OBSERVATIONS ON THE LARVAL AND PUPAL STAGES OF *AGRIOTES OBSCURUS*, LINNAEUS.

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(With Plates XVI and XVII and 1 Text-figure.)

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1. HISTORICAL.

ALTHOUGH the larval stage of *Agriotes obscurus* has undoubtedly been of economic importance for a long period, yet there does not appear to have been a good description of it until Westwood published a brief account in 1839. Marsham in 1808⁽¹²⁾ had figured a larva which he considered to be a stage of *Elater segetis* (= *Agriotes lineatus*), but the figure is too indefinite for accurate determination. Furthermore, he says he was unable to breed out the perfect insect, and was relying on Bierkander for his information.

Westwood⁽¹⁸⁾, however, describes the larva of *Agriotes obscurus* and figures the antenna, the under side of the head and prothoracic segments,

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and the first maxillae and labium; his figures are too small to be of much utility. He further notes that the larva had been figured previously by De Geer and Bierkander; but points out inaccuracies in the figures of these authors, that seem to indicate faulty identification.

Chapuis and Candèze in their work published in 1855⁽³⁾ do not describe the larva, but merely quote references to the writings of Marsham and Westwood. In 1860, Curtis published in his work on *Farm Insects*, an account of Elateridae of importance to agriculture; he did not describe the larva of *Agriotes obscurus*, and considered the larva of *A. lineatus* to be the common and important species.

Schiodte⁽¹⁶⁾ defined larval characters of the genus *Agriotes* in 1869, and described those of *A. lineatus*. He figured the left mandible, as well as the eighth and ninth abdominal segments. No mention is made of *A. obscurus*. Perris in 1878⁽¹⁴⁾ described many larvae of Elateridae; but he merely quotes references to Marsham⁽¹²⁾ and Westwood⁽¹⁸⁾, and does not add any description of *A. obscurus*. Beling⁽²⁾, in a full account of the metamorphoses of Elateridae, published in 1883—4, describes the larva of *Agriotes lineatus* very completely, and states that he could only detect slight differences between the larvae of *A. lineatus* and *A. obscurus*. Finally, the subject is brought up to date by Xamheu⁽²⁰⁾ in 1912 and 1913 by his work on the life histories of Elateridae. He adds little to our knowledge of *Agriotes obscurus*, merely referring to Beling (*op. cit.*) and adding a few descriptive remarks. It has been somewhat difficult to trace literature definitely referring to *Agriotes obscurus*, owing to the long established custom of terming Elaterid larvae under the collective title of "wireworms," without reference to any definite species. This, together with a number of cases of inaccurate identification in the older literature, has often rendered the information of doubtful specific value.

2. MATERIAL AND METHODS.

The idea of studying the life history of certain Elateridae, whose larvae are known as "wireworms," was first suggested to me by Dr Imms, to whom my thanks are also due for advice given from time to time. The first problem requiring solution, was the determination of the exact species of which the common wireworm forms the larval stage. With this intention, the material was purposely obtained from as wide a range of localities, and under as different conditions (of soil, crop, etc.), as possible. The area covered was mainly in Cheshire and around

Manchester, while a fair number of specimens were taken in various districts of Mid-Lancashire and North Staffordshire. Wireworms were taken in soils growing a variety of crops, but the most abundant and sure source of specimens was found to be the potato crop; a visit to a potato field rarely proving a disappointment. Pastures, especially those that had been down for a long period, proved a good source for material. They were, however, only utilised until sufficient observations had been made, owing to the lengthy examination required and the uncertainty of results. The material when collected was put into fairly deep tin boxes, loosely packed with damp soil. The larvae were examined individually under a binocular microscope in the laboratory, being measured and roughly classified into sizes. They were placed, after examination, in plant pots previously prepared. As this type of breeding cage proved to be useful, no trouble from disease having been experienced, some further details may be of interest. The drainage hole of the plant pot was covered with a circular piece of fine wire gauze strengthened by having a strip of zinc soldered round the edge. The gauze was roughly two-thirds the width of the pot; so, no matter how it slipped, the gauze would still cover the drainage aperture and prevent the escape of any larvae. The top of the flower pot was covered over by a perforated zinc plate, having a flange of about an inch in depth. The flange and the weight of the zinc were sufficient to keep the pot covered securely, even in the most boisterous weather. The vessel was filled first with small pieces of broken pots, and then with earth in the usual manner; a potato was placed about half way down in the soil to provide food for the larvae. The pots were buried out of doors in the ground, up to the level of the soil inside the pot. The larvae lived quite healthily in these pots, and no sign of disease was ever observed. For experiments requiring a greater depth of soil, two ordinary three-foot drainpipes were used; the narrow end being capped with cement, which was sloped inside to a central aperture covered by wire gauze imbedded in the cement. These drainpipes were very useful, but were too weighty to handle easily. They were handicapped by being buried in stiff clay soil, which prevented good drainage and rendered the drainpipes liable to become waterlogged. Buried in soil of a more open texture and better drainage capacity, they would be quite free from any disadvantage, save that of weight.

Throughout this work, the endeavour was to keep all the conditions as closely approximating to nature as possible.

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The greater part of the laboratory work has been carried out in the Department of Agricultural Entomology of Manchester and I am also much indebted to Professor Hickson for affording me various facilities. Acknowledgment has already been made to Dr Imms. I am also indebted to Mr J. T. Wadsworth for the photograph of the pupal cell with the pupa *in situ*. Mr J. C. F. Fryer of the Board of Agriculture has kindly given me information as to distribution, etc., of the common wireworms. The work has been carried out during my tenure of a Board of Agriculture studentship and completed during the following year.

3. NOTES ON THE BIOLOGY OF THE LARVA.

The larval stages of Elateridae are practically ubiquitous, occurring in all types of soil. The larvae of *Agriotes obscurus* have been found most commonly in the lighter types of soil, particularly loams rich in organic matter. The range of soils that they inhabit is extraordinarily varied, including the grades between fairly stiff clay to light loam. They are practically always to be found in pastures, even when on clay soils, though in such a case they are much less plentiful. In Cheshire and Lancashire the common wireworm is the larva of *A. obscurus*, as was demonstrated by breeding experiments. This seems to be corroborated by the fact that Newstead records adult *A. obscurus* (when in a state permitting of identification) far oftener than that of *A. lineatus*, as being the common species taken as food by wild birds over the same area. Very probably, *A. obscurus* is the common species in the north of England; while *A. lineatus* seems to be the most common species further south, though *A. obscurus* and *A. sputator* are not far behind in point of numbers. An interesting feature with regard to *A. obscurus* is, that the occurrence of its larvae seems to be, in some way, closely connected with the presence of organic matter in the soil. The larvae are most abundant in soils containing a large percentage of humus, due either to the peaty nature of the soil, or to heavy manuring. The same thing was found in cottage gardens, which are usually very rich in organic matter. This point will be considered later in connection with the feeding habits.

The larvae of *A. obscurus* were found in what may be roughly described as three stages. These stages were, of course, not sharply defined, but merged into one another. They may be given approximately:

Small stage (1) 7 mm. long by 0.75 mm. broad.

Medium stage (2) 10—15 mm. long by 1.0—1.25 mm. broad.

Large stage (3) 17—23 mm. long by 1.5—2.0 mm. broad.

It should be stated that no living specimen was ever found to be more than 21 mm. long, and that 19 mm. is about the average length, taking a number of specimens into consideration. The 23 mm. specimen was an extended spirit example. After about a year, the small stage was no longer present, and only medium and large stages could be found in the plant pots. According to most authorities the larval period is supposed to last five years. From observations on the length and rate of growth, I am inclined to place the period at four years rather than five. The small stages, taken in one year from July to October, varied much in size. It was found, after a couple of months (November—December), that a number of these apparently small specimens were really of medium size. It appears from this that the breadth is a safer criterion than the length (which is difficult to ascertain on the living larva). Judging from the size of specimens taken from July to October, and also from the fact that the adult beetles are common from April to June, it may be assumed that the newly hatched larva commences its free existence in July. Again, there are three larval moults, performed in the usual manner, by splitting the chitinous skin along the thorax, and leaving the old exo-skeleton behind. From these facts, and from the rate of growth, it may be assumed that the larva is full grown in three years. Full size larvae are found actively feeding up to October; but these same larvae apparently do not feed again (at any rate on vegetation), and pupate the next summer. It is thus probable that there are three stages limited by the three moults, and occupying three years. Then there is a period of active feeding, followed by a quiescent condition terminating in pupation, all this taking place in a year. It was found that of the large larvae (17 to 23 mm.) a number fed through the winter, while some were not feeding after October, and were not lethargic; these latter were broader than were the former. This would appear to support the above theory. If the life of the larva is one of five years, then it would seem that the early (small) larval stages would continue over a longer period; this is not confirmed by observations. The rate of growth was found to be of such a uniform character as to suggest that the curve of growth is fairly continuous rather than irregular. It seems to the author that the period of growth is not five years, a period given since Bierkander, but probably requires four years from the egg to pupation. The early (small) stage larvae were never found feeding. It is stated that they

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feed on organic matter in the soil. The medium and large stages were almost invariably observed feeding (with the exception mentioned above in the case of the larger stage), and it seems that they feed continuously, save in the months of December to February inclusive. This observation was obtained from regular examination of potatoes placed in the breeding pots. Feeding is usually active by March and seems to decrease at the end of November. It is very difficult to starve these wireworms. Of 10 large wireworms placed in sifted soil without food November 3rd, 1914, nine were present January 22nd, 1915, and seven on March 8th, 1915. The three missing ones had probably been eaten by the others, as traces of the skins were found. These seven larvae had thus existed in soil free from any vegetable matter visible to the naked eye for 125 days; of the seven larvae only one remained on May 4th, 1915. In a duplicate experiment under similar conditions, 10 larvae lived from November 3rd, 1914, to February 11th, 1915, i.e. 100 days. The larvae will tolerate a large amount of moisture, and will exist for at least a week in water-logged soil. On the other hand, wireworms kept in soil not supplied with water and allowed to dry up will die after a couple of days. It is hard to explain their independence of vegetable growth (such as pasture grasses and various crops) for food, in any other way than by assuming that they feed on the organic matter in the soil. This would help to explain the usual occurrence of these larvae in the lighter soils plentifully supplied with organic matter. In several cases, small and medium sized larvae were found buried in the farmyard manure under growing potatoes. It could not be said definitely that the larvae were feeding, but the condition of the mouth parts seemed to indicate that they were.

The usual depth at which these wireworms are found in the soil varies from one inch in pasture, to eight or nine inches in potato fields. In winter they bury themselves much deeper, and were found as much as two feet deep in the large drainpipes previously described.

The larvae bury themselves in soil surprisingly quickly, though their rate of progress on the surface is comparatively slow.

Eighty-three larvae had buried themselves at least two inches deep in soil, of about the same consistency of that in a potato field, in less than twenty minutes. On being exposed to light, they immediately travel in the opposite direction to the source of the light. They travel slowly, but fairly easily on an unpolished surface, and often progress carrying the abdomen bent in a slight curve to one side. This is one of the difficulties that hinder accurate longitudinal measurement.

4. DESCRIPTION OF THE LARVA.

The full-grown larvae of *A. obscurus* measure about 19 mm. $\times$ 2 mm. (Plate XVI, figs. 1 and 2). They are semi-cylindrical and their colour varies from pale yellowish white, to yellow brown. The young stages are of a paler colour, which darkens as the larvae become older. The freshly-moulted larvae are easily distinguishable by their pale yellow white colour. The junctions of the body segments are of a slightly darker shade than the rest of the body, and are in addition marked with faint longitudinal striae (Plate XVII, fig. 6). The spiracles are placed on darker chitinated areas. The muscular impressions of the ninth abdominal segment are strongly chitinated dorsally and ventrally, and slightly so laterally. The legs are of a darker brown colour.

The head is approximately as broad as long, with the anterior margin of a dark brown, rounded at the angles. On each side of the head, just behind the antennae, but slightly more towards the median line, is a slightly raised, irregularly rounded, pigmented eyespot. Immediately behind each eyespot is a long slender seta. The antennae are short (Plate XVII, fig. 10), each consisting of three segments. The first segment is stout, brownish round the base, with a clear area round the summit. The second is dark brown, longer in proportion to its breadth, narrower than the preceding segment, and somewhat enlarged on its outer and upper margin where it bears two stiff upright hairs. The third segment is dark brown, about one half the dimensions of the second segment, and bears two terminal lobes which are slightly lighter in colour than the second segment. The lobes of the third segment, when seen from above, consist of a long narrow lobe (almost as long as the second segment) flattened at the apex, and a smaller lobe placed ventrally to the larger lobe and nearly half as long as, and a little thicker than, the latter. The third segment bears, in addition, two setae. The head region bears two pairs of setae on the lateral margin, placed near the anterior and posterior edges. No attempt is made to discuss the homologies of the head region.

The mandibles (Plate XVII, fig. 7) are of a dark brown colour, irregularly flattened dorso-ventrally, and sickle shaped. The apex is somewhat blunt, and just below this is a blunt tooth on the inner margin. This blunt tooth is common to the genus *Agriotes* according to Schiodte(16). A second tooth that is more pointed than the former, projects nearly half way down. Just below, is a well-marked process (*la*) projecting inwards which is the "lacinia mobilis." Mangan(11) in describing the

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mandibles of *Periplaneta australasiae*, quotes Hansen (*Ann. Mag. Nat. Hist.*, 6, vol. XII, 1893), as recording the "lacinia mobilis" as occurring in certain Coleoptera. The mandible articulates with the head, by means of the condyle (*co*) and the ginglymus (*gi*).

The first maxillae (Plate XVII, fig. 8) are strongly chitinised around their outer margin, and are of a uniformly brown colour. They possess a distinct cardo (*ca*) into which the chitinised margin continues, swelling into a small dark area. There is no definite distinction between the stipes (*st*) and the terminal lobe of the maxilla. The stipes bears, on its outer margin, two long thick setae and three shorter ones, all close together, and placed rather more than half way up. The maxillary palp (*mp*) consists of four joints, of which the first is broad in comparison with its length, the second nearly as broad but longer, the third narrower and shorter; all three segments are brown, darker at the edges, with clear areas at their summits. Of the three segments, each bears setae; the first, two irregularly placed; the second, two at the summit and two on the outer margin; the third, two on the summit. The fourth segment is short, rounded terminally, and of a light brown colour. A galea (*ga*) and lacinia (*la*) are present in each first maxilla. The galea is short, and composed of two joints; both being about as long as the first two segments of the maxillary palp. The terminal segment bears four short, slightly-twisted setae. The lacinia is not plainly differentiated from the galea, and bears a large number of closely-packed, slender, waving setae.

The labium (Plate XVII, fig. 9) consists of the basal mentum, which is brown, and slightly chitinised at the lateral margins. It bears, at the margin on each side towards the base, a long curved seta, and another on each side towards the apex of the labium.

The mentum articulates with the palpiger, which bears a two-jointed palp on each side. The palpiger is shield-shape, and of a dark brown colour, darker at the sides, and lighter in the median area, and with a clear space across the anterior margin. It bears two long setae placed anteriorly. The first joint of the labial palp swells out towards its extremity, and bears a whorl of small setae, commencing about half way up from the inside, and progressing outwards and upwards. The second joint of the labial palp is rounded, and appears to possess a flattened, pale area at the tip.

Between the two labial palpi is the ligula (*li*) which bears a short seta on each side. The further setae, much smaller than the previous two, are placed at the base of the ligula.

On the underside of the head, adjacent to the first maxillae, is a dark, strongly-chitinated ridge, diverging anteriorly and converging posteriorly. A dark line runs parallel, close to the preceding ridge.

The prothorax has a curved furrow running down each side, and is nearly equal in length to the meso- and meta-thorax taken together. The hairs on the body of the larva are arranged in a definite manner, which seems to be fairly constant. The first eight abdominal sterna each possess three pairs of hairs, arranged symmetrically along the margins of these sterna. On examining the larva in its lateral aspect, it is seen that the first eight abdominal terga, considered up to their mid-dorsal line, possess two lateral pairs of hairs; of which the posterior pair is placed near the margin, a little to the left of the plane of the anterior pairs, which are placed nearer to their margin than the former. Placed mid-laterally, and just over each spiracle (of the first eight abdominal segments), is a pair of short hairs about half the length of the other hairs. In a line with the spiracle and in the same plane as the two posterior hairs, is a single hair of similar length to the paired ones. The ninth abdominal segment bears, on the base of the pseudopodium (or anal papilla), two pairs of short hairs. There are nine pairs of spiracles, the first being thoracic (Plate XVI, fig. 2, *st*), and placed ventrally. The remaining eight pairs are laterally placed on the first eight abdominal segments anteriorly in each segment. The ninth abdominal segment affords a means of distinguishing the genus *Agriotes*; Perris⁽¹⁴⁾ describes the typical anal segment of the genus as follows: "Dernier segment assez-longuement demi-ellipsoïdal, terminé par une pointe, ayant de chaque côté, près de la base, une cavité de l'apparence d'un grand stigmaté."

This applies truly to the larva of *Agriotes obscurus*, but requires to be added to. The anal segment is terminated by a slight constriction, which swells out into a blunt point, outlined in black (Plate XVII, figs. 5 and 6). The cavity, that Perris describes as being like a large stigma, is not a respiratory opening, but is possibly a muscle attachment¹. The walls of the cavity are black, and thickened; only slightly at the sides, but strongly dorsally and ventrally. In shape it is oblong, with the anterior and posterior walls rounded. It is placed very high up, and near the base of the segment. The stigmata are oblong, with their dorsal and ventral walls closely apposed, and strongly chitinated; their median line points forward and upwards, save in the case of the meso-thoracic stigmata, where the median line points forward and

¹ Henriksen (8) also speaks of this structure as an "eye-shaped muscular impression."

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outward. The ninth abdominal segment is equal to the length of the seventh and eighth segments combined, and possesses a ventral papilla or pseudopodium. This, according to Sharp(17), "represents a body segment and is generally described as being the protruded termination of the alimentary canal." The pseudopodium is round, sloping gradually to meet the eighth segment, and with a sudden slope posteriorly to meet the remainder of its segment. The apex is white and flattened and bears a few short hairs. The pseudopodium is of some assistance to the larva in walking. The three pairs of legs are provided with spines and are dark brown, short and terminating in a curved claw. The legs do not require any special description; the right leg of the third pair is figured in Plate XVII, fig. 11.

5. DESCRIPTION OF THE PUPA.

Before proceeding to describe the pupa, some details will be given with regard to pupation, etc. The first pupa was found on Aug. 14, 1915, pupation had therefore occurred within seven days, as the last previous examination had taken place on Aug. 7, 1915. At the previous examination it was observed that several larvae were very sluggish, and subsequent events showed that they were preparing for pupation. The first adult *Agriotes obscurus* was observed in a freshly emerged condition on Aug. 30, 1915. This would place the pupal period at from two to three weeks. Observations on other pupae show that this period is correct. Pupae were found up to the end of September, and all the adults had emerged by the 9th of October. Pupation takes place in an earthen cell at a depth in the soil varying from three to twelve inches. The pupal cell is oval and allows ample space for pupation. The average dimensions of three cells was 5 by 14 by 7 or 8 mm. The photograph (Fig. 1) shows a section through a typical pupal cell, with the pupa lying in a characteristic position.

The internal walls of the pupal cell are smooth, and appear to have been slightly cemented together with some glutinous secretion. The cell will stand air-drying without crumbling away, to a greater extent than an artificial cell made of similar soil but not cemented. The method by which the data concerning the pupal cell were obtained is as follows:—the plant pot, taken into the laboratory and the zinc cover removed, was filled level to the top with soil of a known depth, the soil being slightly compressed to produce cohesion. A piece of stout cardboard was placed firmly over the top and the pot then inverted so

as to stand upside down on the cardboard. The cardboard was gently removed, and the soil in the pot loosened by pressing slightly through the drainage aperture. The pot was then lifted up with a twisting movement; a cast of the interior of the pot was left. This cast could easily be examined with regard to the depth of any specimens in the pot, as the depth of soil added just previous to examination was known. With this method, pupal cells in perfect condition were obtained without trouble. The pupa (Plate XVI, figs. 3 and 4)

Fig. 1. Pupa of *Agriotes obscurus* in earthen cell. $\times 2$. (Phot. J. T. W.)

measures up to 13 mm. long by 3 mm. broad, gradually tapering in the abdomen to a breadth of 1 mm. The general colour is white, speckled on the apices of the abdominal segments with small patches of rusty brown colour. The thorax is nearly as broad as long, and swollen. Two spines project from the anterior angle of the thorax, which is provided at the posterior margin, on each side of the middle line, with a small protuberance. The long, spatulate, posterior corners are each provided with a curved thorn-like structure, of a brown colour and pointing outwards. The third to the sixth abdominal segments are

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slightly tooth-shaped at their lateral posterior margins. There are nine abdominal segments, of which the ninth is provided with two spines. Each spine possesses a small spur at the base. According to Curtis(6), these spines are movable. The ninth abdominal segment is provided ventrally with a flap, broad at the base, suddenly narrowing half way down the segment, and continuing in a smaller piece with parallel sides, which terminates in two sharp points. Beling(2) describes the pupa of *Agriotes obscurus* in a similar manner to the above, and adds that the segments of the antennae are as long as broad, that the wing cases reach to the middle of the fourth abdominal segment, and that the third pair of legs reach to the middle of the fifth abdominal segment. In the pupa described above, the third pair of legs only just reach on the fifth abdominal segment, and do not stretch half way.

6. COMPARISON WITH LARVAE OF CLOSELY ALLIED SPECIES.

The evidence showing that the common wireworms taken by the author in Cheshire and other districts are larvae of *A. obscurus* is as follows:—

All the larvae were examined under a binocular microscope, and were apparently all similar. At this time I was inclined to believe that the common wireworm represented the larval stage of *Agriotes lineatus*. A comparison of my material with Schiodte's figure of the anal segments of *lineatus*(16) did not solve the problem. The larvae undoubtedly belong to the genus *Agriotes*, and agree in general with the figure of *lineatus* given by Schiodte, but differ as to certain details.

Seven larvae at last pupated and the six adults that emerged were *Agriotes obscurus*. This seems to be corroborated by the interesting observations of Newstead (previously mentioned), where the area covered was mainly Cheshire, and part of Lancashire, and the records of adult Elaters devoured by birds give *A. obscurus* far more commonly than *A. lineatus*. As the occurrence of wireworms is admittedly universal, at any rate in this country, and as their attacks are not epidemic, these facts seem to point to *A. obscurus* as being the parent beetle of the larva in question. The identification of the larva provides the next problem.

The author has been unable to procure an undoubted specimen of the larva of *A. lineatus* for comparison, so reference was made to the literature. It was found that there is a scarcity of good accounts of the larvae belonging to the genus *Agriotes*. Some of the older accounts were

incomplete or even wrong, as Perris⁽¹⁴⁾ quotes Bouché (*Naturg.* p. 186), as describing a larva of an *Athous* or *Corymbites* as *A. lineatus*. The best accounts of Elaterid larvae were found in Perris⁽¹⁴⁾, Schiodte⁽¹⁶⁾, and Beling⁽²⁾, from which sources the comparisons are procured. The distinction between the genus *Agriotes* and that of *Elater* seems fairly clear. The possession of a blunt tooth, on the internal margin of the mandible (Plate XVII, fig. 7), indicates the genus *Agriotes* according to Schiodte, while Beling gives the presence of the chitinous cavity on the base of the ninth abdominal segment as indicating the genus. Beling describes *A. lineatus* and *A. obscurus*, as follows:

(1) Larve, sehr fein und seicht punktirt, fast glatt, blass braunlich gelb. In erde, vorzugsweise auf Aeckern....*Agriotes lineatus*.

(2) Larve unregelmässig seicht gerunzelt, starker und dichter punktirt, auch etwas dunkler als die vorhergehende gefärbt, mit derselben angleichenorten lebend....*Agriotes obscurus*.

Beling further says that the larva of *Agriotes ustulatus* Schall. is similar, but is smaller. He adds that the larva of *A. obscurus* seems more strongly and thickly hairy (punktirt) and wrinkled than *lineatus*; but characteristic differences remain to be found. His description of the *lineatus* larva would apply equally well to that of *A. obscurus*.

The position of the muscle attachments on the anal segment seemed to hold out a hope of identification, as the one illustrated by Schiodte differed in position from those observed by the author. This is unfortunately of little account, as the method of preserving the larva affects the position. If the larva is simply killed by being immersed in alcohol, it usually contracts, and the wrinkling of the skin and the position of the muscle attachment, shown in Schiodte, are obtained. Boiling the larva, and then passing it through different strengths of alcohol, preserve it naturally. Neither the muscle attachment placed so closely to the base, nor the wrinkled skin as figured by Schiodte, is ever seen in living or properly preserved specimens. There is a difference, however, between the pseudopodia. Schiodte figures the pseudopodium proper (as distinct from its base), as exhibiting three divisions, the third probably pertaining to the non-chitinous and fleshy tip. In the larvae examined by the author, there were never more than two (including the fleshy tip). As there is no reason to suppose Schiodte's figure is incorrect, this difference of the pseudopodium must be taken as specific. The mandible figured above (Plate XVII, fig. 7) differs from that of Schiodte.

A number of mandibles (both left and right) were examined and

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were found to agree substantially with the figure given. Schiodte, however, figures the blunt tooth near the apex of the mandible as very slight, while the author's figure shows it to be more pronounced.

Furthermore, the position of the spiracle and hairs on the eighth abdominal segment, as represented by Schiodte, does not agree with the condition observed by me in the larvae of *A. obscurus*. These differences are constant in the specimens examined during this work¹. The only other description to which I have had access is that of the larva of *Agriotes pallidulus* Ill. by Schiodte. The dimensions of this larva, 9 mm. long by 1 mm. thick, and its intense yellow colour, together with its anal segment, which is rounder than those of *A. obscurus* or *lineatus*, prevent confusion with either the larvae of *A. lineatus* or *A. obscurus*.

It would seem, that if the above differences between the larvae of *A. lineatus* and *A. obscurus* do not apply generally, then one is possibly a variety of the other, as it was formerly believed (Curtis, *loc. cit.*, p. 159).

7. NATURAL ENEMIES.

It would be natural to assume that the wireworms, on account of their underground existence, are fairly immune from enemies that prey upon them. In spite of this, they are subject to the attack of a number of persistent foes; particularly various species of wild birds. Wild birds are accountable for the destruction of vast numbers of insect larvae. This is especially so during the nesting season, as "practically all birds except doves and pigeons feed their young on an animal diet, whatever may be the character of the food of the adult"(9). Again, as Collinge remarks—"It should be remembered that the nestling season is also that when the destruction of injurious insects is most needed—i.e., at the period of greatest agricultural activity and before the parasitic insects can be depended upon to reduce the pests"(4 and 5). At present, definite information as to the food of nestling birds is somewhat scanty; but according to Collinge, the

¹ Owing to Mr Ford's departure to Rome he was unable to consult Henriksen's paper (8) before he left England. The Danish entomologist mentions that the larva of *A. lineatus* is "brownish yellow, faintly rugose and punctulate, mostly rugose." With regard to that of *A. obscurus* he adds "dark brownish yellow. On each side, between tergum and sternum a pale longitudinal stripe. Punctulate and with few rugae." I may add that the longitudinal stripe is not evident in any of Mr Ford's specimens. Henriksen does not appear to have reared any examples of *A. obscurus* from the larva to the adult.
A. D. Imms.

Starling, Thrush, and Blackbird seem to feed Elaterid larvae to their nestlings as usual constituents of their diet. To quote one example—that of the Starling (Collinge, *loc. cit.*)—the food taken to one nest throughout an averaged period of half a day, required 146 visits and included 13 wireworms (species not stated); this was in the middle of May. It is probable that a large number of Elaterid larvae (as well as other pests) are thus disposed of during the nestling season. With regard to the food of adult birds more information is available, and it is possible to give a rough list of birds that are of importance as destroyers of Elaterid larvae, for “the frequent occurrence of these insects, and especially of the parent beetle, is very marked and goes a long way to prove that they form part of the regular food supply of various species of birds” (13).

The most useful in this respect are Plovers (or Lapwings), Gulls, Rooks, Jackdaws and Starlings, all devouring both adult and larval stages of Elateridae. In districts in proximity to the sea, Gulls are very beneficial—they are usually present where land is being ploughed; and they follow the plough, in numbers, searching for insects that are turned up. In one instance (Newstead, *loc. cit.*), forty-five *Agriotes* larvae were found in the crop of a Black-headed Gull (*Larus ridibundus*). Over the country generally, the Plover (or Lapwing) is one of the most beneficial birds to the farmer—in spring, its habitation is usually ploughed land. It undoubtedly destroys many injurious insects.

The Rook is not quite so wholly depraved as it is thought; for though it certainly takes a fair amount of seed corn, yet wireworms form about 9 per cent. of its food (Leigh⁽¹⁰⁾), and the young are fed on Elaterid larvae (Newstead, *loc. cit.*). Jackdaws and Starlings, both as nestlings and adults, feed on both larvae and imagines of Elateridae.

Curtis⁽⁶⁾ states that the Sparrow preys on wireworms, but, up to the present, there is apparently no evidence available that might mitigate the uselessness of this ever-present pest. The author has little definite information regarding the particular proportion of the food of birds formed by the larva of *Agriotes obscurus*.

Wireworms appear to form a fairly constant constituent of the food of the common Mole (*Talpa europaea*), in fact insect larvae and worms form the greater portion of its diet. In an investigation on the food of moles⁽¹⁹⁾ it was found that out of 100 moles, 41 of the stomachs contained wireworms. Though this investigation only extended over a short period (from Dec. 5, 1913, to Feb. 5, 1914), it yet serves to indicate

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the value of moles from the economic point of view. Digestion in the stomach of the mole is apparently very rapid, thus rendering identification of the stomach contents difficult. It is, at any rate, certain that the animal is a very voracious feeder as Scheffer⁽¹⁵⁾ found that *Scalops aquaticus*, a mole distributed over the eastern region of the United States, will consume more than its own weight of suitable food in a day. In the stomachs of nine moles which I examined it was found that three stomachs contained remains of Elaterid larvae (the remainder of the food was mainly various insect larvae, earthworms and slugs). It is interesting to note that in the districts where these nine moles were trapped, one farmer would not allow moles to be trapped, save when they were becoming too plentiful; on all the surrounding farms the moles were trapped regularly. The district has been examined for wireworms, and it was found that on the farm where the moles were protected, wireworms were very scarce, and then could only be found in small numbers in a very old pasture. On the surrounding farms, where moles were trapped, wireworms were taken in numbers. The animal is often a nuisance in grassland and cornfields, but it should be remembered that the mole is burrowing after food, and not for amusement. Again, as its food consists principally of insect larvae, and, as Adams⁽¹⁾ remarks, the mole does not hibernate, but continues active all the year round, it can well be seen how useful the animal is. These facts together with its voracity, and its need for meals at frequent intervals (Adams, *loc. cit.*), show the utility of the animal. It certainly destroys large numbers of wireworms, and should therefore be merely prevented from becoming too abundant. According to Graf⁽⁷⁾, an important enemy of adult Elaterids is to be found in the Carabidae, species of *Calosoma* being particularly important in the control of *Limonijs californicus* (sugar beet wireworm). Curtis (*loc. cit.*) mentions that the Carabs *Pterostichus madidus* and *Nebria brevicollis* are enemies of the wireworm. While collecting between 1914 and 1915, Carabid larvae and small adults (*Nebria*, sp.) were commonly found in potato drills, where wireworms were attacking the tubers. The adult Carabs most commonly found were *Pterostichus madidus* and *Nebria brevicollis*. It was found, as the result of carrying away two wireworms and a *Nebria brevicollis* in a tin box containing earth, that the Carab attacked the wireworms. On examination, after the day's work, the *Nebria* was alive, and the two wireworms dead and mutilated. Under natural conditions, no Carabs were seen attacking wireworms, though injured larvae were seen.

Wireworms with their tough highly chitinised skins, and underground habits, are almost free from internal parasites. Curtis(6), however, says that wireworms have a Hymenopterous parasite and quotes Bierkander as having found them. Forbes (18th Rept. State Ent. p. 47, 1891—2) records a parasitic fly as having been reared from a wireworm. Out of over 300 larvae collected, not one attacked by an internal parasite has been seen. Graf found the same result with 10,000 larvae of *Limonius californicus*. In this connection, I am informed by Mr Fryer that he has not infrequently found wireworms parasitised by what is probably a Proctotripid, at all events a Hymenopteron, but has never succeeded in breeding it out. No bacterial or fungoid disease was seen in any of the larvae in the field, or in the laboratory. In this connection, Graf reports as having occasionally observed fungoid attack in the field, but says that one fungus and two bacterial diseases were common under laboratory conditions. He also says that one bacterial disease was very fatal to the young wireworms, while the older stages seemed to be immune.

According to Leaflet number 10 of the Board of Agriculture (1916), wireworms are parasitised by a species of the fungus *Isaria*.

The pupae are difficult to rear; any disturbance or any slight variation in humidity or temperature, was sufficient to cause them to perish, and from the same causes some pupae passed into the perfect state but failed to mature. No disease of any kind was noticed. Graf notes that a few pupae of *Limonius californicus* were killed by a fungus.

Graf records a fungoid disease as having caused the death of adult Elaters under natural conditions.

Wireworms seem to be little affected by physical agencies under experimental conditions. They were found to be little affected by excess of moisture, but they could not resist dryness and were killed by frost. Under natural conditions it is probable that these factors are of no importance, as the larvae can always burrow down deeper in the soil, out of the way of frost, or in the search of greater humidity.

8. SUMMARY OF GENERAL CONCLUSIONS.

1. This paper contains an account of the larval and pupal stages of the Elater, *Agriotes obscurus*, whose larvae, together with certain other related larvae, are known as "wireworms."

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2. The common "wireworm" in Cheshire, North Staffordshire, and South Lancashire, is the larva of *Agriotes obscurus*.

3. The life of the larva is probably four, rather than five years.

4. The larva of *Agriotes obscurus* can be distinguished from that of *A. lineatus* by means of the development of the blunt tooth, just below the apex of the mandibles (more prominent in *A. obscurus*); by the orderly arrangement of the body hairs, and the more anterior position of the stigmata; and by the pseudopodium or anal papilla on the ninth abdominal segment of *A. lineatus* having three apical divisions, while that of *A. obscurus* only has two.

5. Birds, particularly the Plover (or Lapwing), are of great value in checking the larvae of *Agriotes obscurus* (as well as other related species). The Plover, which is wholly beneficial, should be stringently protected. The common Mole (*Talpa europaea*) is also of great value in checking the pests, and should not be wantonly destroyed, unless increasing in too large numbers. The amount of damage caused by a mole is probably very small in comparison with the amount of good it does.

6. The larva pupates in an earthen cell in the ground, down to one foot deep; the pupal period is about three weeks; the imago remains resting motionless in the pupal cell for roughly two months, after which it comes to the surface, and hibernates under stones, clods, etc., until the next season.

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DESCRIPTION OF PLATES.

PLATE XVI

FIGURE

1. Fully grown larva of *Agriotes obscurus*, lateral aspect, drawn from an extended spirit specimen. *ant.* antenna; *mu.* muscle attachment; *st.* spiracle; *ps.* pseudopodium. $\times 8$.
2. Mature larva, as above, ventral aspect. *ps.* pseudopodium; *st.* first spiracle. $\times 8$.
3. Pupa of *Agriotes obscurus*, ventral aspect. *ant.* antenna (left); *le.* elytron (left). $\times 8$.
4. Pupa of same, dorsal aspect. $\times 8$.

PLATE XVII

5. Lateral aspect of the ninth abdominal segment of the larva of *Agriotes obscurus*. *ps.* pseudopodium; *mu.* muscle attachment. $\times 24$.
6. Ventral aspect of the ninth abdominal segment of the same. *ps.* pseudopodium. $\times 24$.
7. Right mandible of the larva viewed from above. *gi.* ginglymus; *co.* condyle; *la.* lacinia mobilis. $\times 50$.
8. Right first maxilla of the same viewed from below. *ca.* cardo; *st.* stipes; *mp.* maxillary palp; *la.* lacinia; *ga.* galea. $\times 50$.
9. Labium of same, viewed from below. *m.* mentum; *pg.* palpiger; *lp.* labial palp; *li.* ligula. $\times 50$.
10. Right antenna, seen laterally. *dl.* dorsal lobe; *vl.* ventral lobe. $\times 100$.
11. Right leg of third pair of the larva. *co.* coxa; *tc.* trochanter; *f.* femur; *tb.* tibia; *ta.* tarsus; *cl.* claw. $\times 49$.