlark (*Anthus rubescens*). He concludes that upon about 100 acres of grainfields, from March 29th to April 4th, they destroyed about 1,000,000 grain aphides daily.

FIFTY COMMON BIRDS ON FARM AND ORCHARD.[1]—The proprietors of the *National Geographic Magazine* have re-issued Mr. Henshaw's interesting paper, which was originally issued as Farmers' Bulletin 513 of the U.S. Department of Agriculture. In its present form it will no doubt appeal to a large number of readers, and serve to illustrate to the "man in the street" the magnificent work which the Bureau of the Biological Survey are doing. The fifty coloured figures are excellent.

THE PROTECTION OF BIRDS IN AND AROUND OTTAWA.[2]—Dr. Gordon Hewitt here discusses the general question of the protection of birds and the reasons why this is necessary; the economic value of certain common birds which it is desirable to protect; and a proposal for the protection of the native birds around Ottawa.

In Ottawa it is proposed to regard two areas, Rockcliffe Park and the ground of the Botanical Garden of the Dominion Government's Experimental Farm, as bird sanctuaries in which steps will be taken, not only to prevent the destruction of the birds and the despoiling of their nests, but also to encourage their presence by providing those species which nest in holes and cavities with nesting boxes and sites. To this end the Ottawa Improvement Commission have agreed to provide and distribute 250 nest boxes in the former area, and the Director of the Experimental Farms has agreed to the distribution of 160 in the latter area.

Dr. Hewitt points out that the existence of two such bird sanctuaries will undoubtedly tend to prevent the gradual disappearance from the Ottawa district of a number of birds which are becoming less abundant than formerly. Further, it is reasonable to expect that when the northerly migrations are taking place in the spring, the encouragement offered will meet with a response, and birds which otherwise would have passed on will stay through the season. The scheme will afford the best check that can be adopted in preventing, as far as possible, the gradual departure of a number of native birds from this particular district.

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1 Henshaw, H. W.—Fifty Common Birds of Farm and Orchard. Nat. Geographic Mag., Washington, D.C., 1913, pp. 669-697, 50 coloured figs.

2 C. Gordon Hewitt.—The Protection of Birds in and around Ottawa. Ottawa Nat., 1914, vol. 27, pp. 161-171.

REVIEWS.

HANDBUCH DER PFLANZENKRANKHEITEN. By Dr. Paul Sorauer. Bd. III. Die tierischen Fiende. By Dr. L. Reh. Pp. xx + 774 and 306 text figures. Berlin: Paul Parey, 1913. Price £1 13s.

Professor Sorauer's *Handbuch* has long been regarded as the ablest exposition on the subject; wherever phytopathology is studied it has proved of the greatest assistance to both the investigator and student. Dr. Reh's treatment of the third volume fully sustains the high standard set in the previous ones. He has given us a treatise replete with information dealing with the whole of the animal kingdom in its economic aspect. The work is also of interest in affording an indication of the high level which economic biology has reached.

Anything like a complete outline of the life-histories of even typical examples was manifestly impossible in a work of this kind, but the terse manner in which it is written, the wealth of illustration, and the full bibliographic references make it one of the greatest value, and it must long remain the standard work upon the subject.

It is satisfactory to find ample recognition of the work that has been done in this country of recent years, indeed the author has taken considerable pains to make each section as complete as possible in the space at his disposal. The result is a treatise of enduring value, and worthy of the high reputation of its author.

A TEXTBOOK OF MEDICAL ENTOMOLOGY. By W. S. Paton and F. W. Cragg. Pp. xxxiv + 764 and 89 plts. London: Christian Literature Society for India, 1913. Price £1 1s. 0d.

To medical and veterinary officers and naturalists generally who are located in the tropics, this work will prove a real boon. As the authors state, the general plan of the work has been suggested by the difficulties with which they themselves have had to contend. Particular attention has been paid to the description of methods of breeding and laboratory manipulation, and there is a wealth of useful illustrations.

Briefly, the scope of the work is as follows:—After a general introduction, the second chapter is devoted to the anatomy and physiology of the blood-sucking Diptera, and forms an excellent introduction to insect morphology. The following three chapters deal with the general biology, classification, and life-history of numerous species of Diptera, with similar ones on the Rhynchota, Anoplura, Acarina, Pentastomida, and Eucopepoda.

[JOURN. ECON. BIOL., June, 1914, vol. ix, No. 2.]

There is a useful chapter on laboratory technique and an interesting one on the relation of Arthropoda to their parasites. Ample references are given to the literature at the end of each chapter, and there is a very full index.

The title of the book is not a good one, for a quarter of the work is devoted to Arthropoda other than insects.

The authors have taken infinite pains to produce a really useful work, and in spite of one or two shortcomings, they have succeeded, and at the same time materially added to our knowledge by a considerable amount of original investigation.

TRAITE D'ENTOMOLOGIE FORRESTIERE A L'USAGE DES FORESTIERS. Par A. Barbey. Pp. xiv + 624, 8 coloured plts. and 367 text figs. Paris: Berger-Levrault, 1913. Price 18 fr.

If for no other reason than the general excellence and wealth of illustration, this volume will be welcomed by all interested in forest entomology, but it has many other features to recommend it.

Commencing with a short introduction, in which the author reviews the historical side and gives a general account of insect anatomy and classification, we pass to the main body of the work. The author treats of the different classes of insects under the headings of the different trees, thus we have chapters on the Pines, Oaks, Chestnuts, Birches, Poplars, Limes, Elms, etc. The various insects are briefly but clearly described, and the damage they occasion indicated, with notes on preventive and remedial measures. In all cases there is a wealth of illustration, indeed, many of the figures are unsurpassed for detail and interest. They have been chosen with great care, and must prove of great value to foresters and entomologists alike.

The lucid and terse style in which the work is written should commend it to English readers, who will find much material of real practical value.

THE ELEMENTARY PRINCIPLES OF GENERAL BIOLOGY. By J. F. Abbott. Pp. xvi + 329 and 114 text figs. New York: The Macmillan Company, 1914. Price 6s. 6d. net.

The need of a concise treatise, such as the work before us, has long been felt by both teachers and students of Biology in this country. "In Biology," Professor Abbott states, "the field is so broad and so varied that the student is very likely to lose sight of the fundamental principles that underlie all living nature. Moreover, these principles do not grow out of the laboratory work so obviously as is the case with such sciences as chemistry and physics."

The book is well-planned, although in many cases condensed, nevertheless the ideas are clean-cut, definite, and well put, and there is an entire absence of vague notions so common in works of this kind.

Apart from the value of this book in the laboratory and classroom, we may regard its very publication as an indication of the thorough manner in which biology is taught and studied in the

American Universities, which leads us to inquire whether or not the too rigid adherence to "types" in this country is not starving the student of biology.

The present work is bound to grow (there is room for considerable amplification), and we trust its author will not rest satisfied until he has given us a really standard work built upon the present structure.

Controlled Natural Selection and Value Marking. By J. C. Mottram. Pp. ix + 130. London: Longmans, Green & Co., 1914. Price 3s. 6d. net.

In this interesting little volume the author puts forth a new theory, or, as no attempt is made to prove it, he thinks it would have been better perhaps to have called it a new hypothesis. One of the chief reasons for advancing the Theory is to stimulate research, and also that it supports the Darwinian theory of the origin of species.

The theory is stated under four headings, viz.: (1) Natural Selection appreciates the differences in character which distinguishes male from female, young and old. (2) Natural Selection must treat associations of individuals as units, just as it does single individuals. (3) Natural Selection, just as it brings about diversity of structure by acting on individuals, so it must bring about diversity of structure by acting upon associations of individuals. (4) These diversities of structure found in the unequally valuable number of societies, control Natural Selection in such a way that the less valuable are more liable to destruction than the more valuable.

Whatever value one attaches to the author's views no one will question the interest of the work. Many of the chapters might be considerably amplified, and no doubt will be in future editions. The book is certain to command a wide circle of readers.

Physiological Plant Anatomy. By Dr. G. Haberlandt. Translated from the Fourth German edition by Montagu Drummond. Pp. xv + 777 and 291 figs. London: Macmillan & Co., Ltd., 1914. Price 25s. net.

Professor Haberlandt's *Physiologische Pflanzenanatomie* is deservedly well-known to most botanical students, and the appearance of an English translation will serve to increase the number who may benefit by a study of its pages.

It was in 1881 that the author first put forward his physiological classifications of tissue-systems, which in 1884 were embodied in the first edition of the present work. The present translation is of the fourth German edition.

We believe this to be the only thorough and exhaustive account of the connection between the structure and the functions of the tissue-systems, and it contains a mine of information, methodically described. There are many views advanced which are still debateable, but with these we are not here concerned. We welcome the work, with its wealth of notes and full indices, as a distinct gain to botanical literature, and one which undoubtedly will be largely made use of by English students.

Some Minute Animal Parasites. By H. B. Fantham and Annie Porter. Pp. xi + 319, 1 plt and 56 figs. London: Methuen & Co., Ltd., 1914. Price 5s. net.

The recent rapid advances in protozoology have resulted in a very voluminous literature upon the subject, which it is quite impossible for the layman or even the science student to follow; the need therefore for a scientific but readable account of the various unicellular parasites that are the cause of disease in man and his domestic animals is apparent.

In the work before us the authors have given us a most interesting account of these different minute parasites and the diseases they give rise to, but we are surprised to find that no references are given to the original sources from which the information has been obtained. To the student a short bibliography at the end of each chapter would have proved exceedingly useful. This is undoubtedly a serious defect in an otherwise really useful little work.

A Course of Practical Work in the Chemistry of the Garden. By D. R. Edwardes-Ker. Pp. 40. London: John Murray, 1914. Price 1s. 6d. net.

There must be many teachers in agricultural schools, or where agriculture is taught, who desire such a little text-book as this, and we can strongly recommend it to their notice. The four chapters deal with the chemistry of plants, soils, manures and fertilisers, and sprays and washes; all are thoroughly practical, and in the hands of a capable teacher could not fail to prove highly instructive and valuable.

THE

JOURNAL OF ECONOMIC BIOLOGY.

PRELIMINARY OBSERVATIONS UPON THE LIFE-HISTORIES OF *ZENILLIA PEXOPS*, B. & B., AND *HYPAMBLYS ALBOPICTUS*, GRAV.

(Two previously unrecorded parasites of the Large Larch Sawfly).

BY R. A. WARDLE, M.Sc. (VICT.),

Lecturer in Economic Zoology in the University of Manchester.

(WITH PLATES IV-VI AND ONE TEXT-FIGURE).

CONTENTS.

1.—INTRODUCTION.

The investigation into the methods of controlling the ravages of the Large Larch Sawfly (*Nematus erichsonii,* Htg.) in the Manchester Corporation Estates at Thirlmere, Cumberland, was continued by the Department of Economic Zoology at Manchester, during 1913 and 1914, chiefly with a view to eliciting further information which might bear upon the policy, that is being pursued, of encouraging the natural agencies that tend to keep the pest in check. A large part of the material and data upon which this paper is based was gathered together by my predecessor, Mr. Joseph Mangan, and I must express my indebtedness to him for permission to utilise the same. The inquiry into the percentage-numbers of insect-parasites of the Sawfly has yielded during the past two years extremely interesting and important results. The most noteworthy features have been the great reduction in the percentage numbers of *Mesoleius tenthredinis,* Morley—the Ichneumonid parasite so prevalent in previous years—and the increase in the numbers of two parasites that have hitherto played an extremely insignificant part in the checking of the Sawfly, namely :—

(1). *Hypamblys albopictus,* Grav., an Ichneumonid closely related to *Mesoleius.*

(2). *Zenillia pexops,* B. and B., a Tachinid fly.

Neither had been recorded from the Large Larch Sawfly prior to the publication, in *Nature,* of July 24th, 1913, of Mr. Mangan's letter announcing these results, although there is no doubt that both parasites have been present since the investigation was first commenced.

2.—Hymenopterous Parasites of *Nematus erichsonii.*

The Hymenopterous parasites that have previously been reared from *Nematus erichsonii* are as follows :—

Family Ichneumonidae.

Sub-family Ichneumoninae.

Coelichneumon fuscipes, Grav.	...	1910	Thirlmere.
Cratichneumon annulator, Fab.	...	1911	Thirlmere.

Sub-family Cryptinae.

Microcryptus labralis, Grav.	...	1909 onwards	Thirlmere.
Aptesis nigrocincta, Forster.	...	1910 and 1911	Thirlmere.
Spilocryptus incubitor, Strom.	...	1911	Thirlmere.
Cryptus minator, Grav. ...	...	1910	Thirlmere.
*Hemiteles necator, Grav.	...	1910	Thirlmere.

Sub-family Tryphoniinae.

Mesoleius tenthredinis, Morley.	...	1908 onwards	Thirlmere.
Perilissus filicornis, Grav.	...	Recorded by Cameron (1885).	
Perilissus lutescens, Grav.	...	Recorded by Brischke.	

Family Braconidae.

Microgaster sp. ...	...	Recorded by Lintner (1885).	
*Microplites sp. ..	...	1911	Thirlmere.

Family Chalcididae.

Coelopisthia nematicida, Pack.	...	Maine (1883).
Diglochis sp. (prob. klugii).	...	Minnesota (1909).
Pteromalus (Diglochis) klugii.	...	Posen (1841).
*Perilampus sp.	...	Wisconsin (1910).

Family Cynipidae.

*Anacharis typica. ...	...	Thirlmere (1910).
*Figites sp.	...	Thirlmere (1910).

* *Probably hyperparasites.*

The majority of the parasites were reared at Manchester and at Ottawa; a fuller account of the majority of these parasites is given by Hewitt. (1). No Chalcid has, it will be noted, been recorded from English cocoons, but an unidentified chalcid was reared from a Buttermere cocoon in 1913, and may prove to be an unrecorded parasite.

In spite of the length of this list, in the majority of cases only one or two specimens of the parasite have ever been obtained, possibly because they are normally parasites of Lepidoptera and only accidentally parasites of *Nematus*. In fact, the only species which has occurred in successive years in sufficient numbers to have been of economic interest is the Ichneumon *Mesoleius tenthredinis*. That this parasite should persist year after year is only to be expected, for the sub-family, Tryphoninae, to which it belongs is very largely parasitic upon Tenthredinidae. This ichneumon occurred to the extent of 6 per cent. in Sawfly cocoons from Thirlmere in 1908; this proportion in 1910 had risen to 62 per cent., and the plantations during that year were almost wholly free from attack. The reduction in the number of Sawflies was naturally followed by a reduction in the number of *Mesoleius tenthredinis*, the percentage in 1911 falling to 18, and in 1912 to 8. In 1913 the percentage was even less. These figures apply to cocoons from the Thirlmere district. The percentage number of *Mesoleius* in cocoons from other localities was, in 1913, still fairly high, as will be seen from the subjoined table:—

REARING RESULTS, 1913.

Locality.	No of Cocoons.	Per that hatched	Propor of M. tenthredinis	H. albopictus	Z. pexops.
Thirlmere (Shoulthwaite) ...	1295	41 %	2 %	25 %	24 %
Keswick (Latrigg)	266	34 %	15 %	4 %	56 %
,, (Coombe)	460	33 %	8 %	28 %	18 %
Buttermere	80	36 %	32 %	14 %	None
Crummock (Lanthwaite) ...	537	44 %	10 %	7 %	2·2 %
Grasmere (Wyke)	238	54 %	35 %	1 %	None
Ambleside (Long Heights)*	?	?	51·8 %	14·3 %	?

* Data for Long Heights supplied by Dr. C. Gordon Hewitt.

The percentages given above do not represent actual percentages of the quantities of cocoons taken, but merely represent the ratio of parasites to Sawflies in the cocoons that hatch. This is due to the fact that some 50 per cent. or more of the cocoons do not yield any results, the caterpillars either perishing from fungus, drought or disease, or refraining from pupation until the succeeding year. The Board of Agriculture rearing experiments, carried out in well ventilated breeding boxes placed in the woods at Rhayader, also only yielded a hatching percentage of 33.1. (2). As the fungus occurs naturally in the woods, attacking even 25 per cent. of the cocoons according to Hewitt, there is no doubt that this loss of cocoons in the breeding cages is inevitable and to a certain extent paralleled under natural conditions. As some of these localities were exploited for the first time in 1913, it is not possible in every case to say whether an actual decrease in the percentage of the species has occurred in 1913, as compared with 1912. Those cases in which comparison can be made, however, do indicate a very considerable decrease, and it is possible that this holds good in every case: thus, the apparently high percentage of 51 in Ambleside cocoons is a reduction from percentage of 75 and 56 in two respective batches of cocoons reared in 1912; similarly the Grasmere percentage of 35 is a reduction from 82, and the Crummock percentage has declined from 24 to 10.

A reduction from a high percentage in one year to a much lower percentage in the succeeding year is only to be expected, if correlated with a gradual decline in the numbers of the host, particularly if the former percentage be abnormally high, as was the case in 1912 among Grasmere and Ambleside cocoons. There is, however, some reason to suspect that this percentage decline in the numbers of *Mesoleius* has not in every case been accompanied by a corresponding reduction in the numbers of the *Nematus*. Thus, Shoulthwaite plantation, with a decline in the percentage of *Mesoleius* from 8 to 2, was distinctly worse in 1913 than in the previous year. Under such circumstances, therefore, it is extremely suspicious to find such a decline accompanied by a considerable increase in the numbers of two other parasites, even though there can be absolutely no question as to their being also primary parasites of *Nematus*.

Among the parasites reared from Thirlmere cocoons in 1910, there appeared certain specimens of an Ichneumon which, though resembling *Mesoleius tenthredinis*, was yet sufficiently distinguishable from it by the white colour of the first and second coxae.

Examination of 1909 material showed that a few specimens had also been reared in that year also. In 1911 and 1912 comparatively few cocoons were obtained and no specimens of this ichneumon were reared here, although I understand from Dr. Hewitt that he reared it in Canada (from Thirlmere cocoons) during that period. No proper identification appears ever to have been made, although the insect was alluded to by Mangan (3), until last year, when, comparatively large numbers having been reared from Shoulthwaite and Coombe cocoons, specimens sent to Professor Schmiedeknecht were identified as *Hypamblys albopictus*, Grav., and described as having never before been recorded from *Nematus erichsonii*. A note of this fact was published in *Nature* (Nov. 13, 1913) where, by an unfortunate error, the generic name appeared as "*Hyperablys.*" I take this opportunity, therefore of correcting the same.

Hypamblys albopictus, Grav.

Tryphon albopictus, Grav. *Euryproctus transfuga*, Thomson. *Euryproctus albopictus*, Strobl. *Syndipnus albopictus*, Pfankuch. *Mesoleius transfuga*, Holmgren.	Synonyms.

Description.—This species is described by Schmiedeknecht in Opuscula Ichneumonologica (p. 2791) as *Hypamblys albopictus*, and by Morley in British Ichneumons (Vol. IV, p. 248) under the name *Euryproctus albopictus*. The following description is quoted from the latter source:—

"A shining, punctulate species, with hind tibiae mainly white and abdomen more or less broadly red centrally. Head somewhat constricted posteriorly; mouth, clypeus and, except a black line connecting it with clypeus, face whitish; Clypeus apically broadly rounded, hardly margined and basally sub-discreted; cheeks black and not buccate. Antennae filiform, as long as body and more slender in male; scape whitish beneath; five or more basal flagellar joints whitish—testaceous, becoming apically darker. Thorax white—dotted below radices; mesonotum convex with indistinct notauli, pleurae nitidulous; metathorax subrugulose, with areola wanting or very incomplete, petiolar area smooth and entire. Abdomen nitidulous, apically explanate in male and sub-compressed in female, black; male with second segment, except two discal dots, third entirely and a transfascia on fourth, red, or with only the second segment apically ferruginous in both sexes; remainder apically flavescent-margined; basal segment very slightly curved and subdistinctly sulcate distally to beyond its centre, with central spiracles; ventral plica flavous, hypopygium extending to sixth dorsal segment; terebra short and infuscate. Legs fulvous, anterior with coxae and trochanters of male whitish; hind coxae black and in male apically, with trochanters, whitish; hind tibiae in both sexes whitish with apices, apices of their femora, and all their tarsi, nigrescent. Wings hyaline, stigma and radius infuscate, radix and tegulae white; areolet wanting or irregularly subpetiolate; nervellus intercepted a little below centre. Length, 6 mm."

With regard to the hosts of this ichneumon, Morley adds:—

"This collective species occurs in Silesia, Belgium and France, and from the end of July to early September, in Southern Sweden; it was bred by Brischke (Schr. Nat Ges. Danz., 1871, p. 80) from larvae of *Nematus hypogastricus,* and of *N. testaceous* in Prussia. *E. albopictus* was recorded by Marquand from the Lands End district (Trans. Penz. Nat. Hist. Soc., 1884, p. 346), and by Bridgeman from Brundall, in Norfolk, during July and August. *M. transfuga* was also brought forward by the latter, with some hesitation (Trans. Norf. Soc., 1894, p. 625), from Kings Lynn, in the same country, and bred, probably at Worcester from *Camponiscus luridiventris* by Fletcher."

Camponiscus luridiventris is, according to Cameron, synonymous with *Nematus hypogastricus*. So that in endeavouring to ascertain the possible origin of the appearance of *Hypamblys albopictus* in the Larch plantations we have only two previously recorded hosts to take into consideration, namely: *Nematus flavescens* (*testaceous*), Ste., a common insect on *Salix caprea,* and *Camponiscus luridiventris,* Fall, a widespread feeder on the Alder. It is extremely likely then that this Ichneumon has always been present in the vicinity of the Larch plantations as a parasite of the caterpillars upon Willows and Alders, but owing to the fact that these caterpillars are not numerous enough to become pests, has never been able to increase to a great extent and so come into prominence, until afforded an opportunity by the sudden outbreak of *N. erichsonii.*

Life-history.—Dissections of parasitised *Nematus* caterpillars at various times during the past eighteen months have yielded a considerable quantitiy of Ichneumonid larvae. To diminish the possibility of these larvae belonging to both *Mesoleius tenthredinis* and *Hypamblys albopictus,* the caterpillars dissected were taken solely from Shoulthwaite cocoons, the proportion of *Mesoleius* in this locality being only 2 per cent. of *Hypamblys* during the period covering dissections. It may be pointed out, however, that the scanty information available regarding the life cycle of Ichneumonids seems to indicate that the larvae of closely related species, parasitic on coincident stages of the same host or allied hosts, would be extremely difficult, if not impossible, to distinguish, and that when the times of imaginal emergence agree, as in this case, the times of duration of the various stages probably agree also. The tentative reconstruction of the life-history of *Hypamblys albopictus* described below, is therefore, I believe, not vitiated by the possible intrusion of specimens of *Mesoleius* larvae into the material under examination.

Dates of Emergence.—The dates of emergence of *Hypamblys* from the Sawfly cocoons agree fairly closely with those of *Mesoleius*: both began to appear in 1913, during the last week in April or the first fortnight in May. The earliest emergence recorded for *Hypamblys* was on April 26th, and the majority had emerged before the end of May, the last recorded emergence being recorded on June 10th. The natural time for *Hypamblys* to commence to emerge is probably the first fortnight in May. In 1914 they commenced to emerge so early as April, but as the cocoons from which they emerged had been kept indoors throughout the winter, this early emergence cannot be taken as normal. As will be seen from the sub-joined table, the Ichneumon commences to emerge some time after the first date of emergence of the host, some nineteen to twenty-five days after, in fact.

DATES OF EARLIEST EMERGENCE.

	1913.		1914.	
Locality.	N. erichsonii	H. albopictus	N erichsonii	H. albopictus.
Shoulthwaite	April 29	April 30	Feb. 28	April 2
„			Mar. 11	April 14
Buttermere...	April 24	May 13		May 14
Grassmere (Wyke) ...	April 15	May 10	April 27	May 16
Dodd			April 21	May 11
„			April 21	May 13
Latrigg	April 25	May 8		
Coome	April 15	May 10		

Oviposition.—As regards the number of eggs that the Ichneumon can lay, no definite statement can be made. As each ovary, however, contains twenty-eight tubules, and as at least eight ova, in various stages of maturity, are discernible in each tubule, the number of eggs that the Ichneumon is capable of producing cannot be less than 448, and probably greatly exceeds this number. I have not yet been fortunate enough to observe the actual process of oviposition: all the Ichneumons reared in captivity during 1914 emerged, and died, some weeks before Larch Sawfly Caterpillars were procurable, and numerous attempts to induce the parasites to oviposit in the similar caterpillars of *Nematus ribesii* were fruitless. Mr. Edwards, however, has observed *Hypamblys* females ovipositing within medium sized Larch Sawfly caterpillars: the posterior half of the body was the region attacked.

A batch of caterpillars, however, produced in July, 1914, from the Thirlmere plantations, proved to contain freshly parasitised specimens and Ichneumon eggs in various stages of development were obtained, in addition to newly hatched larvae. The number of eggs and embryos found in parasitised caterpillars was, in the majority of cases, two; in the few cases where this number was exceeded the eggs were in various stages of development and probably had not been all deposited by one individual *Hypamblys*.

Egg.—The newly deposited egg (Pl. iv, fig. 2) measures about 5 mm. in length by 2 mm. in breadth; it is cucumber shaped, but with the ends rounded, and is a vitreous white in colour; the developing embryo is faintly discernable through the semi-transparent chorion. As the embryo develops, the egg lengthens somewhat, not apparently by a process of true growth but by a stretching of the chorion, which is thereby rendered thinner and more transparent. The end of the embryo destined to form the future head, and the developing appendages, are clearly demarcated (Pl. iv, fig. 3).

By further stretching of the chorion the egg becomes almost spherical in shape, and the embryo undergoes a ventral flexure until the future head end and the future tail end almost touch. The head and body segments now become clearly marked, and the abdominal appendages and the posterior appendages—the so-called "tail"—develops (Pl. iv, fig. 4). The egg is ready to hatch, the chorion being now so thin that a very slight prick, whether from the needle of the observer or the mandibles, presumably, of the embryo, is sufficient to rupture it and free the imprisoned embryo.

The duration of these stages is very difficult to estimate, as the actual time of oviposition was in no case known, but from knowledge of the probable ages of the caterpillars examined and the dates when they were collected, I should estimate the period between the oviposition and completion of embryonic development to be about fourteen days.

First Stage Larva.—The newly hatched larva (Pl. iv, fig. 5) averages slightly over 1 mm. in length by .22 mm. in breadth across the thoracic portion. The head is comparatively large, unpigmented except for a pair of long pointed mandibles, reddish orange in colour, crossing each other at the tip and apparently hollow. Behind the head follows a trunk consisting of thirteen segments, the last of which is prolonged into a tail-like outgrowth, measuring one-fifth of the total, *i.e.*, some 0.15 mm. in length. The trunk is made up of a thoracic portion of three large segments, each bearing a pair of lobe-like appendages, and an abdominal portion of ten smaller abdominal segments, each bearing a pair of claw-like appendages. These segments and appendages are better marked in the older larva. Timberlake (5), describing the similar larval stages of *Limnerium validum,* an Ophionine Ichneumon, distinguishes only twelve trunk segments. On the other hand Seurat (6) describing similar stages in the Ichneumon *Mesochorus vittator* distinguishes thirteen segments; Ratzeberg (7) also in describing the larval stages of *Anomolon circumflexum*, considers the number to be thirteen. Other authors also speak of the number of segments being thirteen; *e.g.*, Riley in regard to *Thalessa lunator,* Berthoumieu in regard to *Ichneumon rubens,* Xambeu in regard to *Pimpla oculatoria.* All agree in considering the tail to be a ventral outgrowth of the last segment: this organ is slender, tapering, curved slightly, and possibly serves a respiratory function.

Timberlake (5), describing a similar structure in the larva of *Limnerium validum,* an Ophionine Ichneumon, says:—". . . the organ might properly be termed a blood gill. There is nothing in its structure to contradict this view, as it is a simple hollow tube lined with hypodermal cells, and undoubtedly filled with blood a greater part of the time. Since the larva lies free in the body cavity of the host, it is constantly bathed in blood and lymph fluids, from which the oxygen of its own blood must be derived through the delicate integument of the tail or other parts of the body, especially while still small."

Seurat, however, and Morley also, ascribe a locomotory function to this outgrowth.

The respiratory system agrees very closely with Seurat's description of the respiratory system of *Mesochorus,* consisting as it does of two lateral trunks running from thorax to tail, each sending off a latero-dorsal and a latero-ventral branch to each segment, and branches to the head; the prothoracic commissure connecting the two lateral trunks was quite obvious, but the ventral commissure at the anterior end of the tail was not discernible but may have been present. Stigmata were not discernable. According to Seurat, the tracheal system at this stage is a closed one, air being taken into the trachial trunks via the skin, and the stigmatic trunks being blind at their free extremities.

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The full-grown larva of this stage (Pl. v, fig. 6) averages somewhat over 4 mm. in length, the trunk being 3 mm. in length, and the tail 1 mm. In structure it resembles the newly hatched form, the head being, however, well chitinised and more definite in shape, and the segments and appendages being more clearly demarcated. The mouth-parts (Pl. v, fig. 7) consist of strong, pointed mandibles projecting across a circular mouth cavity, the chitinous rim of which is somewhat indented on the posterior margin.

Apparently this full-grown larva does not feed but lies dormant until the following Spring. Parasitised caterpillars examined early in November, contained these full-fed first stage larvae, lying in the fat body and occurring singly or in numbers, the usual number being two or three. Examination of parasitised caterpillars in the following March yielded the same stage of the larva, the specimens being identical in size and structure with those obtained three months before, and the fat-body of the caterpillar appearing in no ways different from that of the caterpillars in November.

A curious feature about this stage is that it is quite a common occurrence to find full grown, fully-developed larva still apparently within the swollen egg. This phenomenon naturally brings about the question as to whether the free first stage larvae found, had hatched naturally or whether they had been liberated artificially in the process of caterpillar examination. It also leads one to suspect that this first stage larva may not feed upon the caterpillar at all, but remain within the egg and complete its first stage growth at the expense of it. The question is one that requires further investigation. I can find no mention of it in such literature as I have been able to consult. Timberlake certainly mentions having found larvae enclosed in a "thick, homogeneous-appearing transparent capsule of tissue," but he states that the larvae were dead and that this capsule was composed of innumerable closepacked, amoebocytes serving to break down the tissues of the enclosed parasites.

Second Stage Larva.—(Pl. v, fig. 8). In the Spring the first-stage larva becomes active again and moults into the second stage. Examination of parasitised caterpillars in March yielded, in addition to numerous first stage larvae, certain other larval forms, slightly larger in size but differing chiefly in possessing a soft, less chitinised head, a reduction in the size of the abdominal appendages and a comparatively small tail. Only one second stage larva seems to occur in a caterpillar, though it may be accompanied by several first-stage larvae. Very few of these second-stage larvae were found.

The larva is about 6 mm. long, and consists of a head, very similar in size and shape to that of the first stage, but quite soft and unpigmented, and a trunk of thirteen segments, the last of which is prolonged ventrally into a short tail-like appendage. The segments are not so clearly demarcated as in the first stage, and cannot be differentiated into thoracic and abdominal portions. The appendages are greatly reduced. The mouth-parts consist of a pair of mandibles, not very clearly marked, projecting across a circular, funnel-like mouth cavity.

There is no doubt that, when several first stage larvae occur in one caterpillar, only one of these passes over into the succeeding stages. Not only does the size of the imago militate against the possibility of more than one emerging from a single cocoon, but examination of numerous parasitised cocoons in April has never yielded more than one Ichneumon pupa to a cocoon. Whether the remaining larvae become devoured by the successful one or whether they are absorbed by some process of amoebocytosis cannot be definitely stated.

First stage larvae were found in parasitised caterpillars so late as May 9th.

Whether this second stage is succeeded by a number of stages differing only in size, from the stage just described, or whether the final stage larva represents the full-fed, fully developed second stage form, it is impossible to say. At any rate, from the beginning of March onwards, a range of forms can be obtained, differing only in size and development of mouthparts and forming a transition series between the stage described above and the fully developed larva lying in the empty skin of the host caterpillar.

This full grown final stage larva (Pl. v, fig. 9) measures 10-11 mm. in length; the body is flexed ventrally, is dirty-white in colour and consists of a soft, inconspicuous head, and thirteen segments. Trunk-appendages practically absent. Tail is still present, but is very much reduced. In *Limnerium validum* the final stage larva is stated by Timberlake to be entirely destitute of any trace of tail appendage. The mouthparts consist of a pair of well-marked mandibles supported by chitinous ridges. Just below each mandible, on each side of a quadrangular elevation, which may possibly represent the labium, is a mamilliform structure bearing a minute pore. A pair of similar structures lies below the elevation. These four structures apparently represent spinnerets. Two faint, oval elevations some distance above the mandibles may indicate the compound eyes of the future imago.

Pupa.—In late April and May, the full-fed larva emerges from the empty skin of its host and spins a glistening, greyish-white cocoon, structurally resembling thin tissue paper, and apparently composed of an inferior kind of silk. Within this cocoon, which thus forms a lining to the cocoon of the host-caterpillar, the larva proceeds to pupation. The length of the pupal stage is probably short. Larvae that were removed from their cocoons seemed incapable of spinning another, but proceeded half-way to pupation and then perished.

The interest, therefore, of the life-history described above lies in the fact that the life-cycle of the parasite corresponds so closely to that of the host. There is only one brood, the imaginal period is distinctly later in appearance than that of the Sawfly, but the first-stage larva remains dormant through the winter just as the caterpillar does.

3.—Dipterous Parasites of *Nematus erichsonii.*

Four Tachinid flies have been previously recorded as having been reared from cocoons of *Nematus erichsonii*. In 1910 Mangan (2) recorded a Tachinid which he had himself determined to be *Exorista dubia*. Hewitt (1) records three such parasites, namely :—*Frontina tenthredinidarum,* Townsend reared during 1910 in St. John, New Brunswick. *Exorista crinita,* Rond. reared both at Manchester and Ottawa from 1909 onwards. *Exorista* sp. (*E. alacaris* suggested) reared by Mangan in 1911.

According to the Katalog. Palaarktischen Dipteren (Vol. III.), *E. crinita* and *E. alacris* are synonyms, so that, prior to 1913, there is only a record of two Tachinids parasitic on *Nematus erichsonii* in this country. In 1913 a considerable number of specimens belonging to some species of Tachinid was reared here from Cumberland cocoons; the percentages in cocoons from various localities have already been given. Nearly all the specimens were sent to Mr. Wainwright, who identified them as belonging to the species *Zenillia pexops,* B. & B. not previously recorded from the Larch Sawfly and not previously recorded as British. As the material thus identified included specimens from the Crummock district, the locality from which the Tachinids stated by Mr. Tothill to be identical with or closely allied to *E. alacris* had been reared in 1911, it was considered advisable to submit these latter specimens to Mr. Wainwright also, and after careful comparison with the type-specimens he came to the conclusion that the specimens really belonged to the species *Zenillia pexops*. In view of the difficulty of Tachinid determination, well illustrated by this difference in opinion of two recognised experts, the single Tachinid reared by Mangan in 1910 and determined by him to be *Exorista dubia* must be looked upon with suspicion. Although Mr. Mangan now places no faith in this determination no re-identification is possible, as the specimen was accidentally destroyed. Dr. Stewart MacDougall, however, has kindly allowed me to examine the Tachinid material bred out by him from Cumberland cocoons about the same time, and careful comparison indicates without doubt that they belong to the species *Z. pexops.*[1] There seems to be some grounds, therefore, for concluding that up to the present only one species of Tachinid has been reared from British cocoons, namely the species described below :—

Zenillia (*Myxexorista*) *pexops*, B. & B.

Mr. Wainwright states with regard to this parasite :—

"A very little known species; indeed, up to the present, I have only known of a single female, caught by me in the New Forest, and it has not yet been recorded as British. *Zenillia* is very near to *Exorista*, and the common *Phyrxe vulgaris*, Fall., and consists of several species mostly known as parasites of Lepidoptera, though one species, *barbatula*, Rond, has been recorded from *Nematus geniculatus*; of course it is not unusual for parasites of Lepidoptera to be bred also from Phytophaga."

This species was described by Brauer and Bergenstamm (Denkschr. Akad. Wien., LVIII, 1891, p. 332), and assigned to the genus *Myxexorista* :—

2. Macrochaeten discal und marginal.

X. Arten von schwarzer Körperfarbe.

A. Backen breit, herabgesenket (1/3 Augenhöhe). Mundrand zurückweichend, Vibrissen uber demselben. Profil convex wie bei Exorista vetula und pexopsis. Zweites Borstenglied weniglanger als breit. Am zweiten Ringe zwei feine, am dritten zwei stärkere Discalmacrochaeten. Erster. zweiter und dritter Ring mit marginal. Macrochaeten, die, am dritten, den ganzen Rand. einnehmen. Scheitel des ♂ fast von Augenbreite. Stirnborsten regellos und überdiess 2-3 Reihen feineren Borsten. Klauen des ♂ sehr lang. Drittes Fühlerglied des ♂ reichlich 3-mal, fast 4-mal, so lang als das zweite. Taster schwarz. Schildchen scharwz. Gesicht grau. Hinterleib blaugrau mit schwarzen Segmenträndern. Kleine schwarze Art. 7 mm.

To this description the following notes upon the colouration and chaetotaxy may be added, although it must be remembered that as colouration varies so much in Tachinid flies, colour-features cannot be considered to have very great systematic value.

A species ranging from yellowish-grey to dark-grey in scheme of

[1] Since writing, the determination has been confirmed by Mr. Wainwright.

colouration; females tend to be lighter in colour than males. Length, 7-9 mm.

Head.—Space between eye in ♂ equals breadth of eye, in ♀ is less than breadth of eye; parafrontals and occiput yellowish-grey; frontal vitta black; parafacials silver-grey; antennae dark-grey; arista bare. Two pairs of erect, well-developed, vertical bristles; ocellar pair divergent, proclinate, strong, present in both sexes; frontal bristles extend to slightly beyond second antennal joint; two pairs of orbital bristles.

Thorax.—Greyish-yellow to greyish-black, polished; a median pair of fairly well marked longitudinal black stripes; lateral to these, a pair of triangular dark patches; below these, a pair of short black stripes tapering at each end; squamae yellowish.

Three pairs of a strong presutural acrostichal bristles, three pairs of a strong postacrostichals; three pairs of pre-dorsocentrals, four pairs of post-dorsocentrals. On scutellum, three pairs of strong marginals, one pair of weak, eruciate apicals, one pair of fairly strong discals.

Abdomen.—Greyish-yellow to greyish-black; first segment dark and polished; posterior margins of other segments dark; abdominal macrochaetae discal and marginal, consisting of:—One slender pairs of discals, one pair of central marginals, two pairs lateral marginals, on second segment. One strong pair of discals, two pairs of central marginals, four pairs lateral marginals on third segment.

Life-history.—The imagoes commenced to emerge on May 5th (1913); the majority emerged steadily between May 5th and 22nd, and then emerged in fewer numbers, the last one appearing on June 10th. Nothing is known regarding the character of the eggs and the early stage larva. It may be noted, however, that an allied species—*Zenillia libatrix,* normally a parasite of the Brown-Tail Moth in Europe—is believed by Townsend (8) to possess the leaf-oviposition habit; on the other hand, the closely allied *Phryxe vulgaris* is stated, by Vassiliev (9), to be ovo-viviparous, a female laying up to 5,000 larvae.

The various stages of the feeding larva are gone through before winter commences. Examination of Sawfly cocoons early in November, 1913, yielded numerous full-fed Tachinid lavae, each lying within the empty skin of the host, the anterior end of the larva in the posterior end of the skin. Examination in January and February yielded other specimens exactly similar in position and structure. In no case had the *Zenillia* larva pupated.

There seems no reason to doubt, therefore, that *Zenillia pexops* hibernates as a final stage larva, an exception to the general custom in single brooded Tachinids of hiberating in the nymphal condition. The same phenomenon has been also remarked upon by Thompson (10):—" One of the most interesting modes of hibernation which we have yet discovered have been found with some forms which pass the winter as third stage larvae within the dry and otherwise empty skin of the host, emerging therefrom and pupating in the Spring. This method of hibernation we have so far observed only with two undetermined species, one a species of *Datana*, the other infesting a European caterpillar, which is possibly *Cnethocampa processionea*." Thompson describes these resting larvae as being of a golden-yellow colour, due, he thinks, to reserve fatty material, and speaks of the hard, firm texture of the skin. This golden-yellow colour was not evident in *Zenillia* larvae, however, nor did the integument appear to be any tougher than is the condition in Muscid larvae generally.

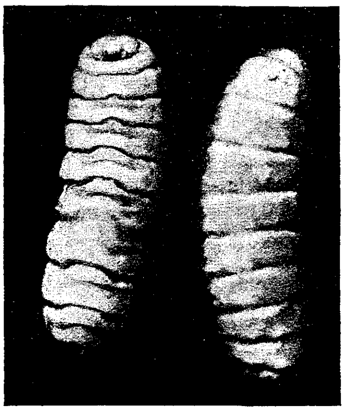

Fig. 1.—Full fed *Zenillia* larvae. × 5.

The full-fed larva (see text figure 1, and Pl. vi, fig. 10) is cylindrical, slightly flattened dorso-ventrally, and measuring 9-10 mm. in length, by 2.5-3 mm. in breadth. Excluding the head, there are twelve segments, of which the first two are somewhat retracted. The head is small, invisible from above: the antennae, as in all Tachinid larvae, are papilliform, with two chitinous rings lying one below the other. There are two mouth-hooklets, stout and not very curved (Pl. vi, fig. 11).

The anterior margins of all segments except the first have a spinulose ring, more pronounced ventrally: anterior ventral margin of third and following segments swollen and spinulose: on fifth to tenth segment this swollen area is elevated in the median line as a spinulose, crescentic pad; anal area (Pl. vi, fig. 10), without tubercles: stigmal pit subcircular, below it an elevated area dorsal to anus; each stigmal plate (Pl. vi, fig. 12) with three elongated slits arranged tangentially round a central button.

Pupation.—The larva does not emerge from the Sawfly cocoon to pupate in the ground, but pupates and forms its puparium within the cocoon. Cocoons examined late in March or early in April contain Tachinid puparia, never more than one puparium in a cocoon.

The puparium is of the usual Tachinid type, cylindrical in shape, but tapering slightly towards the posterior end, smooth, reddish in colour; 8 mm. long, by 2.5 mm. in diameter.

The exact way in which the newly hatched fly obtains exit from the Sawfly cocoon is not very clear, but examination of cocoons from which flies had emerged seemed to indicate that the fibres at the anterior end are first weakened somewhat, and then simply pushed aside by the emerging fly.

The time of emergence was, in the case of laboratory-reared specimens, ten to eleven days after pupation.

Parasites.—Howard's studies of the parasites of the Tussock Moth seem to indicate a greater liability to secondary parasitism on the part of such Tachinids as pupate loosely within the skin of a caterpillar, within its pupal skin, or within its cocoon. No parasites have, as yet, however, been obtained from Sawfly cocoons, which can be definitely indicated as hyperparasites of *Zenillia.* Hewitt (1) records the emergence from Cumberland cocoons in 1910 of two specimens of *Figites* sp., which he thinks may have been parasitic on Tachinids. In Wisconsin cocoons of *N. erichsonii* have yielded a specimen of *Perilampus* sp., a genus of Chalcididae, reared and recorded by Smith (11) from several Tachinidae.

4.—Conclusions from the Economic Standpoint.

It is obvious that the condition that has been present in certain Sawfly-infested Cumberland plantations during the past year, namely, the occurrence in fairly large percentage numbers of three primary parasites of *N. erichsonii* having corrresponding life-history periods, and all parasitic on the same stage of the host, is not conducive to beneficial parasitism. The possibility of what Dwight Pierce has termed "accidental secondary parasitism," or to use Fiske's term, "Superparasitism," that is to say, the parasitism of one individual host by two or more species of primary parasites, or by one species more than once, must not be overlooked.

As Fiske (12) has pointed out, in the case of two such superparasitic larvae in one host, one of three things may occur. In the first place, one larva may conquer the other, either directly by devouring it, or indirectly by bringing about the premature death of the host, and arrive to maturity, though often dwarfed or crippled. Secondly, both parasites may survive, in very rare cases neither the worse for the circumstances, more frequently both so seriously weakened or stunted as to materially reduce their reproductive capacity. Thirdly, neither may survive, a condition induced either by the premature death of the host, through excessive parasitism, or by the insufficiency of food.

From the economic standpoint, therefore, superparasitism in the majority of cases is just as inimical a factor in the control of a pest as hyperparasitism is.

The evidence for the existence of superparasitism on *Nematus erichsonii* is scanty, and much remains to be done.

The occurrence of several eggs or first stage Ichneumon larvae in an individual caterpillar has already been mentioned. Where the eggs or larvae numbered two or three, they were at about the same stage of development, and had undoubtedly been deposited by one female. If the number was greater, ranging from five to as many as twenty-two, the eggs and larvae were at various stages of development, and superparasitism, either by one species or two species, seemed to offer the more probable explanation.

The condition that determines which of these larvae shall proceed to pupation is chiefly, I think, one of age. Comparison of rearing results of cocoons from various localities, during 1913, showed that the earliest specimens of *Hypamblys* emerged, in nearly every case, several days before the earliest *Mesoleius*. Thus in the case of a super-parasitism from both Ichneumons, the *Hypamblys* larva would, in most cases, have the advantage of a few days' start, and so would be likely to survive over *Mesoleius*. This would explain the tendency, in a locality where both *Hypamblys* and *Mesoleius* were present, for *Hypamblys* to increase and *Mesoleius* to decline.

As regards the possibility of superparasitism by Tachinid and Ichneumon, nothing can, as yet, be definitely stated. If *Z. pexops* agrees with *Z. libratrix* in possessing the leaf-oviposition habit, such superparasitism is certainly to be expected, and as *Zenillia* completes the feeding period of its life-history long before either *Hypamblys* or *Mesoleius* does, it would be more likely to survive in competition with either. That *Zenillia* may predominate at the expense of the Ichneumons seems indicated to some extent by the respective percentages of parasites in the localities, Coombe, Latrigg and Shoulthwaite during 1913. These three plantations lie in comparative proximity to each other: they are not separated by mountain barriers. Accordingly, one would expect the percentage of parasitism in these three localities to be very similar. It may be pointed out, however, that Latrigg, with 50 per cent. of *Zenillia,* had only 19 per cent. of Ichneumons, whereas Shoulthwaite, with 24 per cent., of *Zenillia,* had 27 per cent. of Ichneumons, and Coombe, with only 18 per cent. of *Zenillia*, had 36 per cent. of Ichneumons. Thus the percentage of the Tachinid appears to vary inversely with the percentage of Ichneumons. A similar state of things would seem to be suggested by the percentage from Crummock, thus:—

	1912.	1913.
Zenillia	1.4%	2.2%
Ichneumons	24%	17%

And again by the results from Buttermere, thus:—

	1913.	1914.
Zenillia	none	32%
Ichneumons	46%	8%

Such being the case, it is desirable that future work should bear upon the question as to the respective values of *Zenillia* and the Ichneumons in the control of the Sawfly.

It may turn out that the undoubted powers of proliferation and of migration possessed by *Zenillia,* and its ability to withstand superparasitism by Ichneumons, will render it the most valuable of the three chief parasites. On the other hand, the notoriously wide range of hosts that a single species of Tachinid can affect, may prove in this case a factor that will tend to keep its numbers below the normal percentage necessary to the adequate control of the pest. That a percentage of 50 or less is insufficient under normal climatic conditions to keep the Larch Sawfly in check was evinced in 1913, by the condition of Shoulthwaite Plantation, which, though possessing 24 per cent. of *Zenillia* and 25 per cent. of *Hypamblys,* was distinctly worse in 1913 than in the previous year.

Further investigations may tend towards the conclusion that the occurrence of three parasites in comparatively large proportions in the same stage of *N. erichsonii* is a decidedly inimical factor in the natural control of the Sawfly ravages, for whether super parasitism in this case allows of the emergence of one healthy parasite, or whether, as the large proportion of shrivelled caterpillars present in cocoons during 1913 seems to indicate, the death of both host and parasites is brought about, the effect is unfavourable; leading in both cases to a material reduction in the rate of multiplication of the parasites.

In conclusion, I must express my thanks to Mr. A. B. Edwards, Mr. R. D. Marshall, Sir William Ashcroft and others, who have forwarded cocoons; to Mr. C. Wainwright and Prof. Schmiedeknecht, who have identified and given much information regarding the parasites; to Dr. C. G. Hewitt and Dr. R. Stewart Macdougall, for the loan of data and specimens, and to my chief, Professor Hickson, who has been the moving spirit in the Sawfly Investigations since their commencement in 1907.

5.—SUMMARY.

1. An interesting feature of the Large Larch Sawfly investigations during 1913 has been the percentage decline in the numbers of the parasite *Mesoleius tenthredinis*, formerly so prevalent.

2. This decline has not in every case corresponded to a decline in the numbers of the Sawfly, but has been accompanied by the appearance in comparatively large numbers of two previously unrecorded parasites, viz. :—

3. *Hypamblys albopictus, Grav.*, an Ichneumon closely related to *Mesoleius*, and having corresponding life-history stages, though emerging possibly a few days earlier. *Hypamblys* hibernates as a first stage larva.

4. and *Zenillia pexops*, B & B., a Tachinid fly, probably the same parasite that has previously been recorded at various times since 1910 as *Exorista crinita*, *Exorista alacris*, and *Exorista dubia*. *Zenillia* is exceptional, for a Tachinid, in hibernating as a final stage larva. It pupates and forms its puparium within the cocoon of the Sawfly, and emerges about the same time as the host.

5. As *Zenillia* appears to predominate at the expense of the Ichneumon parasites, it is important that future work should bear upon the question of the respective values of the varous parasites in the control of the Sawfly.

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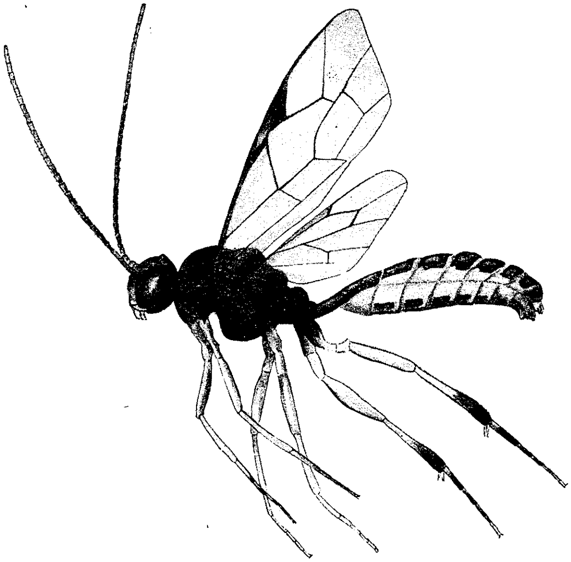
EXPLANATION OF PLATES IV—VI.

Illustrating Mr. R. A. Wardle's paper on the "Life-histories of *Zenillia pexops*, B. and B., and *Hypamblys albopictus*, Grav."

*Fig. 1. *Hypamblys albopictus*, imago.
Fig. 2. Developing egg of *Hypamblys*. Lateral view × 160.
Fig. 3. ditto Later stage × 160.
Fig. 4. ditto Shortly before hatching × 180.
Fig. 5. Newly hatched larva of *Hypamblys*, to show tracheal system. × 200. *g.* gut. *a.* anus. *p.c.* Prothoracic commissure.
Fig. 6. 1st stage larva—full grown. × 30.
Fig. 7. Ventral view of same. × 120.
Fig. 8. Second stage larva. × 20.
Fig. 9. Final stage larva. × 10.
Fig. 10. Full grown larva of *Zenillia pexops*, lateral view. × 11. *post. sp.* posterior spiracles.
Fig. 11. Antero-ventral view of same. × 25. *ant.* antennae. *ant. sp.* anterior spiracle. *m. h.* mouth hooks.
Fig. 12. Posterior end of full fed larva of *Zenillia*. *st.* stigmatic plates.
Fig. 13. Stigmatic plates of full grown larva of *Zenillia*.

* **Drawn by Miss Dust, Manchester School of Art.**



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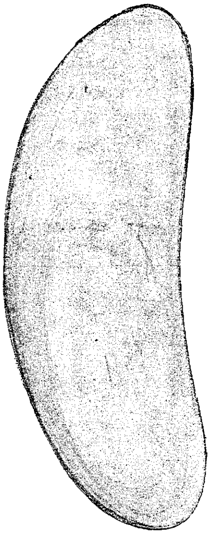

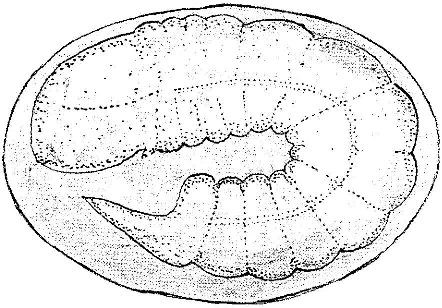

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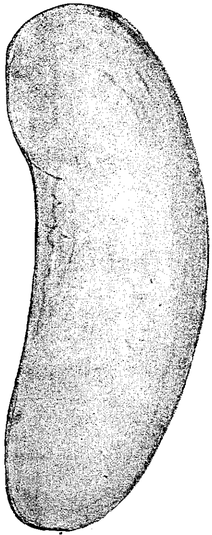

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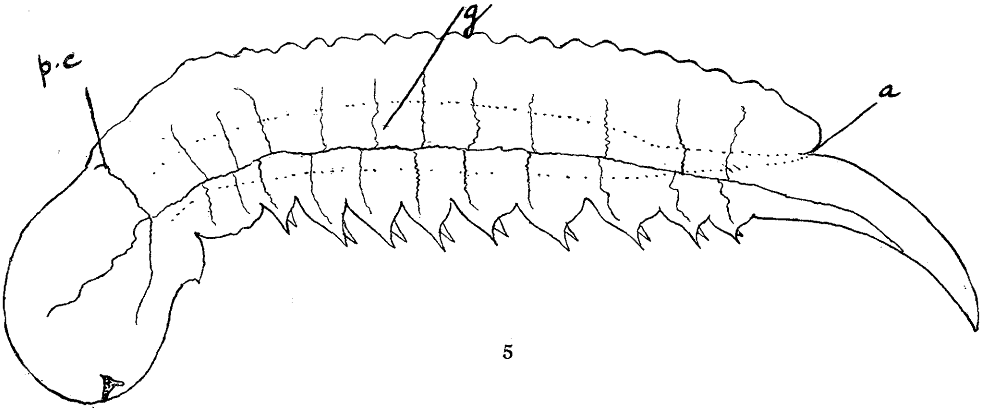

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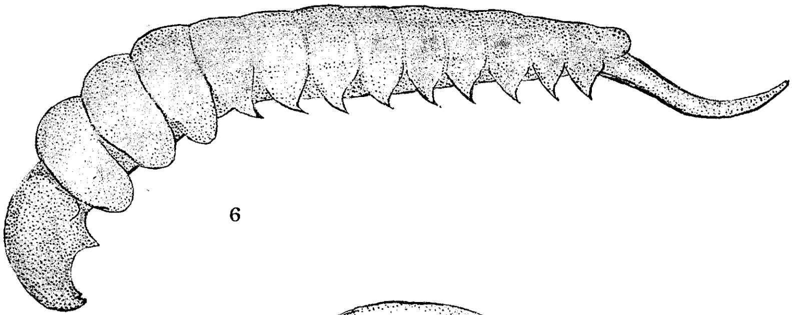
HYPAMBLYS ALBOPICTUS, Grav.



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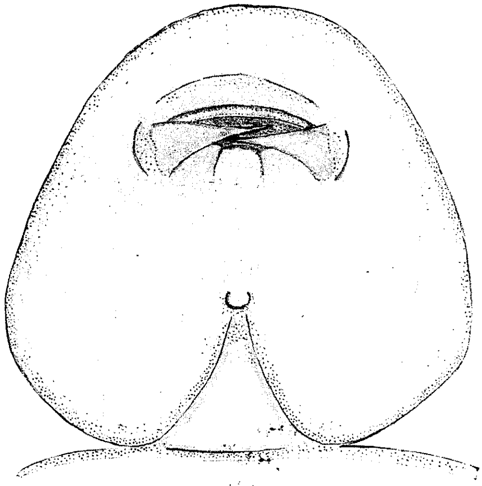

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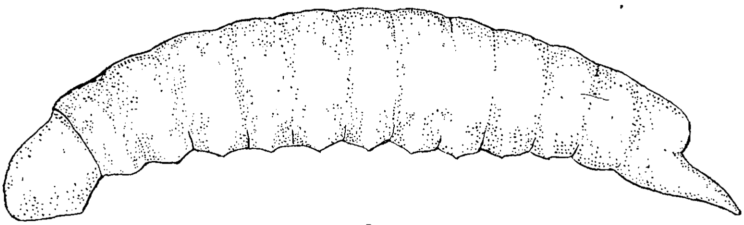

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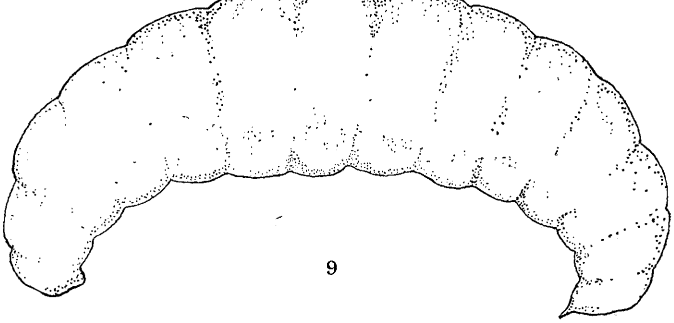

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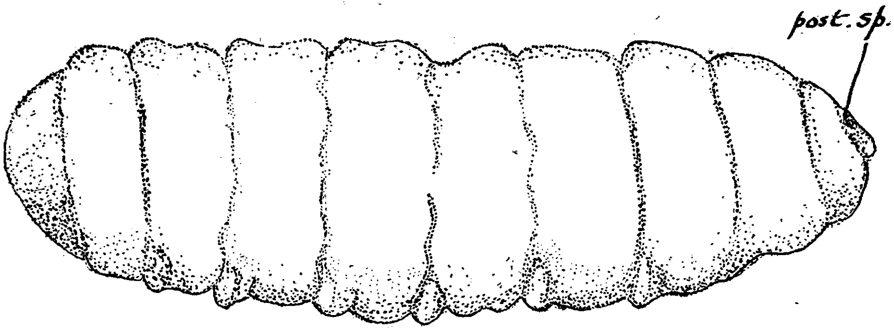

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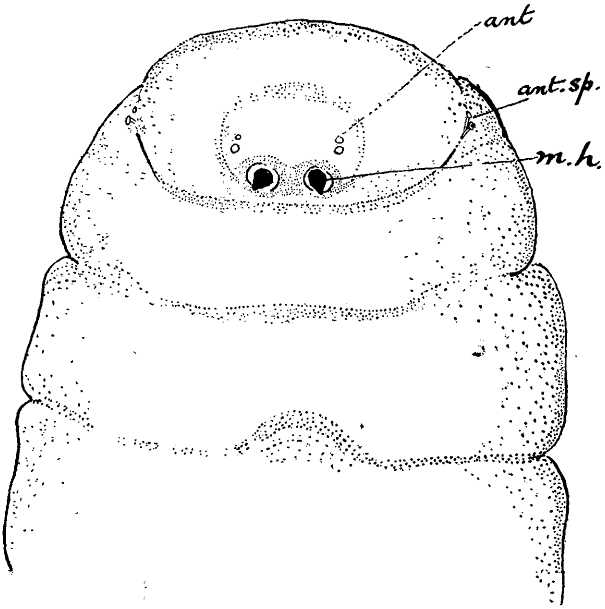

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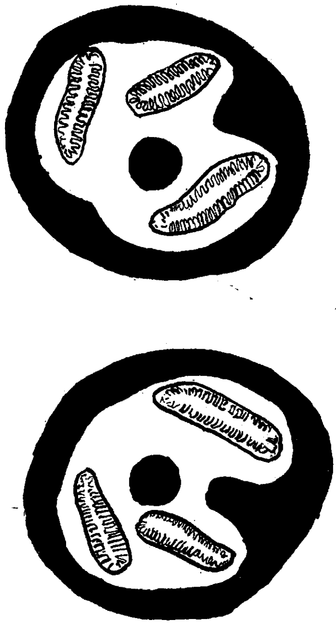

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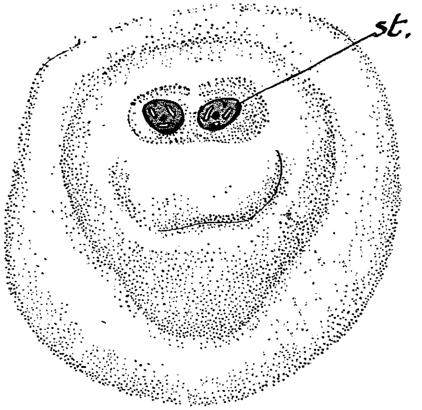


12

ZENILLIA PEXOPS, B. & B.

A CONTRIBUTION TO THE BIOLOGY OF SEWAGE DISPOSAL.

By J. W. HAIGH JOHNSON, B.Sc., F.L.S.,

Chemical Biologist to the West Riding of Yorkshire Rivers Board, Wakefield.

(With 6 Figures.)

During recent years the problem of sewage disposal has become very urgent, especially in populous inland localities, but even rural districts have now been compelled to adopt some definite system of treating their refuse. In the early days this refuse was dealt with by natural means, being applied directly to the land, and there devoured by various forms of animal and vegetable life. Later, as the problem became more acute, chemical means were called into requisition, and substances under various names (usually containing salts of iron or alumina) were used to precipitate the polluting matters from the sewage, lime often being added to assist this precipitation. Although by this means clear effluents could be obtained, it soon became evident that the enormous volume of sludge or mud thus produced entailed a very heavy expense in disposal, and the effluent obtained, although at times clear, often needed further treatment (filtration). Filters in some form or other therefore became an essential part of almost every kind of artificial sewage treatment. The modern sewage filter, however, is not, as might be supposed, a fine-meshed strainer of some inert material, such as stone, gravel, clinker, etc., but consists of rough, often large-sized pieces. The filtering capacity depends not upon the fineness of the material, but upon the slimy or gelatinous growth (Zoogloea) which develops on the filter when sewage is applied. These zoogloea masses form a suitable nidus for the further development of fungal and other forms of life, which further ramify among the filtering material, and thus produce a fairly efficient *mechanical* strainer; but this is not all, for the zoogloea masses can, under certain conditions, absorb soluble polluting substances from the liquid passing over them, so that the action of such a filter is not merely mechanical straining, but effects, more or less, efficient chemical purification.

The chemical evidence of this purification is to be found in the reduction of the "oxygen absorbed"[1] figure and in the decomposition

[1] This term has a definite chemical meaning, namely, the amount of oxygen absorbed, under stated conditions, by the liquid from an acid solution of potassium permanganate, but for ordinary purposes it may be regarded as affording some indication of the amount of purification (oxidation) which is still possible.

[Journ. Econ. Biol., October, 1914, vol. ix, No. 3.]

of complex nitrogenous matters which gives rise, first to ammonia, which may later become further oxidised into nitrites, and finally into nitrates. These chemical changes are essentially those due to oxidation, and it is interesting from a biological standpoint to note that recent experiments in sewage purification attempt to effect this oxidation by blowing air through sewage mixed with a biologically active sewage sludge.

The line of development of such filters has naturally been determined by this power of oxidation, and, consciously or unconsciously, the form eventually selected has been that which most favours the development of a wide range of organisms of both animal and vegetable origin. In fact, the modern sewage filter may now be regarded as an attempt to concentrate the natural agencies of purification into small compass. This intense concentration naturally renders them particularly sensitive to external influences. The whole subject forms a most interesting biological study of great practical importance, which may be conveniently treated under the following heads:—

1. Historical account of the development of the modern sewage (sprinkler) filter.
2. Organisms as an index of pollution.
3. Ecological associations and distribution of organisms in a sewage filter.
4. Some noteworthy dominant organisms occurring on sewage filters.
    a. The Sewage or moth-fly (*Psychoda*).
    b. The water springtail "Podura." *Achorutes viaticus* (L.), Tulb.
    c. Other dominant or sub-dominant organisms.

1. Historical Account of the Development of Sewage Filters.

Considering the prime necessity for disposing of the waste products of domestic life, it is somewhat surprising that, until quite recently, there was little or no improvement on primitive methods of dealing with this refuse. Probably the most advanced system of sanitation previous to the changes introduced in the nineteenth century is to be found in the Mosaic law. Attention was not, however, particularly attracted to these matters until the people gathered together in large and settled communities. In England this became marked about the middle of the eighteenth century, and during the succeeding decades conditions in the neighbourhood of dwellings became so intolerable that relief was generally sought by constructing drains to carry off sewage into cesspools or into the nearest watercourse. During the early portion of this period, on account of the small size of the towns and the slow-flowing nature of the ditches and smaller watercourses, the amount of pollution which eventually reached the larger streams and rivers was consequently small, and rarely, if ever, in excess of the requirements of the animal life incidental to such waters. Indeed, the reputation of many ancient fishing grounds is directly attributable to this adequate food-supply. Later, as the size and numbers of these communities increased, naturally the amount of pollution similarly increased. The most marked increase, however, occurred about the middle of the nineteenth century, and is contemporaneous with the introduction of the rapidly discharging sewers of the water-carriage system of drainage and the increased discharge of poisonous trade refuse. The effect of the above system on the condition of the streams was most marked, for not only did the sewers carry relatively more of the pollution of a district into the streams, but effected this discharge so rapidly that the sensible amount of purification formerly occurring in the ditches and dykes was minimised, while, on the other hand, the increased amount and poisonous character of the trade waste destroyed many of the natural agencies which normally assisted purification; under such exigencies it is not surprising that many of our streams rapidly degenerated into a condition which was little better than that of open sewers! From this time onwards the problem of sewage disposal may be said to have been ever present, but it is only during the last twenty years that rapid strides have been made towards its proper understanding and practical solution.

Is is worthy of note that this progress could never have been so rapid had it not been for the advanced state of general scientific knowledge at the time when the sewage problem became acute. The starting point, so far as concerns this subject, may be said to be the construction in 1675, by Antony Leuwenhoek, of a microscope sufficiently powerful to reveal the presence of minute organisms in water and putrefying fluids. But it was not until 1743 that Baker indicated the scavenging powers of infusoria and many bacteria, and in 1839, Schwann and Schultze proved that micro-organisms were the true agents of decomposition. There seems, however, to have been no attempt to make use of this knowledge in explaining the purification of sewage either when discharged into rivers or thrown upon land. It is true that from very early times sewage was thus disposed of, and was then found to disappear or to lose its polluting character, but it was generally assumed that sewage thus utilised on land was directly absorbed by the growing crops, or when discharged into rivers that it underwent a process of destruction by direct oxidation.

The Sewage of Towns Commission, appointed in 1857, reported that the best method of disposing of sewage was to convey it outside the towns and there apply it to the land, and the same recommendations were repeated by the Royal Commissions of 1865 and 1868. Sir Edward Frankland was a member of the 1868 Commission, the labours of which may be described as the beginning of the application of science to the problem of sewage disposal. Frankland studied the principles upon which the land treatment of sewage depends, and evolved the method known as intermittent downward filtration. In the Second Report of the above Commission, issued in 1870, he described the process taking place in soil, when used as a sewage filter, as being not merely mechanical but also chemical, and concluded "that the process of purification was essentially one of oxidation, the organic matter being to a large extent converted into carbonic acid, water, and nitric acid, and hence the necessity for the continual aeration of the filtering medium, which is secured by intermittent downward filtration, but entirely prevented by upward filtration." He very aptly compared the action of the soil with that of the lungs, and spoke of the "respiration" of the filters"; but it would appear that in spite of the work of Baker, Schwann, and Schultze, he had no idea of the function of living organisms in this oxidation process. It is to be noted, however, that he emphasised the importance of thorough aeration, and it is not surprising that later investigators gave considerable attention to this matter.

Long before Frankland's time it was known that when organic nitrogenous bodies are applied to the soil, the nitrogen becomes eventually converted into nitrate, but it was reserved to Muller in 1873 to indicate, and to Schloesing and Muntz in 1877 to demonstrate that this nitrification process is due to bacteria. In 1882, Warington showed that this change takes place chiefly in the upper six inches of the soil. The destruction of these organic matters is not entirely restricted to bacteria, and in 1883 Dr. Sorby clearly demonstrated this fact in his evidence before Lord Bramwell's Commission on the Metropolitan Sewage discharge. He showed that the sedimentary faecal matter in the River Thames disappeared, and was replaced by small rounded particles, which were the excrement of Entomostraca. He also found large numbers of crustaceans (fresh-water shrimps) and of small annelids and other mud worms actively devouring the deposits from the sewage, thus establishing the important fact that organisms of a higher order than bacteria act as sewage scavengers. In 1886 Dr. Dupré suggested the cultivation of such organisms and their discharge along with the polluting liquid.

During the years 1888 and 1889 the Massachusetts experiments were in progress at Lawrence, U.S.A., and the publication of the results in 1890 stimulated the interest of sanitarians throughout this country. The experiments were undertaken for the purpose of determining the fundamental principles of filtration of sewage and of learning what can be accomplished by filters made of different materials. Special attention was devoted to the nitrification process in filters constructed of gravel, sand, and soil, and it was stated that the purification of sewage was due to micro-organisms, by which nitrifying organisms are apparently meant. The importance of the rôle played by the larger organisms spoken of by Dr. Sorby and Dupré seems again to have been overlooked.

The stimulating effect of these Massachusetts experiments is well demonstrated by the crop of new or improved devices brought forward within the next few years. Thus, in 1891, Waring patented a filter, in which even distribution was secured by means of a layer of fine material, and aeration by means of a mechanical blower. In the same year, Scott-Moncrieff constructed his cultivation bacteria-bed, which depended upon (1) the presence in sewage of bacteria which are capable of peptonising (digesting) the organic matter which it contains, (2) the indefinite multiplication of these organisms in suitable environment, and (3) the fact that in nature organic refuse is destroyed by the same means.

About this time, J. Corbett, at Salford, constructed percolating filters with spray distributors, using crushed clinker or cinders ($\frac{1}{4}$in. to $\frac{3}{4}$in.) as medium. He secured ventilation by means of numerous under-drains, and by working the beds intermittently, allowed thorough aeration during the resting period.

In 1892, Dibdin, carrying out experiments at Barking, devised the contact bed method of treatment, and again emphasised the necessity for aeration. He attained this by quite a different method from that of Corbett, and used water-tight tanks containing coke, which he kept filled with sewage for a definite period, during this period the air which remained attached to the submerged material served to assist in the oxidation and purification of the sewage. When this period of contact was ended the tank was emptied, and the coke then allowed to drain for some time before the tank was refilled; this latter procedure again allowed air—the essential factor in all such purification processes—to penetrate and reach the organic matter and living organisms which developed on the surfaces of the material.

Lowcock, in 1893, used a filter to which air was supplied by mechanical means, being blown through pipes laid in the material of the filter.

In 1897, Colonel Ducat constructed a percolating filter similar in principle to that of Corbett, but used a different method of distribution, and advocated that the filter should be covered in and warmed so as to assist the development of the organisms.

In 1894, Corbett experimented with rotating sprinklers, and in 1898, Whittaker and Bryant constructed filters fitted with these at Accrington.

By this time, it may be considered, the main principles of sewage treatment had been fully realised, and since then any modifications in the application of these principles have been chiefly in details of construction, but latterly the fact that larger volumes of sewage can be treated per cubic yard of filtering material on sprinkler filters than in contact beds has greatly favoured the adoption of the former.

While sewage works' engineers were busy experimenting and devising the most efficient form of artificial filter, a considerable amount of work in connection with the study of the bacterial processes involved was carried out by different observers. In the Massachusetts Report of 1890, the presence of enormous numbers of bacteria in the filtering medium was noted, and, as Warington found in the case of soil, they were infinitely more numerous in the upper portion of the filter. It was pointed out that filtration through fine sand beds or soil reduced the total number of bacteria in a sewage, in some cases as much as 99 per cent.

In 1898, the London County Council issued a report dealing in a general manner with the bacterial flora of the Barking and Crossness sewages. In the same year a report giving results of the treatment of the Crossness sewage on coke beds was very disappointing from a bacteriological point of view, for, although marked purification had been effected from a chemical standpoint, yet little or no improvement was discernible either in the quantity or character of the bacteria in the effluent. It was obvious, therefore, that whatever purification the coke beds effected, they afforded not the least protection bacteriologically.

The seriousness of this danger seems to have been readily realised, and it is not surprising to find that the Second Report of the Royal Commission issued in 1902 dealt almost entirely with bacteriological problems. This Report commences with an investigation into the "Oxidation of Sterile Sewage," by Colin C. Frye, and the conclusion arrived at is that the oxidation of sewage containing no bacteria is very slow and that the chemical oxidation due to the oxygen in the atmosphere is inappreciable. Among other matters this Report also dealt with "The Discovery of Anthrax in Yeovil Sewage," "The Longevity of Typhoid Bacillus in Sewage," "The Self-purification of the River Severn," and "The Effect of Filtration in reducing the number of Bacteria in Sewage Effluents."

The view then taken of the importance of the part played by bacteria in sewage purification is summed up by Dr. McGowan in the above Report of 1902, who quotes from a report of the experts consulted by the Manchester Corporation :—"Thus, for the destruction of impurity, *i.e.,* for the real purification of sewage, there is only one practical means available, viz., the employment of bacteria in some shape or form. In fact, all the methods of sewage purification actually practised are bacterial methods, whether so named or not."

In 1900 Dunbar formulated his absorption or adsorption theory, according to which the biological purification of sewage is commenced by the adsorption or deposition of solid matters from the sewage on to the surface of the filter material, and is continued by repeated absorption of these solid matters, followed alternately by oxidation occurring directly or through the action of enzymes and micro-organisms, assisted by higher plants and animals.

Some five years later Travis went so far as to say that the action of sewage filters was a purely physical operation, and denied "that the purification process is in any sense of the word, or under any circumstances, the result of bacterial action." He stated that micro-organisms are merely incidental and their action only ancillary to the actual purification, and compared their function to that of rats in the sewers. Another mechanical theory in which little or no importance was attributed to bacterial action, was that of Bredtschneider, but few have adopted the views of these two latter observers.

As stated, nearly all investigations of the sewage problem seem for many years to have quite overlooked the function of the larger (*macroscopic*) organisms such as those mentioned by Sorby and Dupre; but in 1900, Dunbar drew special attention to the function of higher plants and animals, and later, in 1907, Höfer went more fully into the scope of their action. In 1904, Dibden also pointed out the large number of active insects and annelids at work on the mud deposited on the surfaces of the material in his slate beds.

Although, as previously stated, all purification results in the oxidation of the polluting substances, yet this process of oxidation is by no means a simple one, and two phases at least are recognisable:—(1) The separation or deposition of solid matter both from suspension and also from colloidal solution, and (2) the oxidation of such deposited solids. However distinct these two phases may at first sight appear to be, it is most probable that solution and dissolution rapidly alternate, so that they intimately co-operate in the general process of purification, and generally speaking, sewage purification cannot be effected without causing the permanent separation of solid matter in some form or other.

During the initial stages of purification a large amount of solid matter is separated out, and it is with the removal and oxidation of this that the chief difficulties of sewage purification arise. These separated solids containing, as they do, much unoxidised carbonaceous and nitrogenous material, are available as a food supply for a wide range of organised life such as bacteria, and macroscopic organisms belonging to both the vegetable and animal kingdoms.

The engineers and others who have devised the various forms of filter beds have consciously or unconsciously chosen those forms which favour the most efficient combination of these agencies, and the ideal filter bed may be said to be one which best preserves (*a*) a balance of maximum efficiency between the active surface for the absorption and retention of solids, and (*b*) the development of the animal and vegetable life most useful for the destruction of the organic matters thus deposited. These two factors act antagonistically, and the balance between the quantity of deposited and retained solids needs to be carefully adjusted to the requirements of the animal and vegetable life which it supports, as an undue increase of the former may act very deleteriously upon the latter—by choking up the filter and so prevent the circulation of air, with consequent death of the organisms. The filter then rapidly becomes waterlogged or "ponded," and purification deteriorates in consequence. From the difference in the mode of use of a contact bed and a percolating filter, the species of organisms found in them naturally show considerable differences. In the contact bed only those organisms can survive which are able to exist practically without free oxygen for some considerable portion of the period during which the bed stands full of sewage, whereas in a good percolating filter the greater portion of the filter is in direct contact with the air, and the organisms there found are those which require the presence of free oxygen.

The number and variety of living organisms to be found in sewage filters is almost inconceivable, and their study demands much greater attention than it has hitherto received. In the following pages an attempt will be made to describe some of the principal organisms found, and their methods of growth, and to discuss the reasons for their special abundance in some cases and their infrequency or absence in others, in the hope that means may be evolved of favouring their growth when that is advisable, or checking their development when they give rise to nuisance, or even restricting their sphere of action when useful but liable to occasion nuisance from over-development.

The practical importance of these studies has been already emphasised in such cases as those mentioned by the Royal Commission of 1898 (Fifth Report, p. 221), in their experiments in checking the too profuse growth of some of the micro-organisms and in the measures which have had to adopted by various Authorities to prevent the undue development of flies.

To facilitate this study, the City Surveyor of Wakefield, in constructing new filters at the Wakefield Sewage Works, has provided an inspection chamber in the body of the material, in which, by means of trays containing filtering medium, samples both of the growths and of

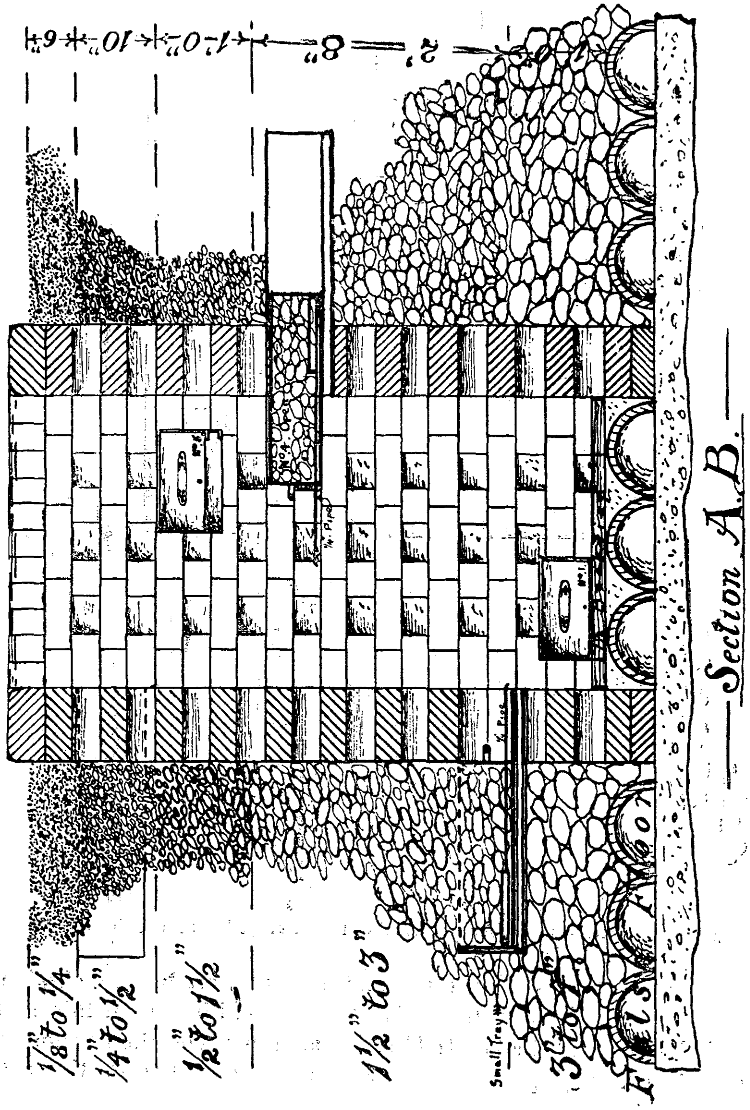


Fig. 1. Inspection Chamber in Percolating Filter at Wakefield Sewage Works.

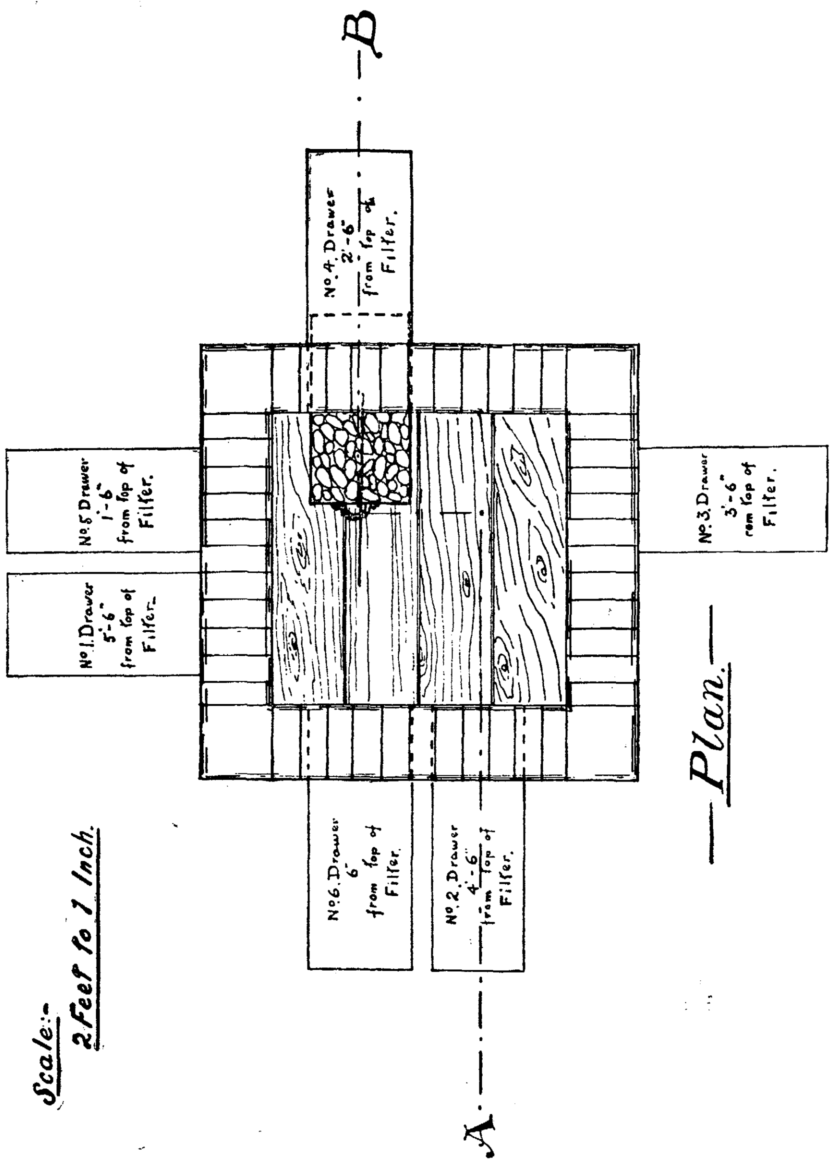


Fig. 2. Inspection Chamber in Percolating Filter at Wakefield Sewage Works.

the liquid in various stages of treatment can readily be obtained at every foot depth throughout the filter. It would be well if this example were followed in all the larger filter installations, and the accompanying plan and section (Fig. 1 and 2), will serve to illustrate the method of construction.

2. Organisms as an Index of Pollution.

Domestic sewage is naturally a very complex liquid, and contains both in solution and in suspension much readily decomposable nitrogenous and carbonaceous matter, which affords a suitable food-supply for a very large and complex flora and fauna. So very large and complex is this organisation that it would be almost impossible to enumerate the individual members occurring in such a liquid, and it is doubtful if any very good purpose would be served by so doing.

If, however, the more frequently occurring organisms be arranged according to the amount of pollution in which they occur, it will be noticed that certain forms never appear in polluted waters, while others never appear in non-polluted water; again, some have a considerable facultative range, while others are very restricted in this respect. Thus one regards the presence of certain organisms as being indicative of pollution or otherwise, and, broadly speaking, the presence of most aquatic forms of life may be regarded as being largely determined by the amount and character of the food-supply, *i.e.*, pollution. Naturally, it would be exceedingly difficult, if not impossible, to satisfactorily account for the presence or absence on this basis in *every* instance, for, obviously, many obscure points in the life-history of these organisms themselves require elucidation, while the chemistry of decomposition is so complex as to preclude any detailed study of its action upon the various stages of such life.

The more characteristic organisms may, however, be readily divided—according to the decreasing amount of pollution in which they develop—into the following three classes:—

(1) Polysaprobes. (2) Mesosaprobes. (3) Oligosaprobes. The characters of these groups are:—

1. *Polysaprobes.*—These organisms inhabit the more grossly polluted waters in which reduction and decomposition of organic matters is actively taking place, giving rise to carbon dioxide and nitrogenous decomposition products with a consequent lack of oxygen. Offensive mud, blackened by sulphide of iron, is usually present, whilst diatoms and the higher forms of aquatic vegetation and fish are absent. There is abundance of lowly organised forms of life, chiefly belonging to the group *Schizomycetes*, or the lowest form of fungi; the bacteria capable of developing on gelatine may exceed one million per c.c.

2. *Mesosaprobes.*—Water in which these organisms are found is less grossly polluted than in the former case. Many of the higher water-plants flourish, and there may be considerable amounts of dissolved oxygen present. Aeration and evolution of oxygen from plant

life facilitate the existence of the larger fauna. Dissolved oxygen varies considerably in amount, but is always present. The decomposition of nitrogenous matter has proceeded further, and oxidation may have proceeded so far as to produce nitrites and nitrates. Samples of water, when incubated, do not usually putresce.

These organisms are divided into two classes, (A) those inhabiting the more polluted waters, and (B) those inhabiting the less polluted.

In the former case (A) purification processes are more vigorous. There is still an abundance of lowly organised life, but in this case, chiefly of the group *Schizophyceae*, or the blue green algae, and in running waters fungi of the higher group *Eumycetes* (or *Mycomycetes*) are to be found. Animal life is fairly abundant and fish rarely die. Bacteria capable of developing on gelatine may amount to 100,000 per c.c.

In the latter case (B) where there is less pollution, and purification is therefore less rapid, benthon (*benthos*, depths) forms of life, or those which live on the bed of the stream, are more prevalent, especially diatoms. A great variety of vegetation is found, particularly in members of the group *Chlorophyceae*, or the green algae.

3. *Oligosaprobes*.—These organisms occur in waters of great purity, where the organic nitrogen has been almost completely mineralised. The "oxygen absorbed" figure is low, and in consequence the rate of absorption of dissolved oxygen is very slow. The water has a slightly alkaline reaction and is highly transparent, and any mud present contains little organic matter. Polysaprobic forms are quite absent, but there is a great variety of animal and vegetable life. The representatives of the flagellate group Peridinales are more numerous, and of plant life members of the group Charales, which are very sensitive to pollution, begin to appear.

It will be seen from the above classification that there is a progressive increase both in the relative numbers and variety of the higher forms of life as we pass from the most to the least polluted waters, and also that the presence of green algal forms of life (*Chlorophyceae*), marks an advance in the purity of the water, so that in polluted streams there is a lack of that green colour so characteristic of the life found in natural watercourses.

The following list gives some of the more characteristic organisms arranged according to the pollution intensity; in each division the vegetable organisms precede those of animal origin.

1. Polysaprobes.

Schizomycetes.

Spirillum undula, Ehrbg.
,, rugula (O. F. Müller).
Sphaerotilus natans, Kütz.
Zoogloea ramigera, Itzigohn.
Beggiatoa alba (Vaüch.), Trev.
Chromatium okenii (Ehrbg.), Perty.
Lamprocystis roseo-persicina (Ktz.), Schröter.

Schizophyceae.

Arthrospira jenneri, Stitz (if with Beggiatoa, etc.).

Euglenales.

Euglena viridis (if very abundant).

Flagellata.

Bodo putrinus (Stokes), Lemm.

Ciliata.

Paramaecium putrinum, Cl. u. L.
Vorticella microstoma, Ehr.
,, putrina, O. F. Müller.

Vermes.

Tubifex rivulorum, O. F. M.

Diptera.

Eristalis tenax, L. Larvae.

2. Mesosaprobes.

A. (strong).

Schizomycetes.

Sphaerotilus natans (if with diatoms and Cladothrix forms).
Thiothrix nivea (Rab.), Win.
Chromatium okenii (Ehr.), Perty).
Lamprocystis roseo-persicina (Ktz.), Sch.[1]

Schizophyceae.

Oscillatoria tenuis, Ag.
,, formosa, Bory.
Arthrospira jenneri, Stitz.[2]

B. (weak).

Schizomycetes.

Cladothrix dichotoma, Cohn.

Schizophyceae.

Oscillatoria limosa, Ag.

Euglenales.

Euglena acus, Ehrbg.
,, spirogyra, Ehrbg.
,, deses, Ehrbg.
Phacus caudata, Hübner.

Bacillariales.

Melosira varians, Ag.
Diatoma vulgare, Bory.

[1] If associated with algae. [2] See also Polysaprobes.

A. (strong).

Phormidium autumnale (Ag.), Gomont.

Euglenales.

Euglena viridis var. lacustris, France.

Bacillariales.

Hantzschia amphioxys (Ehr.), Grun.

Nitzschia palea (Ktz.), W.Sm.

Stauroneis acuta, W.Sm.

Protococcales.

Stichococcus bacillaris, Naeg.

Confervales.

Ulothrix subtilis (Ktz.).

Myxomema tenue (Ktz.).

Prasiola crispa (Lightf.), Menegh.

Phycomycetes.

Leptomitus lacteus, Ag.

Euascomycetes.

Fusarium aurantiacum, Sacc.

Flagellata.

Oicomonas termo (Ehr.), Kent.

Monas vivipara (Ehr.).

,, vulgaris (Cienk), Senn. =M. guttula, Ehr.

Anthophysa vegetans (O.F.M.), Bütsc.

Peranema trichophorum (Ehr.), St.

Chilomonas paramaecium, Ehr.

Ciliata.

Urotricha farcta (Ehr.), Cl. u. L.

Colpidium colpoda, Stein.

Paramaecium caudatum, Ehr.

Stentor coeruleus, Ehr.

B. (weak).

Synedra ulna var. spendens (Ktz.).

Navicula rebissonii, Ktz.

,, cryptosephala, Ktz.

Navicula cuspidata, Ktz.

,, mesolepta, Ehr.

,, amphisbaena, Bory

,, ambigua, Ehr.

Gomphonema olivaceum, Ktz.

,, parvulum, Ktz.

Rhoicosphenia curvata (Ktz.). Grun.

Nitzschia communis, Rabh.

Surrella ovalis, Bréb. v. ovata. = S. ovata, Ktz.

Conjugatae.

Closterium acerosum, Ehr.

,, peracerosum, Gay.

Protococcales.

Stichococcus bacillaris, Naeg.

Scenedesmus quadricauda (Turp.), Bréb.

Confervales.

Ulothrix subtilis (Ktz.). cf. Oligosaprobes.

Tribonema bombycina, Derb. Sol.

Edogónium, species.

Cladophora crispata, Ktz.

Vaucheria sessilis, (Vauch.), D.C.

Monocotyledoneae.

Holodea (Elodea) canadensis, R. u. Mchx.

Lemna minor, L.

Dictoyledoneae.

Ceratophyllum demersum, L.

A. (strong).

Carchesium lachmanni, Kent.
Epistylis coarctata, Cl. u. L.

Vermes.
Tubifex rivulorum, O.F.M.

Rotatoria.
Rotifer vulgaris, Schrank.
Callidina elegans, Ehr.

Crustacea.
Asellus aquaticus (L.).

Diptera.
Chironomus plumosus, L. (Larvae) (if numerous).
Psychoda phalaenoides (L.). (Larvae.)
,, sexpunctata, Curtis. = Ps. phalaenoides, Meigen. (Larvae.)

B. (weak).

Rhizopoda.
Arcella vulgaris, Ehr.
Centropyxis aculeata (Ehr.), St.

Heliozoa.
Actinophrys sol, Ehr.

Ciliata.
Coleps hirtus, Ehr.
Nassula elegans, Ehr.
Paramaecium bursaria (Ehr.), Focke.
Stentor polymorphus, Ehr.
Carchsium epistylis, Cl.

Spongiae.
Ephydatia fluviatilis (L.).
Euspongilla lacustris (L.).

Rotatoria and Gastrotricha.
Melicerta ringens, Schr.
Rotifer vulgari, Schr.
Anuraea aculeata, Ehr.

Bryozoa.
Plumatella repens (L.).

Crustacea.
Asellus aquaticus (L.).
Gammarus fluviatilis, Rös.
Daphnia pulex, De Geer.

Diptera.
Chironomus. Larvae bright yellow, not red.

Pisces.
Gasterosteus aculeatus, L.

3. OLIGOSAPROBES.

Schizomycetes.
Chlamydothrix ochracea (Ktz.), Mig.
Gallionella ferruginea, Ehr.
Crenothrix polyspora, Cohn.

Schizophyceae.
Merismopedia glauca (Ehr.), Näg.

Chrysomonadales.

Dinobryon species.

Peridiniales.

Ceratium hirundinella, O. F. M.

Peridinium cinctum, Ehr.

Bacillariales.

Cyclotella meneghiniana (Ktz.,

Tabellaria flocculosa (Roth.), Ktz.

Meridion circulare, Ag.

Fragilaria virescens, Ralfs.

Asterionella formosa, Hass.

Eunotia arcus (Ehr.), Rabh.

Navicula mesolepta, Ehr.

,, major, Ktz.

,, limosa, Ktz.

Gomphonema acuminatum, Ehr.

Cymbella cistula (Hempr.), Kirch.

Bacillaria paradoxa, Gmelin.

Surirella splendida, Ktz.

Conjugatae.

Closterium lunula, Ehr.

Mougeotia genuflexa (Dillw.), Ag.

Protococcales.

Eudorina elegans, Ehr.

Volvox globator, L.

Tetraspora gelatinosa (Vauch.), Desv.

Richteriella botryoides (Schmid.).

Botrytococcus braunii, Ktz.

Confervales.

Ulothrix variabilis, Ktz.

,, subtilis var. variabilis (Ktz.), Kir.

Chaetophora elegans (Roth), Ag.

Rhizoclonium hieroglyphicum (Ag.), Ktz.

Cladophora glomerata, Ktz.

Vaucheria sp.

Florideae.

Lemanea torulosa (C. Ag.), Sirodot.

Bryophyta.

Fontinalis antipyretica, L.

Hypnum riparium, Schimp.

Monocotyledoneae.

Potamogeton pectinatus, L.

Ciliata.

Carchesium polypinum, Ehr.

Hydroidea.

Hydra oligactis, P. = fusca, L.

,, viridis, L.

Rotatoria and Gastrotricha.

Notholca longispina, Kellicott.

Mollusca.

Limnaea stagnalis (L.).

,, peregra, Müll.

Crustacea.

Gammarus pulex (L.), De Geer.

Coleoptera.

Dytiscus marginalis, L.

Pisces.

Gobio fluviatilis, Cuv.

In the Polysaprolic zone two organisms—*Sphaerotilus natans* and *Zoogloea ramigera*—are of outstanding interest in the Flora of a sewage filter, and as they are not very frequently described in the text-books, the following brief account may be found useful.

Sphaerotilus natans, Kützing.

In its typical form (Figs. 3 and 4) the growth occurs as slimy, tufted, felted masses attached to some submerged object in polluted streams, developing most luxuriantly in running water, which replenishes the supply of oxygen necessary to check putrefaction in masses of the growth. The colour varies from nearly pure white to dirty yellow or brown, and at times a reddish tint is observable. This organism consists of gelatinous filaments 6-8 μ thick, containing cells about 2 μ broad, and 4-6 μ long. The gelatinous sheath, which is usually of considerable thickness, is not, however, readily visible, and is not shown in fig. 4. In older specimens, however, a shrunken, brownish coloured sheath may be readily identified, often almost or quite devoid of cell contents.

Multiplication ordinarily takes place by transverse cell division or fission, but it is also said to occur by means of "swarm cells," which are liberated at the ends of the filaments.

Two other species have been described under the names of *Sphaerotilus fluitans* and *Sphaerotilus roseus;* these, however, possess

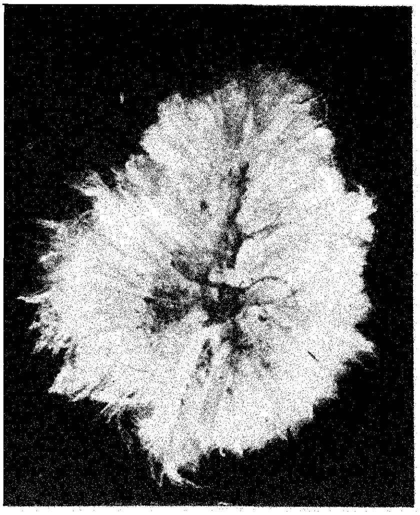


Fig. 3. *Sphaerotilus natans*, Kützing. × 1.
(Phot. J. W. H. J.)

Fig. 4. *Sphaerotilus natans*, Kützing. × 1,000.
(Del. J. W. H. J.)

but slight distinctive characters, and are probably only forms of the above.

Sphaerotilus can be found in almost every stream receiving considerable quantities of unpurified sewage. It also frequently occurs in great abundance in streams which receive warm effluents containing organic matter from industrial premises.

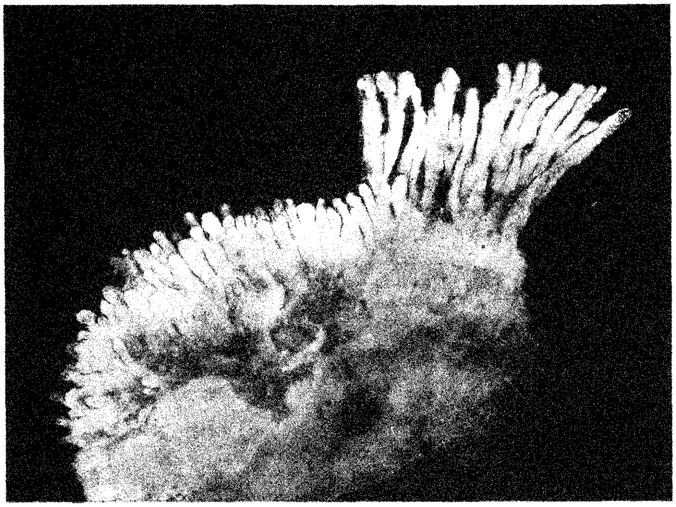


Fig. 5. *Zoogloea ramigera*, Itzigsohn. × 100.
(Phot. J. W. H. J.)

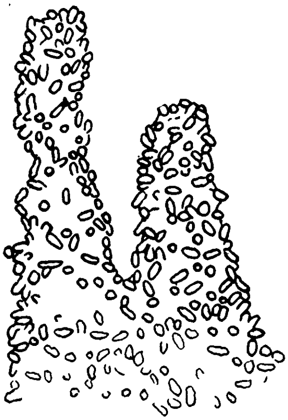


Fig. 6. *Zoogloea ramigera*, Itzigsohn. × 1,000.
(Del. J. W. H. J.)

Zoogloea ramigera, Itzigsohn.

Sphaerotilus when occurring in more grossly polluted waters, often takes this form (Figs. 5 and 6). It usually occurs as a white or greyish, often branched gelatinous mass, adhering to submerged twigs, algae, etc. The branches measure about 1.0-2.0 m.m. in length and about 15 μ in breadth, and contain rod-like cells about 1 μ thick imbedded in the gelatinous matrix. There is a considerable variation in the thickness of the branches, and at times they are very short and thick, when the growth assumes a rounded gelatinous form. On the other hand, attenuation may be so great that the connection with the filamentous form (*Sphaerotilus*) is readily seen.

The following varieties of this organism have been noted :—

a. compacta. As microscopically small gelatinous masses closely packed among the type form ; cells as short rods.

b. carnea. As flesh-coloured masses on the sides of the sewage carriers ; cells 1.5 μ thick.

c. uva. On stalks and roots of submerged plants in subglobular masses varying in diameter from $\frac{1}{4}''$—$\frac{3}{4}''$; cells long and somewhat over 1 μ thick.

(*To be continued.*)

REVIEWS.

Manual of Fruit Pests. By the late M. V. Slingerland and C. R. Crosby. Pp. xvi + 503 and 396 text figs. New York: The Macmillan Company, 1914. Price 8s. 6d. net.

The removal by death, in the spring of 1909, of the late Professor Slingerland, robbed the United States and the world generally of one of the most practical and far-seeing workers in economic biology, and a man whose place it will be unusually difficult to fill. He not only brought a well-trained mind and long experience to the problems he grappled with, but was gifted with a broad and practical spirit, so essential and yet so rare. His published writings are well known to all economic biologists, but as the joint-author, Mr. C. R. Crosby, informs us, a large amount of his work remained unpublished at the time of his death, including the present work, which had been commenced by him in 1908. Mr. Crosby has completed this, and given us the very admirable and practical treatise now before us.

It is one of the few works treating of the insects attacking fruit that can be strongly recommended to the practical fruit grower, for the information contained therein is concise yet clear, well illustrated, and the remedial measures recommended the outcome of a long and practical experience with the problems of insect prevention and destruction.

Many of the pests or near allies are common to this and other countries, so that it will appeal to a wide circle of readers who cannot fail but profit by a careful perusal of its pages.

Flies in Relation to Disease: Non-Bloodsucking Flies. By G. S. Graham-Smith. Pp. xvi + 389, xxvii pls., 32 figs. and 20 charts. 2nd edition. Cambridge: The University Press, 1914. Price 12s 6d. net.

We welcome a second edition of this extremely valuable and interesting work. In the first edition the author stated "an attempt was made to collect, tabulate and examine critically the various facts and hypotheses relating to the life-histories, habits, and disease-carrying potentialities of non-bloodsucking flies, which had been published up to the end of the year 1912." The work published during 1913 is now treated in a similar manner, together with recent unpublished observations by the author, and numerous additional illustrations and charts.

With its great mass of facts and references, as a book of reference it should be accessible to every medical officer of health in the country, while its purely biological portions will be appreciated by all.

A REVISION OF THE ICHNEUMONIDAE. Pt. III. Tribes Pimplides and Bassides. By Claude Morley. Pp. xiii + 148, 1 cold. plt. London: British Museum (Natural History), 1914. Price 5s. 6d.

The third part of Mr. Morley's excellent revision follows on the same general lines as the two previous parts. Nearly fifty new species are described, with accompanying critical notes.

In view of the relationship between these parasites and many injurious forms of insect life, the importance of a thorough systematic revision of the Ichneumonidae cannot well be overestimated, and for such a task no one is better qualified than the present author. We look forward with considerable interest to the early appearance of further parts.

FABRE, POET OF SCIENCE. By Dr. C. V. Legros. Translated by Bernard Miall. Pp. 352 and portrait. London: T. Fisher Unwin. Price 10s. 6d. net.

Dr. Legros' interesting work can scarcely be termed a biography, for it contains very little about the actual life of Fabre; nevertheless, the various data given have proved sufficient whereon to hang a charming description of his work and methods, illustrated by copious extracts from his writings.

The only criticism we would offer, and it recurs again and again to the mind as one reads this book, is that Fabre had an overestimated idea of the value of his work, and was ill-equipped by lack of training. He created and lived in an unnatural atmosphere, in which almost everything he saw and described was "marvellous," "extraordinary," "immense," "brilliant," or "stupendous." "He watches at night, by the dim light of a lantern," "in unsociable silence, invisible to all, he worked," and so on, with adjectives and adverbs galore.

Dr. Legros depicts his subject rather as the showman than the shy, unsociable student of nature, and we leave the book with a feeling that we would rather have the poetical and highly-coloured descriptive writings of Fabre than the "admiring commentary" of his biographer.

THE PHILOSOPHY OF BIOLOGY. By J. Johnstone. Pp. xv + 391, 31 figs. Cambridge: The University Press, 1914. Price 9s. net.

Dr. Johnstone's work will appeal to a wide circle of readers beyond biologists; in all probability they will outnumber the biologists, for after a very careful perusal of this work we feel a sense of disappointment and that the really important parts might well have been contained in a hundred pages or so. One grows tired and weary of words and sentences that express so little, nevertheless, with patience the reader will find much of interest, that might have been more tersely and lucidly set forth.

THE

JOURNAL OF ECONOMIC BIOLOGY.

A CONTRIBUTION TO THE BIOLOGY OF SEWAGE DISPOSAL. Pt. II.

By J. W. HAIGH JOHNSON, B.Sc., F.L.S.,

Chemical Biologist to the West Riding of Yorkshire Rivers Board, Wakefield.

(With 27 Figures.)

Crude sewage in its passage through a filter, or at most say two such filters, each of some 6 or 8 feet high, may be changed into a clear and comparatively innocuous fluid. The organic pollution has thus been oxidised or "mineralised" in the process, and naturally one would presume, therefore, that in such filters the varying intensity of pollution, between the crude sewage and the purified effluent, would provide suitable conditions for the development of a range of organisms similar to that already given.

The relative absence of light within the filter, however, precludes any extensive development of algae, and therefore the dominant forms are almost entirely restricted to those of fungal and animal origin.

The inspection chamber (Figs. 1 and 2) enables ready examination of the filtering material to be made by simply pulling out the drawer at the desired level. The expanded metal work used to support both the contents of the drawers and the material in the bed around the drawers, offers a minimum resistance to the passage of the liquid through the filter. A small metal tray, 6in. × 8in., at the back of each drawer serves to intercept sufficient liquid—which is discharged by means of a small pipe *outside* the drawers—for chemical analysis without in any way disturbing the material of the filter or drawer.

When assigning, on a pollution basis, the position of any given aquatic or semi-aquatic organism it should be realised that in a sub-aerial position the organism can tolerate much more pollution than would normally be the case if totally submerged.

3.—Ecological Associations and Distribution of Organisms on Sewage Filters.

The character of the organisms occurring in any portion of a sewage filter will, as previously stated, primarily depend upon the amount and character of the pollution. Apart from this primary factor the possible variations in conditions of aquatic ecology are remarkably few compared with those of terrestrial ecology, where a variation in the character and quantity of light, water, exposure to wind, acidity or alkalinity of soil, &c., may cause most remarkable modifications in the flora of a landscape.

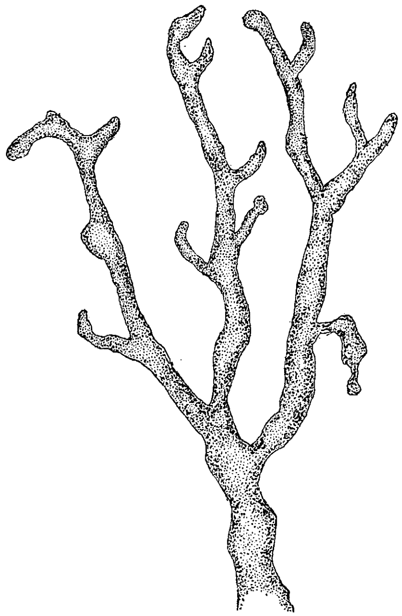
The first of the above factors has been casually introduced already, and the general absence of light in a filter prevents the development of green (chlorophyllaceous) forms of life; a glance at the list of organisms, pp. 117 to 121, will serve to emphasise the fact that by far the greater number of B. mesosaprobes and oligosaprobes, *i.e.,* the organisms suited to purer liquids, are included in this category, and therefore the influence of light might be advantageous at this stage of purification. On the other hand it will be noticed that the organisms belonging to the most polluted liquids are chiefly bacterial, and do not therefore suffer from this absence of light. With regard to the former it is interesting to note that Hofer suggested the discharge of such liquids into large fish ponds. The partially purified sewage assisted the development of numerous algae, etc., and these in turn provided an abundant food supply for the fish. In this way it was found that the fish developed much more rapidly than under natural conditions, and their sale reduced to some extent the cost of treatment. In the presence of trade refuse partial treatment would be essential, and care would have to be exercised to prevent any untoward accident to the stock from the possibly poisonous character of these discharges.

Of the remaining factors the influence of the reaction of the crude sewage is perhaps the most important. Normally, a sewage effluent is neutral or very slightly alkaline to litmus, the amount of alkalinity may be very small indeed, requiring five or more minutes to effect any marked change of colour in the litmus paper. A solution of this character is well suited to the development of most bacteria and numerous other forms of life; whereas an acid liquid would be inimical to many, and occasion a change in the usual flora of a filter. Yet this influence can at most be only temporary, and the alteration is chiefly restricted to the primary processes of purification, because the liquid tends to become alkaline under treatment, but even if the effluent be acid the normal reaction of the great water masses is so uniformly slightly alkaline that the acid would eventually become neutralised, when the usual changes would then occur.

With such modifications as have been indicated, ecological associations in a sewage filter follow very closely upon the lines of pollution intensity, and the remarks under the previous sections serve to outline the causes affecting such associations.

All that now remains is to describe such associations as are commonly encountered on a sewage filter. It must not be imagined, however, that any sharply defined zones can be distinguished; the change in the flora on passing from the top to the bottom is a gradual one, and it would be difficult to say where one zone ends or the next commences.

The upper portion of a filter receiving crude sewage contains chiefly those forms of life which belong to the Polysaprobes, and this



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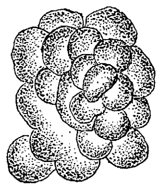

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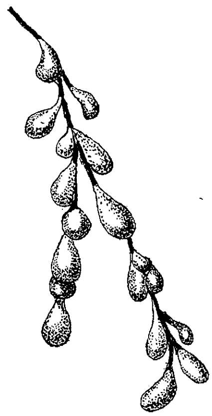

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Fig. 7: *Zoogloea ramigera,* Itzshn. × 300.
Fig. 8. ,, ,, var. *uva.* × 1.
Fig. 9. ,, ,, var. *compacta.* × 500.
Del. M.J.

zone is especially prolific in these lowly organisms. The filter material rapidly becomes coated with a slimy or gelatinous growth of *Zoogloea ramigera,* which may be regarded as a large number of bacteria embedded in a gelatinous matrix (Figs. 7—9). This zoogloea is perhaps the most characteristic and important organism of this zone, and forms a suitable nidus for the development of fungal and other forms of life; whilst its gelatinous character enables it to directly absorb *soluble* polluting substances—as already described in Dunbar's adsorption theory. *Sphaerotilus natans, Beggiatoa alba, Thiothrix nivea, Chromatium okenii, Polytoma uvella,* etc., may also occur while species of *Saprolegnia* (Fig. 10) and other higher fungi are often brought down the sewers and develop on the top of the filter, together forming a fairly efficient strainer. The numerous hyphae which are to be found in this mass are not readily identified, but *Mucor racemosus* and *Mucor circinelloides* can be frequently recognised in subcultures.

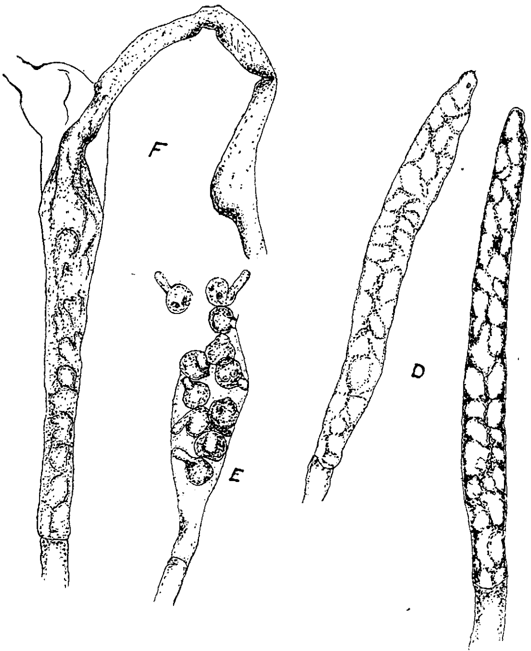

Fig. 10. *Saprolegnia* sp. found on sewage filter.
D. Division of concentrated protoplasm into spores.
E. Germination of spores while still within the cell (sporocyst).
F. New cell grown up through old. All × 300.
Del. J.W.H.J.

Botrytis vulgaris is also found in such situations; this fungus attacks cellulose very vigorously, and in one instance the growth was so dense that it very seriously obstructed a small water-course. Two characteristic chromogenic bacteria were also isolated from this material, *Magenta bacillus* and *B. violaceus.*

In some instances, however, where the discharges from modern industrial processes such as dyeing, carbonising and brewing have given an acid character to the liquid, the filter may then become covered with an orange coloured fungus, *Fusarium auriantiacum,* and tufts of *Oospora lactis* may become very abundant. The former organism seems to be associated with the decomposition of carbohydrates, while the normal decomposition under neutral or slightly alkaline conditions is perhaps more intimately connected with changes in the nitrogenous contents of the sewage.

Some fungi are capable of existing under apparently very adverse conditions and *Sporotrichum lanatum,* Wall., was identified in material taken from the sill of a purification works treating dye waste. The

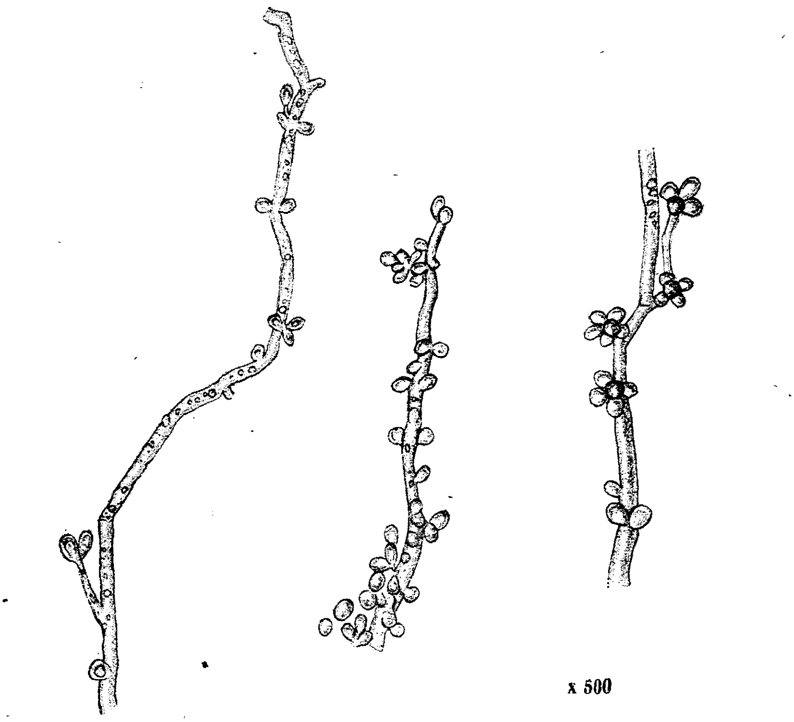

Fig. 11. *Sporotrichum lanatum*, Wallr. Showing numerous spores. × 500. Del. J.W.H.J.

material, although deeply stained with the dye liquids, was still alive and rapidly produced spores which led to its identification (Fig 11).[1]

Agarics rarely appear on sewage filters, but *Hypholoma candol-*

[1] *Sporotrichum lanatum*, Wallr. (Fl. Crypt. Germ., ii, p. 276, 1833).—Tufts cushion-shaped, soft, elastic of loosely interwoven branched hyphae; conidia globose, small whitish, at length falling off. No measurements are given in the description of the species, but in the specimen from Yorkshire the woolly look is very characteristic; the spores are very abundant and are borne on short sterigmata often in groups near the tips of the branches, they measure up to 5 μ in diameter. The original substratum was decaying goosefeathers in Germany, it has also been found on paper in Holland.

leanum, Fr., has occurred on partially dried sludge in a settling tank, and often develops along with *Pilobolus* on the drying sludge.

The sub-aerial character of this zone markedly affects the range of organisms occurring in such a grossly polluted liquid, and organisms belonging to the mesosaprobes, such as *Phormidium autumnale,* which often forms a large bluish-black coating over a considerable portion of the surface and in summer dries up into blackish paper-like sheets, *Podura,* and the larvae of *Psychoda, Chironomus,* etc., while birds, flies, spiders, snails and worms often abound. In addition to these larger forms of animal life, amoebae, infusorians (*Paramaecium, Vorticella,* etc.) and rotifers may occur in large numbers.

The flora and fauna of a filter also exhibit certain seasonal variations, the most noticeable being characterised by a change in the colour of the filter surface, which is usually of a dirty grey or blackish slimy appearance. This change is generally attributable to the depredations of some form of animal life, *e.g.,* "*Podura*" (*Achorutes viaticus*) which devours the accumulated deposits of slime, etc., on the filter material and thus reveals the natural colour of the clean filter medium. This natural cleansing often commences at one point and gradually extends over the whole surface, and occurs chiefly in spring and autumn.

The flies found about such installations can scarcely be said to be restricted to any particular zone, but their eggs, larvae, etc., are naturally most numerous near the surface which is directly available for the deposition of eggs. Besides the two species of *Psychoda* which are described later, *Spathiophora hydromyzina, Camptocladius arterrimus,* species of *Chironomus* and *Trichocera hiemalis* are of fairly frequent occurrence. Hitherto, 109 mature spiders have been examined from three works near Wakefield and the results obtained show such a remarkable dominancy of relatively rare species that a detailed list of their occurrence seems justified. The figures within the brackets refer to males and females respectively :—*Erigone atra,* Bl., 4 (2, 2); *E. arctica,* White, var. *maritima,* Kul., 19, (7, 12); *E. dentipalpis,* Wid., 6 (3, 3); *E. promiscua,* Cb. 4 (2, 2); *Lessertia dentichelis,* Sm. = *Tmeticus simplex,* F.O.P.Cb. 60 (7, 53); *Araeoncus humilis,* Bl., 1 ♂; *Porrhomma thorellii,* Herm., 15 (2, 13). It will be noticed that the three dominant species with their percentage occurrences are :—*Lessertia dentichelis,* Sm., 55; *Porrhomma thorellii,* 13.6; and *Erigone arctica* v. *maritima,* 17.4; these three species together constitute 86 per cent. of the total arachnida observed. The two former species are of distinctly rare occurrence in Britain, while the occurrence of the latter variety at such a distance from the sea is also interesting. The *Lessertia* appear to belong to the variety *sublucicola.*

Arion hortensis is perhaps the most frequent slug, and is doubtless attracted by the large amount of organic matter deposited from the sewage. In contact beds the rather rare leech, *Trocheta subviridis,* has at times occurred in considerable numbers.

Besides the bacterial forms already enumerated, free-swimming species such as *Colon bacillus, Spirilla*, and other putrefactive bacteria may be present in large numbers; the number of the latter depends chiefly on the amount of putrefaction which has been allowed to occur. This brings us at once to the problem of septic and non-septic methods of purification, or purification by means of putrefactive changes on the one hand and direct oxidation on the other. Although in both instances the objective is the same, viz., the oxidation of the polluting substances, yet much of the objectionable nature of sewage disposal may be obviated by avoiding or restricting these primary putrefactive changes. Furthermore, recent experiments have shown that the putrefactive portion of the pollution is most readily absorbed by organised life and disappears first in the process of purification. Again the septic treatment—if it be septic—cannot be recommended on economic grounds as a much greater amount of oxygen is required to render innocuous the primary products of decomposition than would otherwise be the case if direct oxidation had been adopted.

Opportunities for the examination of the organisms at any considerable depth below the surface of the filter have until recently but rarely occurred. Such information as is at present available indicates that the zoogloeal masses rapidly become much less, while rotifers, paramaecia, nematodes and small earth-worms increase, and fungal hyphae are still present in less quantity than nearer the surface. In cases where the treatment is performed by two filters in series a number of algae have usually developed on the surface of the second, such as *Prasiola crispa, Stichococcus flaccidus, S. dissectus, Ulothrix variabilis, Myxonema tenue* (often with peculiar swollen cells); although "Podura" occasionally occurs, flies are relatively scarce. The deposit on the filter material loses its slimy character and becomes brown in colour. This zone does not appear to have any outstanding characteristic, but functions as an intermediate between the other two. The next zone does not support many living organisms, most fungi have entirely disappeared, bacteria are much less frequent, while numerous worms and a rich brown deposit of humus are the chief indications of the final stage. Algae would under normal conditions develop in such a liquid, but the absence of light within the filter precludes their development. The effluent channel, however, usually exhibits brown masses of small diatoms and green strands of algae. *Van Heurckia* *rhomboides* v. *saxonica* (Rabh.), G. S. West, *Gomphonema parvulum, Acnanthes lanceolata,* and var. *dubia* are most common among the former, while species of *Mougeotia, Myxonema, Cladophora, Vaucheria, Rhizoclonium* and *Ulothrix* are of frequent occurrence among the latter. At times grey patches of *Carchesium lachmanni* may appear, and more especially if the effluent is occasionally of doubtful purity. It will thus be readily seen that the flora and fauna of a water-course provide indelible evidence of the *general* character and purity of the liquid in that water-course.

The following table shows the chemical changes in a tank effluent as it passes through a filter :—

WAKEFIELD SEWAGE WORKS.

(Results expressed in parts per 100,000).

Monthly Average Analyses of Samples taken from Inspection Chamber.

	Chlorides (as Cl.). Tank Effluent	Oxygen absorbed in 4 hours from N/80 KMnO4 Effluent taken at depths in feet of							Nitrates and Nitrites (as N). Effluent taken at depths in feet of						Alkalinity (as CaO).* Effluent taken at depths in feet of						
		Tank Efflt.	1	2	3	4	5	6	1	2	3	4	5	6	Tank Efflt.	1	2	3	4	5	6
1913																					
October	17·7	5·11	4·57	3·35	3 20	3·14	2·71	2·21	—	·23	—	·38	—	·64	2·7	1·5	trace	nil	nil	nil	nil
November ..	19·8	6·01	5·76	2·69	2·95	3·33	2·81	2·26	—	·29	—	·46	—	·56	2·8	1·1	trace	nil	nil	nil	nil
1914																					
January	—	4·37	3·12	2·05	1·67	1·36	1·45	1·42	·47	·59	·78	1·37	1·18	1·29	3·0	1·1	trace	nil	nil	nil	nil
February ..	—	5·10	2·73	2·78	2·08	1·65	1·07	1·18	·55	·58	1·02	1·03	1·22	1·22	3·1	·6	·5	trace	nil	nil	nil
March	13·6	5·03	2·00	1·64	1·69	1·27	1·03	—	·67	—	1·12	—	2·20	—	2·7	trace	nil	nil	nil	nil	nil
April	15·4	5·16	2·89	2·02	1·76	1·25	1·22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	21·6	4·90	3·10	—	2·40	1·69	1·33	1·22	—	—	—	—	—	—	—	—	—	—	—	—	—
June	20·0	4·54	3·09	1·97	2·14	1·78	1·45	—	—	—	—	—	—	—	3·4	1·8	·3	nil	—	—	—

* These figures indicate the caustic alkalinity due to added quick-lime only, and the nil results do not in any way influence the statement on page 128, as the liquid is still slightly alkaline to litmus.

4. Some Noteworthy Dominant Organisms Occurring on Sewage Filters.

(*a*) The Sewage-Fly or Moth-Fly (*Psychoda*).

The great increase in late years in the number of percolating filters for sewage purification has drawn attention to the troubles arising from their use, of which perhaps the chief is the nuisance caused by flies, which breed in the interstices of the filters.

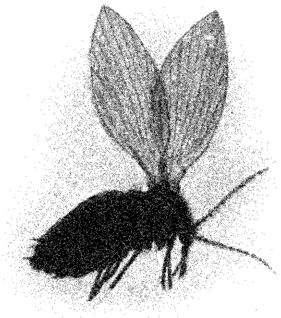

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Fig. 12. *Psychoda phalaenoides* (L). (female). Showing the characteristically jointed antennae, but no wing spots.
Fig. 13. *Psychoda phalaenoides* (L). (female). Much less hairy than Fig. 14.
Fig. 14. *Psychoda sexpunctata*, Curtis. (female). Showing some wing-spots, while others have almost been obliterated. All × 10.

Phot. J.W.H.J.

All percolating filters serve to some extent as a breeding ground for flies of various kinds, and in consequence they are the favourite haunts of swallows, wagtails, and other small insectivorous birds. In the majority of cases these flies, although varying in numbers according to the season, are not so numerous as to make their presence obnoxious, at least beyond the confines of the sewage works. In other cases, where circumstances favour their development, they may appear in myriads at certain times of the year and be carried by the wind into inhabited neighbourhoods so as to give rise to an intolerable nuisance.

This nuisance may be looked upon as causing annoyance :—(*a*) from the presence of the insects in such numbers in and about dwellings, where they are troublesome by reason of the personal discomfort they produce, and although not all persons are affected, it seems certain that in some cases the flies or perhaps the readily abraded hairs produce great skin irritation; (*b*) by their unsightly appearance, attaching themselves as they do to any object, particularly any moist surface; and (*c*) by their settling upon articles of dress and food.

The flies which are chiefly responsible for this nuisance belong to the genus *Psychoda,* and appear to be chiefly restricted to the two species *Ps. phalaenoides* (L.) and *Ps. sexpunctata,* Curtis[1] (Figs. 12—14.

When a filter in which the top layer consists of large pieces of filtering material, or which has dry built side walls, is examined during warm weather these flies, their pupae and their larvae, are to be found in the interstices of the material. If a piece of material be removed from the top of the filter, the dry portion of its under surface is usually covered with the mature insects. These are small active brownish-grey hairy flies, with transparent wings and long and characteristically jointed antennae. The wings are longer than the body, which they completely cover, and when at rest have a characteristic roof-like slope. Both the body and wings are densely covered with hairs, which give the fly at first sight the appearance of a small moth, and hence the name *Psychoda* (moth-like). The hairy covering on the wings and body offers considerable resistance to flight, and consequently movements are chiefly restricted to running, hopping, or short flights. The fly was very common in the old-fashioned unattended street urinals, flitting from slab to slab or running about their edges. It has a marked predilection for moist decaying animal and vegetable matter, and for malodorous moist situations in general. It is sometimes found in swarms in hot-houses and about open drains in spring and autumn. It must not, however, be concluded that *Psychoda* is restricted to polluted areas, for it occurs in the woods and forests far away from human surroundings.

There are two distinct species, one lighter coloured and larger than the other, and recognised when examined with a pocket lens, by a

[1] This species is apparently identical with *Ps. alternata,* Say, the latter name being some 15 years older should replace the above.

larger development of small hairs on the body and wings, and by dark spots which occur at the end of a vein or nervure, on the periphery of both wings. Thus *Psychoda sexpunctata* is distinguished from the other, which is known as *Psychoda phalaenoides*. It will be sufficient, therefore, to describe one species only, noting the points of difference which the other presents.

Psychoda sexpunctata, Curtis, like most insects goes through four different stages in its life cycle, viz., egg, larva, pupa, and imago.

The eggs (Fig. 15) are deposited in moist surroundings, and these of course are available in a sewage filter.

As is common among the Nemocera, the eggs are stated to be irregularly disposed in a gelatinous mass of indefinite shape attached to some solid object; the egg mass measuring 1 to 2 mm. across and containing some 15 to 40 eggs. In one case, however, an egg mass contained over 100 eggs, while in others the eggs were deposited either singly or in twos and threes.[1] A single insect was found to contain over 100 eggs. The individual eggs are small (0.2 to 0.3 mm.), sausage-shaped, opaque, and filled with yolk granules. Hatching takes place within a few days after deposition; the time naturally varies with the temperature, and during summer weather this occurred within 48 hours, while in October five days were required. The eggs are usually laid amongst moist decaying organic matter, which is thus immediately available for the newly hatched larvae, and Curtis (Royal Agricultural Society Journal, 1894, p. 103), so early as 1849, records the abundance of similar larvae and pupae in rotten potatoes, in decaying leaves, dung hills, and putrescent fungi.

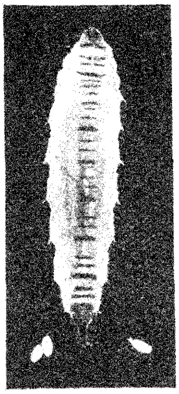
Recently attempts have been made to rear these insects artificially, and it was found that during warm weather the life-cycle was regularly completed within 17 or 19 days. During cold weather, however, this period was greatly increased. The number of eggs laid by *P. phalaenoides* seemed to be less—about 60—than was the case with *P. sexpunctata*. Although some 13 successive generations of the former were reared, yet no males were ever seen; while in the latter case the males amounted to 60 per cent. of the number examined.

The larvae (Figs. 15, 16) are whitish, somewhat flattened, transparent grubs, $\frac{3}{4}$ to 9 mm. or $\frac{1}{30}$ inch to $\frac{1}{3}$ inch in length, afterwards becoming brown and less transparent. They possess no legs, but have a well-defined brownish chitinous head and eleven body-segments. The head has well-developed mouth-parts, and two reddish-pigmented spots indicate the eyes (Ocelli), while the other parts are ill-developed.

[1] The number of eggs laid by a single female appears from recent observations to range from 70 to 140.

The first ten body-segments are very much alike, and show dark brown transverse chitinous bands along the back (Fig. 15), the first four segments have two such bands, and the following six three each. Each segment is also provided with characteristic bristles. The final segment is considerably modified, and carries both the anal[1] and breathing (spiracular) appendages.

The larva is extremely voracious and almost ceaselessly engaged in devouring food during the whole period of its existence, this food in the case of the sewage-fed larvae consisting of deposited organic



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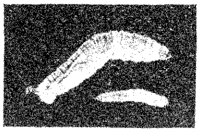

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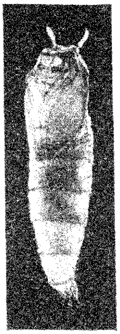

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Psychoda.

Fig. 15. *Eggs and full-grown larva.* The latter shows the dark chitinous plates and lateral bristles; the respiratory appendage is seen from above.

Fig. 16. *Two young larvae* (side view). The larger shows dark head with eyespot and the positions of both the anal and respiratory appendages; the dark transverse lines indicate the positions of chitinous plates.

Fig. 17. *Pupa.* Showing anterior horn-like breathing appendages, eyes, antennae, wings, three pairs of legs, and body segments, the latter usually terminating in a ring of dark bristles. All × 10.

Phot. J.W.H.J.

matter, fungal hyphae and the zoogloea masses which develop upon the filtering material. In this mass of slime the larvae move about with a worm-like motion, assisted by the action of their strong mouth parts. They can remain totally submerged for some considerable time without much inconvenience; food is often obtained whilst the head of the larva is buried in slime, for the respiratory apparatus is situated in the tail and this is raised above the surface, thus securing the necessary supply of air.

The larva after moulting some 3 to 5 times attains a length of

[1] J. A. Dell describes two anal apertures, but the author is inclined to agree with M. Zuelzer's description of a single aperture opening at the apex of the large anal papilla.

about 6 mm., and ceases to eat, the head becomes retracted, the last larval skin is shed, and the insect assumes the pupal form. This takes place while the animal is still buried in the slime, but it soon makes its way to the surface, where it lies with its respiratory appendages exposed.

The pupae are usually shorter (3.5 mm.) and thicker than the larvae and although at first whitish, they rapidly become brown and less transparent. In the pupal stage all the organs of the perfect insect are developed, and the head, thorax and abdomen can easily be distinguished. The wings, legs, etc., are found in a sheath pressed closely and immovably to the body. The head is not at this stage distinctly marked off from the rest of the body, but the compound eyes can be seen through the pupal skin, and from the front of the thorax arise the two long, transversely wrinkled respiratory appendages. The thorax carries the two wings and six legs, while the abdomen consists of seven segments, the last segment having four large spines, which assist the pupa to move about in the filth and so keep the respiratory apparatus exposed to the air. The abdominal segments are provided with numerous bristles, characteristically disposed, and appearing at the lower end of each segment as a complete ring, seen in the figure as a dark band (Fig. 17).

The pupal stage does not last many days, a short period in the life of the insect, and pupae are therefore relatively rare. At the end of this stage the pupa, by the aid of its spines, raises itself above the surrounding slime, its sheath splits longitudinally, and this is soon followed by a lateral rent near the head, forming a T- shaped opening, out of which the mature insect emerges fully equipped for its aerial existence.

The imago or perfect insect is easily recognised by its small moth-like appearance and its uncertain fluttering flight; closer examination reveals the characteristic bead-like joints of the antennae and the hairs which cover both body and wings. The prominent genital armature of the male and the structure of the wings sufficiently characterise the genus *Psychoda*; while the presence of dark patches at the end of the wing nervures serve to identify the species *Ps. sexpunctata,* Curtis (Fig. 14). These dark patches are due to the excessive development of dark coloured hairs, and uninjured specimens normally possess ten such spots on each wing, but the hairs are easily removed by friction, and many insects are found with fewer spots, so that those examined by Curtis may easily have shown only the six from which the specific title originated.

It is possible that the skin irritation which the insects cause in certain individuals may be due to these hairs entering the pores of the skin. This irritation is apparently not due to bites, inasmuch as the rudimentary mouth parts are short and fleshy and incapable of injuring the skin. In fact the insect appears to pass this stage of its existence without taking food, since none has ever been found in the alimentary canal. Nor can the irritation arise from a sting, as the ovipositor of the insect is not suitably modified. The insects are so light that 2,000 only weigh a gram., or a million of them one pound. They are dioecious, the males being about one-tenth of an inch (2.5 to 3 mm.) in length, and the females about a sixth of an inch (4 to 4.5 mm.), the latter being much more numerous. The female becomes impregnated while resting, and lays her eggs, as already stated, in the moist material so plentiful in the filter, thus completing the life-cycle. The male insects usually hatch out first, followed later by females.

The only other species likely to be confounded with the above is *Psychoda phalaenoides* (L), which is less hairy, darker in colour, and has no wing spots. So closely do the species resemble one another that the *Ps. phalaenoides* of Meigen is apparently from his description *Ps. sexpunctata* of Curtis. Both species are generally to be found on the same filter, but the relative numbers vary at different times of the year. Thus in one case in October last they were all *Ps. sexpunctata,* Curtis, in April only about 20 per cent. were of this species, while in June they were all *Ps. phalaenoides.*

The difficulty of accurately identifying the eggs, larvae, and pupae of the two species will be readily realised, and in the plates illustrating these stages it should be mentioned that they were obtained from a filter on which at the time only *Ps. phalaenoides,* L., were to be found.

From this brief life-history it may be gathered that it is only in the larval stage that the fly plays any part in sewage purification. During the whole of this stage it is actively and voraciously at work devouring and breaking down the solid matters which have been deposited or developed from the sewage, and although the destructive power of a single larva may be almost negligible, yet the combined effect of the myriads present in a sewage filter must have a very appreciable result.

It is only in the final stage that the insect is liable to cause nuisance, and this is no mere sentiment, for the agency of house-flies as disease carriers is now well recognised, and it will be readily understood that these sewage flies, coming as they do directly from excremental matter, may easily carry with them germs of such diseases as diarrhœa or typhoid, but the following experiments with *Psychoda* show that their capabilities in this direction may not be so great as might be imagined.

From each of three collections containing a few hundred flies, twenty were emulsified, and a proportion of the emulsion, corresponding in the amount to the bulk of two flies, was plated on neutral-red-bile-salt-lactose agar.[1] Further, in order to locate any particular infected portions of the flies, two were dissected, the heads, bodies, and legs, and wings being plated separately. The plates were incubated for 48 hours at 37° C., but no presumptive colonies of *B. coli* appeared. The flies in two of these collections were killed, with a minimum amount of chloroform and ammonia respectively, in order to avoid unnecessary damage during transit, while the flies in the third collection had been kept alive until used for the experiment.

In further experiments flies were obtained directly from the moist filtering material by shaking them into the cover of a Petri dish, and were allowed to walk or fly over the surface of a neutral-red-bile-salt-lactose agar in the dish, which was incubated for 48 hours at blood-heat (37° C). It was found that although the flies left many hair-marked tracks on the medium, yet no colonies (presumptive *B. coli*) developed along these tracks. During incubation all the flies perished, and it was observed that in a few cases red colonies developed around the dead bodies, and in the case of flies taken lower down from the sides of the filter, only two or three of these colonies were seen. Others observed on the dish were obviously caused by infected filter material, a dark particle of which was visible as the nucleus of each colony.

These experiments lend support to the statement that the mature fly does not feed at all, and suggest that the danger of their carrying infection may be somewhat remote, but it would be unfair to make any definite statement on this point until the experiments have been frequently repeated.

The appearance of the insect in such numbers as to create a nuisance necessitates conditions favourable to all its stages; for the egg stage, the presence of moisture; for the larval stage, a plentiful supply of suitable food containing organic solids and moisture; for the pupal stage, favourable situations in which it may lodge and from which it may escape in the winged form; and for all stages a plentiful supply of oxygen.

The excessive development of flies naturally attracts a large number of enemies which prey upon them. Among these are insectivorous birds, such as swallows and wagtails; spiders often weave webs which entirely surround the filters, while the dipterous insect *Spathio-*

[1] This substance is used as a primary medium for isolating *Bacillus coli* and allied species; the delicacy of this test will be realised from the fact that 1 c.c. (20 drops) of sewage usually contain 100,000 such bacteria.

phora hydromyzina, Fn., often kills in a frenzied manner large numbers of *Psychodae.* The presence of masses of fungal hyphae in the dead bodies of these flies suggests the possibility of fungal attacks, such as are known to occur in the ordinary house-fly. Besides these direct enemies there are indirect means of attack, such as is afforded by the presence of snails, leeches, worms, "*Podura*" and beetles, which consume the food of the larvae, and it is noteworthy that when "*Podura*" is plentiful *Psychoda* is scarce. The reduction of the amount of colloidal and suspended matter in the tank effluent exerts a similar influence and should be carried as far as practicable; this may often be done by the aid of careful chemical precipitation.

(*b*) The Water Springtail.

Achorutes viaticus (Linn.), Tullb.

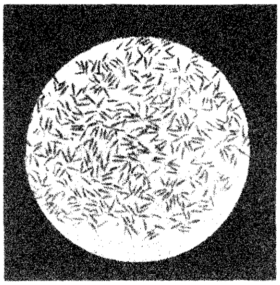
These small wingless insects, which were referred to as "*Podura,*" are found on some filters quite as abundantly as the sewage fly, *Psychoda,* but as previously stated, the two insects seldom appear together in profusion.

Springtails occur as bluish-black masses, most evident on small pools of ponded sewage on the filters or on the surface of a humus tank, where at first sight they remind one of small soot particles floating on the surface of the liquid. They may also be found in great profusion on the moist surface of the filtering material, often giving it a bluish-black appearance, and on drying masses of sewage sludge. Each insect is about 2 mm. or $\frac{1}{12}$ inch in length (see Fig. 18).

When closely watched, the insects are seen to be constantly in motion, either crawling on the surface of the water, or, if disturbed, making sudden jumps, sometimes several inches in length. Although resting on the surface of the water they are never wetted by it, and if a stick be immersed near a patch of them they are at once dispersed, but reassemble as soon as the stick is withdrawn. This movement is not due to any alarm but merely to a physical cause, namely, the distortion of the water surface by the wet stick. The water is not level where it meets the stick, but, from capillary attraction, runs for some considerable distance up the wetted surface, and thus the insects are temporarily placed on an inclined plane, down which they at once glissade to the general water level, and *away from* the stick. That the motion is due to the distortion of the water surface is readily proved by smearing the stick with vaseline and repeating the experiment, when they at once appear to cluster round the stick because the greasy end now depresses the water surface so as to form an inclined plane down which the insects glissade *towards it.*

A very interesting experiment is to place several of the insects with a little water in a narrow vessel having high perpendicular sides; here again because of the capillary attraction the water surface is not level, but slopes up the sides of the vessel; consequently the insects become huddled together near the centre of the vessel, and although they make numerous attempts to disperse by jumping, yet whenever they alight near the water's edge they slide back again, and are thus kept crowded together in the centre.

Podura aquatica (Fig. 19) has often been reported as occurring on sewage filters, but it is doubtful if such records are correct, since the insects recently found in localities given for *Podura* have, on detailed examination, proved to be *Achorutes*. They are common on the



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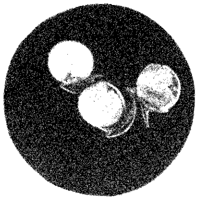

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Achorutes viaticus (Linn.), Tullb.

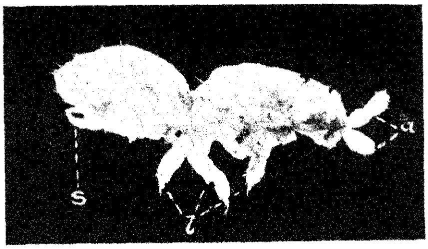
Fig. 18. Group of insects (natural size).
Fig. 19. *Podura aquatica* showing how the spring (*s*) projects backwards beyond the body. × 25.
Fig. 20. Eggs of *Achorutes viaticus* (Linn.), Tullb., showing separation of ruptured outer integument and the developing embryo. × 25.

Phot. J.W.H.J.

sewage works at various places in the West Riding, at Harrow-on-the-Hill, and at Stratford-on-Avon, and all have been found to possess the double-clawed feet which characterise the genus *Achorutes* and distinguish it from *Podura*. Moreover, most small water-springtails are generally regarded without detailed examination as *Podura aquatica*; whereas authentic records of this insect are comparatively rare, and in one instance at least the sewage works' manager reports *Podura* while the local entomologist records *Achorutes viaticus* for the same situation. Some authors have noticed the shortness of the "spring" in the insect found on sewage filters, and have wrongly referred it to *P. tullbergii*, Lubbock.

Characteristics.—*Achorutes viaticus* is a-metabolous, that is, it undergoes no larval or pupal changes. The eggs (Fig. 20), which are whitish and sub-globular, measure 0.2—0.25 mm., or 0.01 inch in diameter, and are therefore relatively large for the size of the mature insect. They occur either singly or in clusters of 15 or more, and are to be found in the interstices of the top few inches of the filtering material, usually in close proximity to the numerous whitish skin-casts of the insects. As incubation proceeds, the differentiation of the various parts of the embryo becomes more and more marked, the outer integument becomes brown, eventually ruptures and separates, leaving an inner white and more oval envelope containing the embryo, which at the end of a few days emerges as a little fully-formed insect.

The period of incubation and number of eggs incubating naturally vary with the season of the year, and although insects hatch out in the depth of winter and may be found in large numbers on filters even after these have been covered with snow for several days, yet they are most



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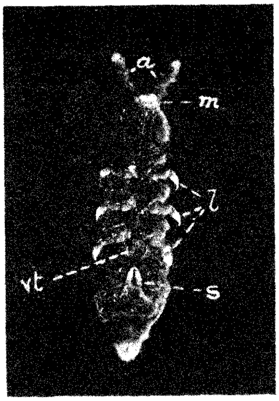

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Achorutes viaticus (Linn.), Tullb.

Fig. 21. Moult or skin-cast. × 25.

Fig. 22. Ventral view of insect showing position of ventral tube *(vt)*, and forked spring *(s)* when the latter is flexed up to the abdomen. × 25.

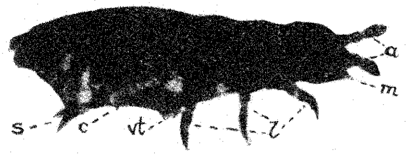
Phot. J.W.H J.

abundant in warm weather, and judging from the number escaping with the effluents from sewage filters, the maximum is reached between June and August.

Within a few hours of birth the insect can both walk and jump, and from this time onwards it undergoes no further metamorphic change, but simply increases in size and vigour, until when mature it measures 2 mm. (0.08 inches) in length, about 10,000 of them weighing one gram, or over 4 million to the pound.

During this period of growth the skin of the insect is shed repeatedly and the cast skins (Fig. 21) may be seen as whitish particles wherever *Achorutes* is abundant. The rate at which moulting occurs must necessarily vary with many factors, such as the age of the insect, season of the year, amount of food, etc. From observations made during November on 12 young specimens the moulting was so rapid that 12 cast skins were obtained within 48 hours. In casting the old skin the slit through which the insect emerges usually extends along the ventral groove as far backwards as the ventral tube; immediately after the moult the insect is often much paler in colour, being at times almost white, often mauve or pale purple.

The mature insect (Figs. 22, 23, 24) is usually of a glaucous deep blue-black colour, but as previously stated it may vary from almost pure white, through mauve and purple to blue-black. The under surface is often mottled with yellowish or lighter coloured patches.



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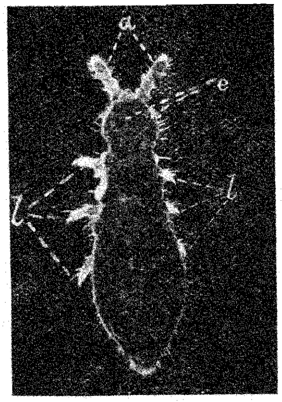

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Achorutes viaticus (Linn.), Tullb.

Fig. 23. Lateral view showing spring *(s)* extended backwards. × 25.

Fig. 24. Dorsal view showing various organs and general covering of hairs and bristles. × 25.

Phot. J.W.H.J.

Habits and Distribution.—The species under review is not usually very active, and it was perhaps for this reason that the genus received the title of *Achorutes* (Gr. not dancing). It may at times be found in profusion on damp walks, or on moist decaying animal or vegetable matter throughout the year. It is perhaps the most common and widely distributed species of the genus. Schaeffer mentions that it occurs in Siberia, Norway, Russia, Denmark, Britain, Spitsbergen, Greenland, and California in the Northern Hemisphere, while it has been recorded from the sub-antarctic regions of South Ameıica, and recently from two small islands south of New Zealand. It may therefore be fairly reasonably termed a cosmopolitan species.

Axelson, in his work on the *Apterygotenfauna Finlands,* has classified the Apterygota according to the situation in which they are found, and this method is well calculated to emphasise the outstanding characters of any species. *Achorutes viaticus* occurs only in 4 out of his 12 types of fauna, and three of these are situations characterised by the abundance of food, viz. : (1) *Humus fauna* among dung, etc. ; (2) *Littoral fauna* both of fresh and salt water ; (3) *Water-surface fauna.* It has also been found in (4) the *Winter fauna,* showing that the species is fairly capable of tolerating cold. Another interesting point brought out by this classification is the fact that it is a lowland form, no record having ever been obtained of its existence in mountainous districts. Although so very widely distributed, its identity does not appear to have been recognised by any authority dealing with its appearance and function on sewage filters, and it is only when the records of specialists on the group Collembola are consulted that any adequate idea of its concurrence is obtained.

Carpenter mentions (Proc. Roy. Phys. Soc., Vol. XIV, p. 225, and Mins. of Plans and Works Comm., Edinburgh, 11th April, 1906, p. 334), that he found these insects in millions on the seashore in Scotland amongst decaying seawrack; again on a wall near a newly manured turnip field; at South Queensferry on seawrack, and at Comiston on putrid turnip. Other observers have seen them in England on a footpath at Stratford-on-Avon Sewage Works (Collinge, Thysanura and Collembola, Birm. Nat. Hist. and Phil. Soc., 1910, pp. 6 and 7); at Berkhamstead about a rubbish heap where decaying mangels had been thrown, and on the water draining from it; on a garden footpath (Collinge and Shoebotham, The Apterygota of Hertfordshire, Jour. Econ. Biol., 1910, Vol. v, pt. 3, p. 99); in Ireland near a manure heap at Portadown (J. W. Shoebotham, Ann. and Mag. Nat. Hist. Ser. 8, Vol xiii, January, 1914). Professor Carpenter also states that they are present in the Dublin Sewage Outfalls. The above situations agree remarkably well with those given by Axelson in his faunal classification.

Food Supply.—The insects must be regarded as scavengers, and Prof. Carpenter in his report upon the occurrence of similar insects in the water hydrants of the City of Edinburgh says : "As to the food the present species in common with many others subsist chiefly if not entirely on decaying vegetable (and perhaps also animal) matter, fungi, and confervae."

Mr. H. D. Bell, at Stratford-on-Avon, has attempted to measure the amount of carbon dioxide and ammonia evolved from a given weight of the living insects. He corroborates the view that the principal food is the slimy material on the filtering medium, and states that its removal from sprinkler filters by the insects prevented "ponding" and gave an increased amount of nitrates in the effluent. Further, on filters where ponding had occurred it was remedied by artificial inoculation with *Achorutes*.

The specimens obtained from Harrow-on-the-Hill occurred among the green alga *Prasiola crispa,* which has the property of absorbing sewage pollution in a manner very similar to that of the *Ulva latissima* so well known in Belfast Lough. The alga in this manner becomes very rich in nitrogenous substances and constitutes a rich food for such insects.

The dark colour of the insect usually prevents any direct observations being made upon the contents of the alimentary tract, but on two or three occasions—in paler varieties—the whole of the tract has been clearly outlined by the green colour of the ingested *Prasiola,* and from this it appears that the insect at times feeds upon living plant tissue.

Culture Experiments.—During the winter months attempts were made to rear the insects in captivity. At first considerable difficulty was experienced in obtaining a suitable food supply, for bread and similar usual aliments were found unsuitable.[1] Experiments with the green alga *Prasiola crispa* were more successful, but its use was liable to introduce other insects than those under observation, and particularly their eggs, so that it could not be considered satisfactory, while slime obtained from clinker on a percolating filter formed an excellent food supply and could readily be obtained without the above contamination. Small pieces of clinker covered with this slime were rapidly attacked by the captive insects, and the disappearance of the slime, together with the presence of numerous skin-casts on the clinker, left no doubt as to the nature of their food on sprinkler filters. The slime consisted chiefly of *Zoogloea* masses, developing fungal hyphae, and debris which this growth had retained from the sewage. The food supply thus seems to be similar to that of the *Psychoda* larvae on such filters.

In these latter experiments, although the insects were kept alive for some considerable period, yet no noticeable increase in numbers was ever observed; the cold season of the year may perhaps have had some deterring influence on reproduction.

Observations have been made during the past six months upon the occurrence of *Achorutes* on the sewage filters in the West Riding, but no very definite information has yet been obtained to show why on one set of sewage works these insects may be found in myriads, while on another apparently similar they may be scanty in number or even

[1] Mr. G. B. Kershaw has recently employed moist blotting paper for this purpose and found it very suitable (*The Surveyor*, Nov. 13, 1914, p. 397).

absent. The points of difference in the various sewage works taken into consideration have been the nature of the filtering medium, whether slag, clinker or stone; the size of the top layer and its condition as to ponding, the nature of the sewage treated, whether wholly domestic or containing trade refuse; the kind of tank effluent dealt with, whether produced by simple settlement, septic treatment, or precipitation, and whether containing much or little suspended matter. It must be confessed that it has not been ascertained what are the controlling factors which favour or prevent the prevalence of *Achorutes*. It should, however, be borne in mind that these observations have been made during the winter months, when the insects are often few, but so far as they have gone they tend to support the view previously expressed that the two kinds of insects do not occur in profusion on the same filters, and generally *Achorutes*, unlike *Psychoda*, prefers situations where the sewage is ponding.

(5) Other Dominant or Sub-dominant Organisms.

Almost any organism may, under suitable conditions, develop into a dominant or sub-dominant species; most of these species have already been reviewed in the ecological associations dealt with in a former section. A few of these associations, although occurring on sewage filters are better illustrated in polluted watercourses, and are therefore treated from this point of view.

The *Colon bacillus* or *Bacillus coli*, as it is sometimes termed—although it cannot develop either in sewage or water to any appreciable extent—belongs to this class, for it is present both in the crude sewage and also in the final effluent; the untreated sewage containing some 100,000 per c.c (20 drops). This bacillus is normally an inhabitant of the intestinal tract, and according to Dr. Houston human excreta contains from 100 to 1,000 millions of these bacilli per gram. The *Colon bacillus* can be readily identified in water even if only present to the extent of 1 per 10 c.c. Its identification therefore constitutes a very delicate bacteriological method of estimating or detecting sewage pollution. Unfortunately, however, there is no means of distinguishing between human and other sources of faecal contamination.

Bacteriological Examination of River Samples.—After a number of determinations had been made it became obvious that the gelatine counts (although giving more characteristic colonies than those on the Agar medium) were apt to be misleading, as at times the purer river waters gave higher figures than those obviously more polluted. This may in part be due to the inhibiting effect of substances in the polluted waters, as mentioned in the earlier pages of this paper; but upland waters of undoubted purity are capable of yielding unusually large numbers of *uniform* colonies, so that mere enumeration of colonies, without considerable attention to their character, can afford no appropriate basis for comparison among rivers of such widely different quality as those of the West Riding. Eventually it was decided to abandon both these counts, and to extend the investigations into the number and nature of the *B. coli,* which offers a much better and safer criterion of animal pollution.

The variations in the numbers of this bacillus are very marked, but in making comparison between different rivers, or even different portions of the same river, numerous factors should be borne in mind. A gradual reduction in numbers occurs in consequence of sedimentation, and thus a stream polluted in its higher reaches would naturally, if no further pollution occurred, contain less *B. coli* in its lower portion; this is borne out by the numbers generally found at the lowest points of observation on the Rivers Aire and Calder at Methley, and on the River Don at Conisboro'. The numbers are obviously affected by the amount of dilution of any polluting discharge, and of this some indication is afforded by the rainfall. The effect of increased rainfall is to reduce by dilution the numbers found, but on the other hand a flood prevents sedimentation and stirs up deposited solids in the beds of the streams, and this may cause a marked increase in the numbers of these bacilli.

The term *B. coli* includes a group of bacilli, all of which possess certain well-defined primary characteristics, but which may show widely varying secondary characters, some of them liable to be lost, modified, or developed, under change of environment. Without explaining in any great detail the methods employed for separating the general group into its various strains or races, it may be stated that one characteristic most commonly used as a guide is the power of producing fermentation in solutions of various kinds of sugar.

All varieties of the bacillus should ferment both Glucose (Grape sugar) and Lactose (Milk sugar), but some fail to produce this change in Saccharose (Cane sugar), that is they are cane sugar negative, or briefly C.S.N., in contra-distinction to the cane sugar positive, or C.S.P. varieties.

The percentage number of C.S.P. varieties in faecal matter according to Mac Conkey (Journal of Hygiene, Vol. v, page 333) only amounts to 28, the remaining 72 being C.S.N. The *B. coli* hitherto found in the Yorkshire river samples contain 82.3 C.S.P. and only 17.7 C.S.N., whereas Dr. Houston (6th Annual Report, Metropolitan Water

Board, page 40), in the raw waters of the Thames, Lee and New River, finds 63.8, 64.4, and 60.9 per cent. respectively of C.S.N. varieties.

This difference in the sugar fermenting capacity of the *B. coli* found in these rivers compared with those of Dr. Houstón is presumably due to the different environment possibly caused by the presence of trade waste. The inimical effect of acid trade waste on this organism will now be dealt with, and considering the very marked effect which it has on the life of this organism, it is only reasonable to suppose that such substances, even in small quantity, have a marked effect on the character of this organism.

Effect of Acid Waste on the B. coli contents of the Bradford Beck.—A sample of the Beck at its junction with the Aire, although obviously very polluted, contained fewer bacteria than the river immediately above, while in the river at some distance below the junction the bacteria were much more numerous than above. The following table will serve to make this clearer:—

Bacteria per c.c. of River Water.

	B. coli.	Bacteria developing on:—	
		Agar at 37°	Gelatine at 20-22°.
River Aire (Baildon Bridge)	730	3,200	60,000
Bradford Beck*	300	2,000	about 2,000 (Covered with mould)
River Aire (Buck Mill)	8,750	39,500	537,000

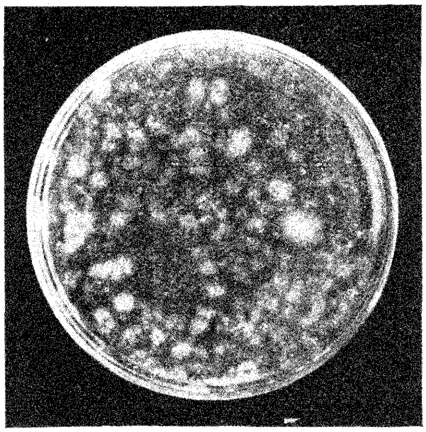
The reduced bacterial life in the Bradford Beck in the presence of gross sewage pollution was opposed to previous experience and suggested the presence of some inimical substance, probably the sulphuric acid used as a precipitant at Frizinghall Sewage Works, and this suggestion was supported by the presence of numerous colonies of *Oospora lactis*, Sacc., a mould which readily develops in an acid medium.

The two accompanying photographs (Figs. 25, 26) show the appearance of this fungus in Petri dish cultures on prune gelatine after

*Since the samples could not be examined until 18 hours after taking, these figures show a greater reduction than would occur in nature; for during the whole of this time the acid would be operative, whereas in nature dilution—which retards its action—occurred almost immediately below the point of sampling.

two and three days' growth respectively, and also serve to illustrate its relative frequency in the Bradford Beck samples.

A further example of the reduction of bacterial life attributable to the presence of acid was recently observed during an examination of Lupset Beck, near Wakefield. This watercourse receives the discharges from Ossett Spa Sewage Works, consisting of both treated and untreated sewage, a large portion of the latter being composed of acid waste from dyeing and carbonising processes. It was impossible to find *B. coli* in 1 c.c. either of the effluent or of the stream below these works, and even in the crude sewage, which contained excreta, only two colonies per c.c. developed. The mould (*Oospora*) noted in the Bradford Beck, also appeared in the acid samples.



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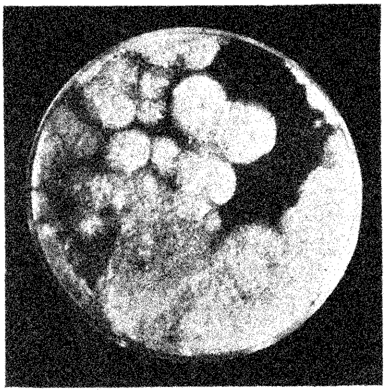

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Fig. 25. *Oospora lactis*, Sacc. Colonies developing from 0·1 c.c. of Bradford Beck water after two days' growth on gelatine. (Half natural size).

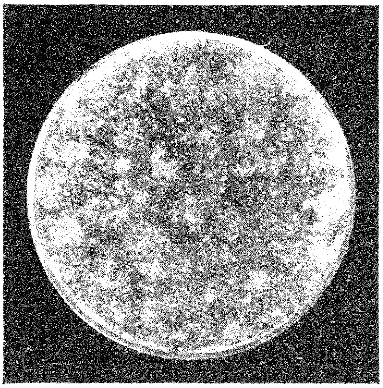
Fig. 26. *Oospora lactis*, Sacc. Colonies developed from 0·01 c.c. of Bradford Beck water after three days' growth on gelatine. (Half natural size).

Phot. J.W.H.J.

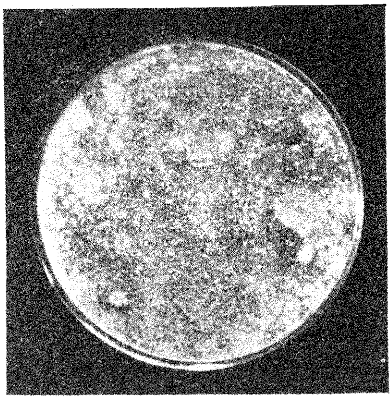
The photographs (Figs. 27*a*, 28*b*, 29*c*) show the development of this fungus after 48 hours in cultures containing 1 c.c. of (a) crude sewage, (b) water from the Lupset Beck near its junction with the River Calder, and (c) filter effluent from the sewage works. It will be noticed that in culture (*c*), which was slightly alkaline, no growth of the mould occurred, and that the culture dish is thickly studded with numerous colonies of bacteria, whereas on the other two culture plates the colonies are almost entirely overgrown by the fungus.

The growth of the mould *Oospora lactis,* Sacc., under such conditions suggested that it possessed high resistant powers towards germicides, and this was fully supported by the results given in the table on p. 155.

The medium used in these experiments was a 10 per cent. decoction of prunes, to which 12.5 per cent. gelatine had been added. Nine c.c. of this medium rendered sterile was placed in each of a number of tubes and 1 c.c. of a 0.1, 0.5, and 1.0 per cent., or, of acids and alkalies a 2.0, 10.0, and 20 per cent. solution of the reagent



27*a*



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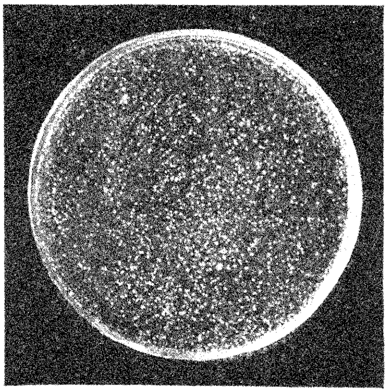


29*c*

Oospora lactis, Sacc.

Fig. 27*a*. Petri dish culture from 1 c.c. crude sewage; Ossett Sewage Works. (Half natural size).

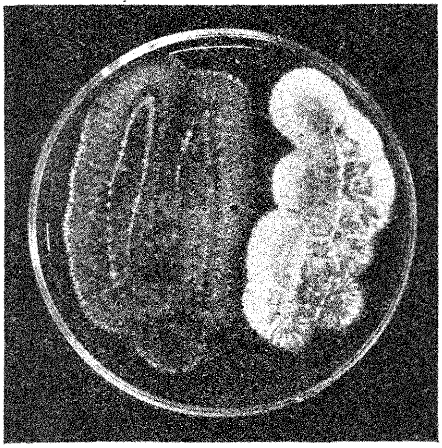
Fig. 28*b*. Petri dish culture from 1 c.c. Lupset Beck water, below Ossett Sewage Works. (Half natural size).

Fig. 29*c*. Petri dish culture from 1 c.c. filter effluent, Ossett Sewage Works. (Half natural size).

Phot. J.W.H.J.

was added, and, after the tube contents had been well mixed by shaking, they were poured into Petri dishes. When the gelatine had solidified each dish was roughly divided on the outside into two parts by means of a grease pencil line, and each half inoculated from one of two previous cultures of the fungus. These cultures, although showing no microscopic difference, exhibited some slight cultural variations, one (the right-hand half in the photographs) being constantly much whiter and slightly more vigorous in growth than the other (Figs. 30, 31).

The table of the results obtained after the use of the various reagents shows, as might be expected, considerable differences; formalin having a much stronger action on this organism than either mercuric chloride or carbolic acid. The amount of acid and alkali required to prevent germination is about fifty times as great as the



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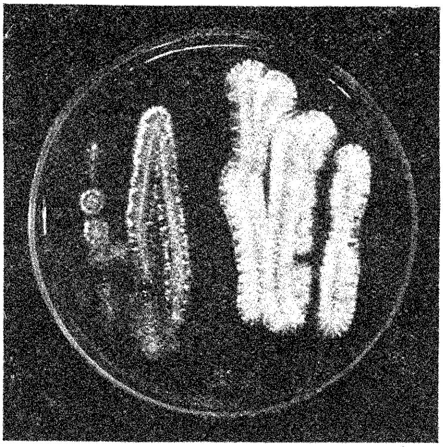

31

Oospora lactis, Sacc.

Fig. 30. Petri dish culture on medium containing 10 parts per 100,000 of carbolic acid. (Half natural size).

Fig. 31. Petri dish culture on medium containing 50 parts per 100,000 of carbolic acid. (Half natural size).

Phot. J.W.H.J.

amount of formalin; while in a medium with 1 per cent. of either hydrochloric or sulphuric acid, or sodium carbonate, growth is prevented. With 0.2 per cent. ammonia (NH_3) a peculiar liquefying growth occurred, while with a similar amount of sodium carbonate ($Na_2 CO_3$) there was a very luxuriant growth of *Oospora*. It is possible that with a liquid medium containing well established cultures widely different results might be obtained, but the above results sufficiently illustrate the resistance which this organism offers to antiseptics.

Effect on various Reagents on the growth of *Oospora lactis*, *Sacc.* (after 48 hours).

Re-agent.	Parts per 100,000.	Amount and character of growth.	Parts per 100,000.	Amount and character of growth.	Parts per 100,000.	Amount and character of growth.
Carbolic Acid	10	Good growth	50	Growth but less than preceding	100	No growth. Needle track showing
Mercuric Chloride	10	Good growth	50	No growth ...	100	No growth
Formalin	10	Good growth	50	No growth ...	100	No growth
Hydrochloric Acid	200	Good growth	1000	No growth ..	2000	No growth
Sulphuric Acid	200	Good growth	1000	No growth ...	2000	No growth
Ammonia	200	Deep seated liquefying growth	1000	Very slightly liquefying	2000	No growth
Sodium Carbonate	200	Very good growth	1000	Very slightly liquefying	2000	No growth

Considerations such as the above show that very small quantities of special substances may very greatly influence the flora and fauna of a stream (see U.S. Department of Agriculture, Bureau of Plant Industry, Bulletins Nos. 64, 76, and 115; also Surveyor, 1913, pp. 833, 869), and that a purely chemical standard for sewage effluents cannot be considered sufficient. For example, the small amounts of acid which so favour the growth of *Oospora* in the water of the Aire would not be taken into account in the suggested chemical standard of the Royal Commission on Sewage Disposal, and there are other substances which, even if present in very small amounts, may temporarily defer the decomposition of organic matters and thus vitiate the Commission's test of the absorption of dissolved oxygen, which in a large measure depends upon bacterial action.

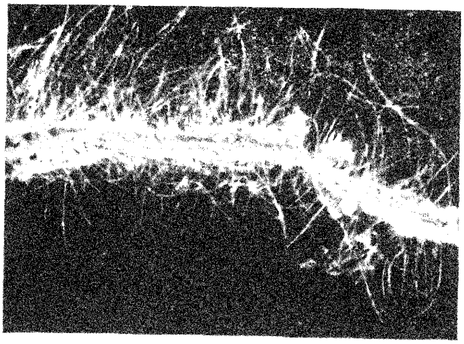

Fig. 32. *Thiothrix nivea* (Rabh.), Win., developing around decaying *Carchesium* stalk. (Canal bye-pass, Horbury). × 100.
Phot. J.W.H.J.

Thiothrix nivea in the River Aire.—The polluted condition of the Aire below Leeds causes great nuisance; in October, 1911, the river at the Thwaite Gate Ferry had a distinct odour of sulphuretted hydrogen, and the stones near the water's edge were thickly covered with a white growth. This proved to be one of the so-called "sulphur bacteria," and was identified as *Thiothrix nivea* (Rabenh.), Winogr. (Figs. 32, 33). This organism has apparently not been previously recorded in Britain, and has presumably been confounded with other sulphur organisms such as *Beggiatoa*. *Thiothrix* also flourishes in the bye-pass on the Calder and Hebble Canal at Horbury, where it forms a white felted mass attached to the free-floating portions of aquatic plants (*Potamogeton*) and animals.

Thiothrix nivea is found as a delicate white covering on stones, algae, or submerged aquatic plants. It usually occurs in polluted liquids which contain sulphuretted hydrogen, and when associated with certain algae is classed by Kolkwitz and Marsson as a *Mesosaprobe.*

Although it is found in polluted liquids it develops best in situations where a certain amount of aeration is possible, as was illustrated in the River Aire, where the growth was restricted to a narrow zone along the bank the gentle lapping of the water naturally assisted aeration. Its marked development and frequent occurrence in the aerated water of the canal bye-pass at Horbury lends further support to this view. Although in this case the presence of sulphuretted hydrogen could not be demonstrated.

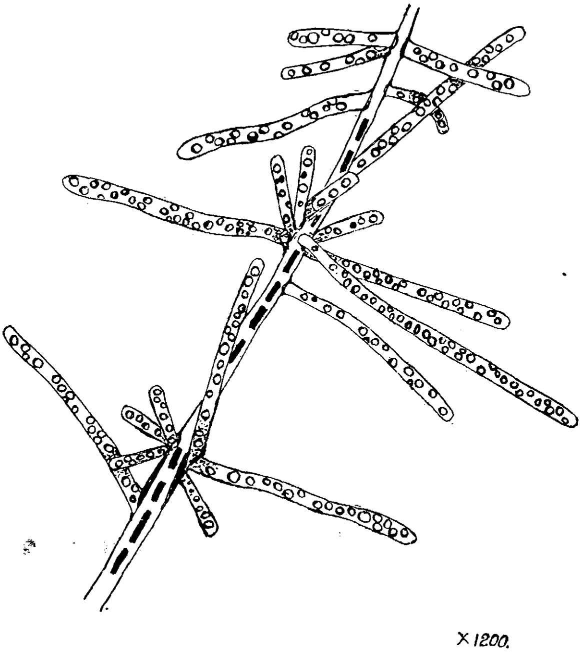

Fig. 33. *Thiothrix nivea* (Rabh.), Win., developing around a fungal filament of *Sphaerotilus natans.* (Canal bye-pass, Horbury).
Del. J.W.H.J.

Thiothrix belongs to the group of white sulphur bacteria, *Beggiatoaceae,* and may be distinguished from the closely allied genera by the following characters :—

Beggiatoaceae.

Filaments of uniform thickness, free swimming, gonidia wanting *Beggiatoa.*

Filaments of uneven thickness, attached, developing motile rod-like gonidia - - - - - *Thiothrix.*

Filaments contained in a common gelatinous envelope *Thioploca.*

Thiothrix filaments are non-motile, being 1.7 μ thick, and tapering in older specimens to 1.5 μ. They are usually attached by a somewhat thickened gelatinous base, 2.0—2.5 μ in diameter, and contain numerous sulphur granules, which in older or starved specimens disappear, when the organism may be confounded with *Sphaerotilus natans,* Kütz.

Dominant Algae.—Where land is used for the final treatment of sewage "ponding" is liable to occur, and in such cases green coloured organisms often appear in such profusion as to colour the liquid.

Species of *Chlamydomonas* and *Euglena* are amongst the most frequent, and in one instance a large area was similarly coloured by *Richteriella botryoides*; chiefly of the *fenestrata* variety. This alga has only once been previously recorded in the British Isles—Lough Beg, Ireland—and it is doubtful if the variety has ever been obtained before in these islands. Its appearance, therefore, in such profusion is the more remarkable.

Dr. Letts has shown that the marine alga, *Ulva latissima,* so common in the "sloblands" of Belfast Lough, possesses in a remarkable degree the property of rapidly absorbing soluble nitrogenous sewage matters. This same property is also exhibited by the green alga, *Prasiola crispa,* which, under suitable conditions, develops both in the thalloid and filamentous forms on the surface of sewage filters. The latter form often occurs as green filaments between the "setts" of the quiet streets in our towns, while the former is frequent on the bare moorland, where it is entirely dependent upon human source for its nitrogenous supply.

OXIDATION OF SEWAGE WITHOUT THE AID OF FILTERS.

No account of modern methods of sewage disposal would be complete without some reference to the recent experiments which have been made in this direction with "activated" sludge. In 1908 Dr. H. Maclean Wilson suggested the possible presence of a sewage-coagulating enzyme in the "humus" from a sewage filter, and although the author was unable to isolate successfully an enzyme, yet ample evidence was obtained of the coagulating effect of this "humus" on sewage matter.

Dr. Fowler, when in America, saw a laboratory experiment in which sewage was purified by long continued "blowing" of air through the liquid. The addition of "humus" was suggested, and after continued "blowing," this "humus" or mud became more and more efficient or active, so that now a mixture of 25 per cent. of "activated" mud and 75 per cent. of sewage, after one or two hours' blowing produces a liquid which when settled is comparatively clear and odourless, thereby affecting a purification of 75 per cent. or more, moreover, the liquid seems particularly suited to the requirements of fish life. The mud settles rapidly and is of a brownish colour, containing some 96 per cent. of water, and dries well; the dry residue contains the very large percentage of 4.6 of nitrogen.

Microscopically, the bulk of the mud shows nothing very characteristic, but the repeated presence of *Opercularia* suggests an association which I have noticed in rapidly flowing water where *Zoogloea ramigera* was the dominant organism, and from experiments now in operation it seems possible that zoogloea, assisted by other minute organisms chiefly of animal origin, may be responsible for the rapid purification thus effected. That such minute animal life, *i.e.*, protozoa, rapidly destroy nitrogenous substances is proved by the increased amount of nitrogen and its derivatives observed when soil is partially sterilised, and the protozoa are thus destroyed.

Whatever may be the *modus operandi* of this purification, the process has been developed along lines of natural biological evolution; each improvement in the method of aeration has produced a corresponding increase in the number and the variety of organisms which were capable of participating in the oxidation of the polluting organic matter, and has thus given an increased efficiency. In this respect it may be well to remember the importance which Professor Frankland originally attached to aeration, and how in the successive stages from land—which is often subject to sewage sickness—the development proceeded to contact beds, which provide a more certain aeration, and then to intermittent filters providing constant but scarcely perfect aeration, and lastly to the stage where the medium is dispensed with and the purification concentrated upon the organisms themselves in the presence of an adequate air supply. Although the bulk of the mud may be relatively small when compared with the material of a filter, yet, owing to its fine state of division, the active surface presented to the liquid is enormous, and purification is consequently much quicker.

If this process can be successfully developed it appears to offer a simple solution to the question of fly and other troubles, for with a few hours of this treatment the putrescible portion of the pollution would be so far oxidised that the food supply of flies, etc., would be destroyed, and with this the disappearance of their troublesome myriads would be assured.

In all biological purification systems the question of the admission of trade refuse to sewers is a very serious one. Attention has already been directed to the disturbing influence which these liquids may exercise upon the ordinary process of purification. However, considering that in many instances the greater proportion of the pollution proceeds from such sources, it follows therefore that any system to deal efficiently with this problem must of necessity be capable of dealing with the bulk, at any rate, of the trade refuse. Generally speaking, trade refuse, if mixed with ordinary sewage in reasonable quantity, presents no serious difficulties in treatment, as the two liquids often inter-react and thereby assist precipitation. With the more objectionable discharges—where the deleterious effect upon the filter is out of all proportion to the quantity discharged—it would perhaps be more economical to treat them separately, or only admit them to sewer after efficient primary treatment.

In conclusion, no ecological work of this kind has hitherto been attempted in Britain, and it is only recently that any serious attention has been given to the study of the flora and fauna specially adapted to the purification of sewage. While many of these forms are undoubtedly well known to most biologists, there are, however, others, which—although of frequent occurrence—are practically unknown to the British Flora. This is especially noticeable among the lower fungi, and the following list will give some idea of the species likely to be encountered in such work. Some difficulty has been experienced with regard to the previous records of these organisms, and those marked * are apparently new to Britain :—

Schizomycetes.

**Zoogloea ramigera,* Itzshn and vars. ; *Sphaerotilus natans,* Ktz. ; *S. roseus,* Zopf. ; *S. fluitans,* Schka. ; *Cladothrix dichotoma,* Cohn. : *Gallionella ferruginea,* Ehr. ; *Chlamydothrix ochracea* (Ktz.), Mig. ; **Thiothrix nivea* (Vauch), Win. ; *Beggiatoa alba* (Vauch). Trev. ; **B. leptomitiformis* (Menegh), Trev. ; **Chromatium okenii* (Ehr.), Perty ; **Hillhousia mirabilis,* G. S. West ; and var. **palustris ;* **Clonothrix fusca,* Roze.

Eumycetes.

Fusarium aurantiacum, Sacc. ; **Sporotrichum lanatum,* Wallr. ; **Mucor circinelloides,* V. Tiegh ; **Acremonium spicatum,* Bon. ; *Dematium pullulaus* de B. ; **Aspergillus fumigatus,* Trev. ; *A. niger,* V. Tiegh ; *A. grisues,* Lk. ; *Sachsia suaveolens,* Lind. ; *Thamniduim vulgaris,* Fr.

Considerable difficulty is experienced in the identification of these fungi because the nature of their habitat usually precludes fructification. Recourse must therefore be had to (*a*) subcultures, and (*b*) recognition by purely vegetative characters. Subcultures are very liable to contamination from bacteria, spores, etc., and growth in artificial media is often disappointing. Vegetative forms on the other hand are less characteristic, but more readily observed and are free from many of the serious disadvantages of cultivation methods.

Considering the difficulty of direct identification of such material, the accuracy of many of the previous records is open to grave suspicion. Even the Royal Commission on Sewage Disposal has not given much assistance in this respect, and in the Eighth Report (Vol. II, Appendix) the oft-repeated remark that "grey algal growth" occurs in various streams, possibly suggests hazy ideas of the confines of algae and fungi.

Much therefore remains to be accomplished; apart from the direct economic aspect of this problem, the study of the phyto-zoological distribution in relation to food supply is one of vital interest to all biologists.

In connection with this paper, I desire to express my thanks to Dr. H. Maclean Wilson for many kind suggestions and also for the use of blocks; to Prof. G. H. Carpenter, Dublin, Messrs. R. S. Bagnall, Walter E. Collinge, and J. W. Shoebotham for specimens and assistance in the identification of Collembola; to W. Falconer for the identification of spiders; to Miss A. Lorrain Smith, and Messrs. W. B. Grove and C. Crossland for assistance and suggestions with regard to the Eumycetes; also to Mr. P. H. Grimshaw for the identification of several dipterous insects. Thanks are also due to many surveyors, and managers of sewage works, and to the Staff of the West Riding Rivers Board for kind assistance in obtaining specimens for identification.

Summary.

1. The evolution of sewage treatment by means of land, chemical precipitation, tanks, contact beds, sprinkler filters, and, lastly, by mechanical aeration in the presence of "biologically active" mud.

2. The sewage problem is attributable to the increase in size and number of towns; the discharge of obnoxious trade wastes; these factors are further accentuated by the introduction of the water-carriage system of sewage disposal.

3. Organisms and their various functions in sewage purification.

4. Organisms and their relation to the pollution.

5. *Sphaerotilus natans* and *Zoogolea ramigera.*

6. Resumé of ecological factors and associations observed in filters and streams.

7. The Sewage- or Moth-Fly (*Psychoda*).

8. The Water Springtail "Podura" (*Achorutes viaticus,* Tulb.).

9. Other dominant or sub-dominant organisms.
   (a) *Colon bacillus* as an index of pollution: its presence and variable character in river waters.
   (b) Effect of acid on the colon-bacillus content of river water and development of *Oospora lactis* in such liquids.
   (c) Resistance of *Oospora* towards germicides.
   (d) Effect of small quantities of special substances on the flora and fauna of streams.
   (e) Notes on the occurrence of *Thiothrix nivea, Euglena, Chlamydomonas, Richteriella, Ulva* and *Prasiola.*
10. "Activated" sludge method of treating sewage.
11. Treatment of trade refuse on biological filters.
12. List of new or uncommon fungi isolated from polluted waters.

CORRECTIONS.

The following errors occurred in printing part 1 of this paper:—

Page 111, line 27, for Dupre *read* Dupré; line 29, for Höfer *read* Hofer; line 30, for Dibden *read* Dibdin.

Page 117, line 7, for Vaüch *read* Vauch.

Page 118, col. B., line 4, for rebissonii *read* brebissonii; line 5, for cryptosephala *read* cryptocephala; line 15, for Surrella *read* Surirella.

Page 119, col. B., line 13, for Carchsium *read* Carchesium; line 19, for vulgari *read* vulgaris.

Page 120, line 28, for Botrytococcus *read* Botryococcus.

Page 121, line 19, for Polysaprolic *read* Polysaprobic.

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NOTES ON *TELEPHORUS RUFUS*, L. AND ITS VARIETIES.

By OLGA G. M. PAYNE, M.Sc.,

Late Research Assistant, Department of Agricultural Entomology, University of Manchester.

(With Plate VII).

On account of their great variability in colouration, the Telephoridae present many difficulties to the systematist, and it is mainly with the view to establishing definitely one at least of the species of *Telephorus,* that this research work was undertaken. During the year 1911, several apparently similar *Telephorus* larvae were obtained from a field, near the Entomological Laboratory of the Manchester University, at Fallowfield. The adults bred out from these larvae varied, resembling both *T. darwinianus,* Shp., and *T. lituratus,* Fall., and it was found impossible to determine to which species the larvae belonged. It was therefore suggested that in the year 1912 as many as possible of these larvae should be reared, in order to find out if the adult differences were due to different types of larvae, or whether the above specimens were merely colour variations of one species.

In order to carry out these investigations, a number of Telephorid larvae were obtained from the locality mentioned. Before being placed in the breeding tins, they were carefully examined so that any differences (if present) might be noted. The larvae were found to differ considerably in size, but this seemed to be due rather to varying degrees of maturity than to actual specific differences.

Colour variations were also to be noted, some of the larvae being a much darker brown than others. There were, however, intermediate degrees of colour between these two extremes of light or dark. No structural differences were to be observed to coincide with those of colouration. In order to find out if the colour variations of the larvae in any way determined those of the adult, the colour of each larvae was carefully noted on the breeding tin. It was found later that there was absolutely no coincidence between larval and adult colour variations. The adults obtained on breeding out the larvae varied considerably in colour and also in size, the colour variations being much more marked than those of size. The chief colour variations to be noted were, a light form, a dark form, and an intermediate form between those.

Connecting up these three varieties were several transitionary forms, making almost a complete colour series. The presence of these transitionary forms is a strong argument in favour of the view that only one species is here being dealt with.

The beetles were forwarded to the British Museum, where Mr. Gahan kindly examined them and compared them with the specimens there. After careful examination he came to the conclusion that all the beetles reared belonged to a single species. Fig. 2 (Pl. vii) is a typical example of what is commonly known as *T. lituratus*. The light form represented in Fig. 1 Mr. Gahan considered as corresponding with the continental *T. rufus*, L.

In the *Catalogus Coleopterorum Europae* (1906) *T. lituratus*, Fall., is given as a variety of *T. rufus*, L. It is noteworthy that the Linnean name of *rufus* is older than Fallen's specific title of *lituratus*. The darker form, of which Fig. 3 is an example, Mr. Gahan considered as agreeing in colour with typical *T. darwinianus*, Sharp. He was not, however, sure that this dark form is to be considered identical with the species of Sharp (Trans. Ent. Soc. Lond., ser. 3, Vol. v, 1886, pp. 436-37), owing to differences in habitat and to certain differences in size and structure. In *T. darwinianus*, Sharp, the antennae are proportionately not quite so long, especially in the male, as in the dark variety of *T. lituratus*. The pronotum is relatively a little broader and the elytra shorter than in the latter species. This opinion was endorsed by Mr. Halbert, who was good enough to examine the beetles and compare them with those in the Dublin Museum.

The great variability of colour of *T. lituratus* is noted by Fowler, whose description is given below (Coleoptera of the British Isles, Vol. IV, 1890, pp. 138-39).

"*T. lituratus*, Fall. (*rufa*, L; *maculicollis*, Steph.); *bicolor*, Panz.). This species varies very much in colour; as a rule it is testaceous, with the vertex of the head, an irregular marking on the disc of the thorax, and the greater part of the abdomen and legs black; the antennae are more or less dusky with a lighter base; occasionally the thorax and legs are entirely testaceous, and rarely the elytra are black; head finely punctured, antennae varying in the sexes; thorax about as long as broad, obsoletely punctured, anterior angles rounded, posterior angles almost right angles; elytra finely sculptured, with distinct traces of raised lines; legs rather robust. L. 6½—9 mm."

"Male with antennae much longer than in the female, without impressed lines on the central joints, third joint about twice as long as second."

"Female with antennae shorter, third joint of antennae only slightly longer than second; elytra not covering apex of the abdomen; seventh ventral segment sinuate at each side, central lobe sharply incised at the apex. On Umbelliferae, etc., moderately common and generally distributed throughout England and Wales, and probably Ireland; very common in some parts of the Midlands; less common further North; Scotland, scarce, Tweed, Forth and Tay districts."

At the beginning of the above extract it will be seen that *T. rufus*, L., is here considered by Fowler as synonymous with *T. lituratus*, Fall., while as before noted continental authors consider *lituratus*, Fall., as a variety of *T. rufus*, L., the latter being the older name.

T. rufus can be distinguished from its variety *lituratus*, Fall., in the total absence of any dark marking on the head, thorax, tibiae, femora and the first joint of the antennae. The elytra are also not quite so dark as in the var. *lituratus*, and they are at the same time more rounded at the tips. The *darwinianus* variety appears to correspond with the "rare" form, in which the elytra are dark, in Fowler's description of *T. lituratus*. They can, however, hardly be considered as rare, as over thirty per cent. of the beetles obtained had blackish elytra.

In addition to mentioning the black form of *T. lituratus*, Fowler (p. 139) includes a definite species, *T. darwinianus*, Sharp. His description is given below.

"*T. darwinianus*, Sharp. This species, which was introduced by Dr. Sharp, is closely allied to *T. lituratus*, but may be known by its broader and stouter build, much shorter and stouter antennae, of which the third joint in both sexes is not much longer than the second; the thorax, moreover, is proportionately longer and the elytra proportionately shorter; the general colour is darker, the elytra being often of a more or less dark brownish-testaceous colour, especially towards the apex; it is possible that the species may be a form of *T. lituratus*, but it appears to be more distinct than others, which are regarded as quite separate. L. 8—10 mm.

"Found on the coast under seaweed, and not, apparently, on plants or herbage:—Scotland, local, Solway and Firth districts (Firth of Forth at Aberlady, etc.); Dr. Sharp has observed that some of the females have the elytra and antennae deformed (reminding one of the apterous forms in some of the neighbouring genera), and appears to be in great favour with the males; this fact and their peculiar habitat makes it seem possible that the beetle is a form of a neighbouring species, probably *T. lituratus*, which has been altered by its environment." Some additional localities are given in Fowler's supplementary volume (Vol. vi, 1913, p. 277).

The question now remains, is the dark form which was bred out to be considered identical with the species *T. darwinianus,* Sharp, or is it to be considered only as Fowler's dark variety approximating to *T. darwinianus?* In Fig. 3 it has been called var. *darwinianus.* If the darker specimens were found only under estuarine conditions it would seem highly probably that there is a very interesting example of the formation of a new species under the action of a different environment. The fact, however, remains that the darker forms are produced in fair numbers under inland conditions.

With regard to the slight structural difference it does not seem that very much importance can be attached to them, as throughout the var. *lituratus* there are small structural variations in each beetle. Only one instance of a deformed female has been observed.

Without further observation on estuarine species it is of course impossible to do more than doubt the validity of Sharp's species, though it seems very probable that this dark variety *darwinianus* of *T. rufus* and the *T. darwinianus* of Sharp are identical.

It may be that estuarine conditions, warmth and moisture tend to produce the dark colouration to the exclusion of the other types. In which case the presence of dark adults among inland forms could be explained by assuming that the larvae most susceptible to the variable conditions of heat and moisture in the soil tended to produce the darker adults.

Without further experimental work it is, however, impossible to assert more than the opinion that *T. lituratus,* Fall., and *T. darwinianus,* Sharp, are to be regarded as varieties of *T. rufus,* L. A dissection of the male genitalia might possibly shed welcome light on the question, as it has been recently proved of value in the allied genus *Chauliognathus.* Time and opportunity, however, have prevented any further work being prosecuted.

Dr. D. Sharp, Mr. C. J. Gahan, of the British Museum, Mr. J. N. Halbert, of the Dublin National Museum, and Mr. J. Ray Hardy, of the Manchester Museum, have been good enough to assist me in the identification of the species.

EXPLANATION OF PLATE VII.

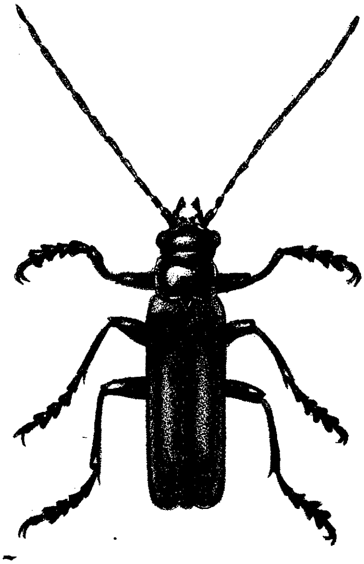
Illustrating Miss Olga G. M. Payne's paper on "*Telephorus rufus,* L., and its varieties."

Fig. 1. *Telephorus rufus,* L. ♂ × 4.

Fig. 2. *Telephorus rufus,* L. var. *lituratus,* Fall. ♂ × 4.

Fig. 3. *Telephorus rufus,* L. var. *darwinianus,* Sharp. ♂ × 4.

N.B.—The fore-legs in each figure have an unnatural extension which is not exhibited in living examples.



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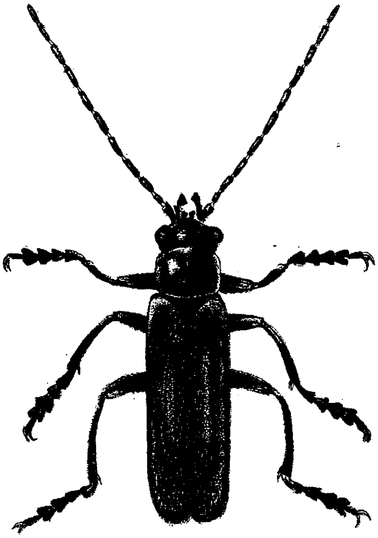

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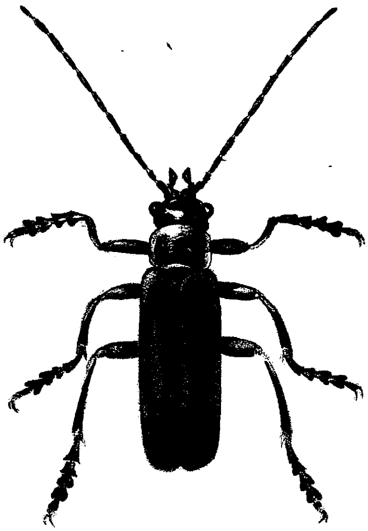

3.

Huth, London.

TELEPHORUS RUFUS, L. & its Varieties.

REVIEWS.

COCOA. By Dr. C. J. J. van Hall Pp. xvi + 515, and 140 figs. and map. London: Macmillan & Co., Ltd., 1914. Price 14s. net.

In this excellent series of works dealing with tropical agriculture, Dr. van Hall's treatise must rank as one of the best yet issued, for it not only presents an interesting and exhaustive account of all appertaining to the subject of cocoa, but it is also stamped with the hall-mark of a wide and practical knowledge of the subject.

After a brief historical account of the use and culture of the cocoa plant and its gradual spread from Mexico to other countries, the geographical distribution and climatic conditions relative to it are dealt with. Especially valuable are the chapters dealing with the chemistry of cocoa and cocoa soils, and the botanical characteristics of the cocoa plant, as also that on the varieties of cocoa. Two chapters are devoted to the technical side of cocoa cultivation, which may be read with profit by all concerned with the subject, they are replete with sound and practical advice, nothing seems to have been overlooked that would in any way prove useful to the planter.

A very useful summary is given of our present state of knowledge of the diseases and enemies of cocoa, and a really comprehensive survey on cocoa-growing countries, if for no other reason, this last feature is sufficient to make the book invaluable.

Dr. van Hall's work forms an excellent compendium on an all-important subject, containing as it does a large amount of very practical matter, the outcome of long experience and study, and a considerable quantity of statistical matter of the highest importance.

THE COCO-NUT. By E. B. Copeland. Pp. xiv + 212, 23 figs. London: Macmillan & Co., Ltd., 1914. Price 10s. net.

Professor Copeland's work, whilst dealing mainly with the coconut industry of the Philippines, will be read with interest and profit by all connected with the industry. "The behaviour of the coco-nut is intelligible," we are told, "in the light of the knowledge of its physiology, and surely in no other way"; in spite of this statement, however, the present work contains only a very short chapter of eighteen pages on the subject.

The two most important chapters, in our opinion, are those dealing with diseases and pests, and field culture, both are very complete, and contain an amount of information not to be found in any similar work. In the author's opinion, coco-nut raising is profitable, and its future is safe, no other business seems to him quite so certain as this one to continue for a term of decades to pay large profits at all times. For this desirable end it is essential that the planter should be up-to-date in all concerned with this industry, and there is much in the work before us that will prove of great value to the intelligent grower. Science with practice is evidently the author's rule, and the business side of his subject is kept prominently in the fore. He has had ample personal experience to warrant him in expressing positive opinions on many debatable matters which make his work a distinct acquisition to the literature on the subject.

IMPURITIES OF AGRICULTURAL SEED. By S. T. Parkinson and G. Smith. Pp. 105 and 153 figs. London: Headley Bros., 1914. Price 3s. net.

The scope and aim of this little handbook are excellent, as also most of the illustrations. The subject matter of the first forty pages might very well have been fuller, nevertheless they have been written with care and lucidity.

With the aid of this work and a good magnifying glass, the intelligent grower will be able to examine his seed samples with profit.

It is a pity that for so many species of plants obsolete names are used, and that specific names are spelt with capital letters.

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

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