THE LIFE-HISTORY OF THE AUSTRALIAN MOTH-LACEWING, *ITHONE FUSCA*, NEWMAN (ORDER NEUROPTERA PLANIPENNIA).

By R. J. Tillyard, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), C.M.Z.S., F.L.S., F.E.S.,
Entomologist and Chief of the Biological Department, Cawthron Institute, Nelson, N.Z.

(Plates IV & V.)

In a previous publication (1919), I brought our knowledge of the Ithonidae up to date, so far as the perfect insects were concerned, and gave a short account of the work which had been done by Mr. Luke Gallard and myself in discovering the habitats and dates of appearance of the commonest species, *Ithone fusca*, Newman. This paper also recorded our success, in November 1918, in obtaining numbers of fertile eggs, larvae and pupae. I promised then to give a full account of the life-history in a later paper, and that promise is now being fulfilled.

The study of the life-history, begun in 1918, was continued in 1919 when I paid a visit to Jervis Bay from 8th to 22nd September, spending most of the time digging the sandy soil around the Naval College in a search for larvae and pupae. The result of eight days' digging, in which several members of the Naval College staff most cheerfully joined, was a total of 21 larvae in various stages of growth, and 15 cocoons containing larvae or newly-formed pupae. The same year Mr. Gallard continued his investigations at Woy Woy and Epping, finding a number of larvae in all stages of growth.

Nothing was done in 1920, as I was absent from Australia; but in October of last year I again visited Sydney, and a fortnight was spent on the same ground where the larvae were originally discovered in 1918. On this occasion there were with me, besides Mr. Gallard, M. André Tonnoir, the well-known Dipterist of Brussels, and Mr. A. J. Nicholson, the newly-appointed Lecturer in Entomology at Sydney University. During the fortnight 30th October to 12th November, a large number of adult *Ithone* were taken and paired in special cages, about 7,000 fertile eggs being obtained from them. Of these, about 5,000 were sent across to New Zealand, 1,000 to America, and nearly a thousand were fixed at various stages of development for future embryological studies. Digging was also carried out for the larvae, and a considerable number obtained, although it was too late in the season for most of them. The most successful day was 8th November, when, as a result of a few hours' digging round a single *Eucalyptus* tree by Mr. Nicholson and myself, no less than 57 larvae in different stages of growth were obtained, together with a representative collection of the various Coleopterous larvae found in the same soil, on which the *Ithone* larvae prey. A special study was also made of the habits of the imago, and their rapid destruction by hosts of enemies.

Before beginning the actual account of the life-history of this remarkable insect, it will be of interest to show how it came about that the larva was at last discovered after some years of fruitless endeavour. In September 1915, I discovered the species *Heterithone fulva*, Till., on Stradbroke Island, and noticed a number of them drowned in two large water-tanks. Coupling this with the close similarity of the insects to the Megaloptera, it appeared likely that the larva would be either aquatic or sub-aquatic. As a result, both Mr. Gallard and myself searched chiefly, during the following two years, in lagoons and moist places, without any success. In October 1917, Mr. Gallard was staying with his family in Mr. Hansford's cottage at Ocean Beach, near Woy Woy, when Mrs. Gallard discovered one evening a fine *Ithone fusca* sitting on a fence-post. The soil was sandy, with no fresh-water creek or lagoon within a mile or more. In a few days, Mr. Gallard had found about two dozen of the insects, mostly hiding in an outhouse near the cottage. We therefore concluded that it was likely that the larvae lived in the sandy soil; and we proceeded, during November and December of that year, to pay a series of visits to this locality, digging up the ground all round the cottage, and especially in the vicinity of the outhouse and around a number of trees near by. We found a number of rather large cocoons made of sand; but from these there emerged a very common Noctuid moth, whose caterpillars we also sometimes found at the bases of tree-trunks. The only other insects in the soil appeared to be various larvae of Diptera, Brachycera, some cocoons of Thynnid wasps, and a number of different species of Coleopterous larvae of the family SCARABAEIDAE. It never occurred to either of us that one of these apparently Scarabaeid larvae was in reality the unknown larva of *Ithone,* and we certainly dug up and threw aside quite a number of them, so set were our minds on finding a larva which would conform to the primitive Planipennian type, as exhibited by the PSYCHOPSIDAE or HEMEROBIIDAE. But in 1918, when we succeeded in pairing the adults, it was with the greatest astonishment that we saw emerging from the fertile eggs a number of tiny white melolonthoid grubs. On making an enlarged drawing of one of these under the camera lucida, it was at once seen that the larva of *Ithone* was a soft-bodied, burrowing insect, closely similar to a Scarabaeid larva in general appearance. We were then able to recall at once the particular grub which we had dug up time and again, and thrown away, but which, it now appeared, was in reality the prize we had been searching for.

From that time on, larvae were easily obtained, and we soon found that they could be distinguished from all the true Scarabaeid larvae, not only by their detailed structure, but especially by a very strong odour of citronella which they gave out, and which frequently arose from the soil while we were digging; when this odour was noticed we were sure to get a larva of *Ithone* in the next spadeful or two of soil.

A further pitfall awaited us through the chance happening that the first pupa discovered was lying free in the soil. Again, the similarity of *Ithone* to the Megaloptera occurred to my mind; and as the pupa was elongated, not curved round like those Planipennian pupae which are enclosed in cocoons, I took it as proof that the larva did not spin a cocoon, and said so in my previous paper (1919, p. 416). However, Mr. Gallard and myself almost simultaneously discovered, shortly afterwards, the cocoon of *Ithone* with the larva inside it, so that I was able to correct this mistake by a postscript in the same paper (p. 437).

The outline of the life-history was now complete, and it only remained to observe the larvae in captivity, study their feeding habits, their methods of burrowing and progression, the spinning of the cocoon, and the emergence of the imago from it. The discovery of the pupa free from the cocoon, in the soil, was explained when we found that the pupa cuts its way out of the cocoon by means of its huge mandibles, and travels some way in the soil before disclosing the imago.

I should like here to put on record the large share that Mr. Gallard deserves of the credit for the discovery and working out of this life-history. He has been most enthusiastic in the work, and has at all times taken upon himself the giant's share of the heavy labour of digging the soil, without which no larvae could have been obtained. My best thanks are due to him for the very great assistance he has given me. I also wish to thank Mr. W. C. Davies, Curator of the Cawthron Institute, for the excellent photographs which he has taken of the various stages of the life-history; these have been collected together and are reproduced on Plate iv. The text-figures have been prepared by myself, with the aid of an Abbé camera lucida.

The Life-Cycle of *Ithone fusca*.

The complete life-cycle of *Ithone fusca* appears generally to last exactly two years. When digging the soil during the first two weeks in November, which is the period during which the imagines are on the wing, we found plenty of larvae, but no pupae. Most of these larvae were from half- to three-quarters grown. As there is no record of a second brood, these larvae must last through a second summer, and would not become adults until the following November. Nevertheless, as with other Planipennia, it is probable that some, if food were abundant enough, might complete their life-cycle in one year, while others, when food is scarce owing to drought, may take three years to reach maturity.

The life-cycle is made up as follows, taking as an example an egg laid on 1st November :—

Stage.	*Dates.*	*Duration.*
Egg	.. 1st Nov.–2nd Dec.	.. 31 days (average).
Larva (five instars)	.. 2nd Dec.–14th Sept.	.. 1 year 9½ months (average).
Larva in cocoon	.. 14th Sept.–7th Oct.	.. About three weeks.
Pupa in cocoon	.. 7th Oct.–31st Oct.	.. About three weeks.
Imago	.. 31st Oct.–2nd Nov.	.. Two or three days.

The above are all given as average periods. The eggs may hatch a little sooner if the weather is very hot during the embryonic period, or they may be a little retarded if the weather becomes cold. The female imago usually pairs within an hour or two of emergence, and most of its eggs are laid the same night; she seldom lives more than two days. The male also seldom lives more than two or three days, though I have succeeded in keeping them alive for a week. They take no food in the natural state, though their mouth-parts are well developed.

No definite times can be given for the separate larval instars, as ecdysis depends entirely upon the amount of growth, and this in turn is dependent upon the amount of food taken. One or two good meals are enough to enable the larva to grow to its full size for any given instar, but many days may pass during which the larva is burrowing in the ground without finding any food at all. Consequently, in any given brood there are always some larvae which grow much faster than the rest, and there are also others which, finding no food at all, die at last from sheer exhaustion.

Emergence of the Imago.

The adult *Ithone fusca* emerges just about sundown during the fortnight from the end of October to the middle of November. The pupa discloses the imago while still in the soil; the imago crawls out with its wings still unexpanded, and makes for the nearest post or tree-trunk, up which it climbs to a height of from one to three feet. Its wings expand so rapidly that they are generally fully formed by the time the insect has come to rest. They are held outwards away from the body during expansion, and are then folded down in a somewhat flattened, roof-wise manner. It is very curious to be watching a clear patch of sandy soil and to see, quite suddenly, a slight falling in of the sand, so that a small pit is temporarily formed, from the middle of which there emerges an adult *Ithone*, scurrying off almost like a cockroach to find a suitable perch to rest and expand its wings.

As soon as the sun is set, the moth-lacewings begin to vibrate their wings very slightly but rapidly, and then take flight. The females, which are always much less in number than the males, fly rapidly like ghosts across the bracken and herbage, and settle upon some convenient tree-trunk. The males dash hither and thither exactly like Hepialid moths, and soon begin to assemble in swarms around the females. While on the tree-trunks they will often rush about and circle round and round, while at other times they will sit at short distances apart, rapidly vibrating their wings, ready to dash off again at a moment's notice.

Calm evenings or those with a light north-east wind were those which favoured the swarming of *Ithone*. On nights with a cold south or south-east wind, there was little or no emergence. Most of the insects selected the west or north-west side of the trees, this being the warmest and most sheltered. The largest swarm I noticed was on a trunk where three females had settled close together. Around these were swarming more than a hundred males. While bottling them and sweeping them into my net they ran all over me like cockroaches, getting down my neck and up the sleeves of my coat. A single female may have anything from four or five up to more than 50 males around her.

Pairing takes place very rapidly, the male sidling up to the female, and the latter raising her wings slightly on one side, so that the male may come closer. They then remain alongside one another, the male seizing the curved end of the female in his claspers. In captivity, the act of pairing sometimes lasted a considerable time, up to half an hour, but under natural conditions it appears to be much quicker, probably because of attacks from a multitude of enemies.

Enemies of *Ithone.*

On a favourable night, when *Ithone* may be expected to swarm, the whole of the life of the bush seems to be getting ready for the event. We could see huge spiders spinning their tough webs everywhere, in feverish haste; while battalions of ants of various kinds, especially Bulldogs (*Myrmecia*), Mound ants (*Iridomyrmex detectus*) and Greenheads (*Ectatomma*), began to swarm up the trees and take up expectant attitudes, waiting to pounce upon their victims. Huge Lycosid spiders, commonly called "triantelopes," came out from their lairs, also ready to pounce; and even frogs took up suitable positions at the bases of the tree-trunks.

Immediately the swarm begins *Ithone* falls a victim to its enemies in hundreds. Approaching my first tree, I saw four male *Ithone* struggling wildly, each in the grip of from eight to ten savage Greenheads, which had already bitten off most of their wings. On the next tree a male *Ithone* was struggling in the grip of a large spider; on returning later, I found that all except part of its wings had been devoured. A little further on, some Bulldog ants had seized a couple of victims; while in various places they could be seen struggling in the broad spiders' webs stretched from bush to bush. It was often a race between myself and these numerous enemies, to see who could secure the *Ithone* first. I should estimate that less than half of the swarm survives the first *mauvais quart d'heure.* In the early morning, the Thickhead and other birds are abroad hunting down the remainder, so that by 8 a.m. little of the previous night's swarm is left.

The actual flight of *Ithone* lasts under an hour, and it is necessary to search thoroughly for females while they are about, the males being so abundant that one could easily secure 50 or so without getting a single female. By the time darkness has set in the flight is finished, and from then onwards only occasional specimens are to be got, either resting on trees, running about on the ground, or sometimes coming to light.

Oviposition.

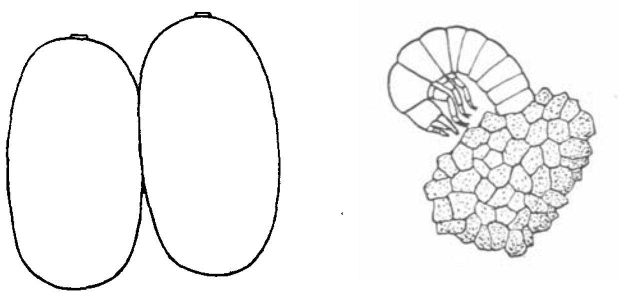
The female, when about to oviposit, runs about on the ground until she finds a suitable place where the soil is soft enough. She then proceeds to work her abdomen down into the soft soil, using all the time her peculiar sand-plough for digging it up, until her wings come to lie almost flat on the surface, and her legs sprawl out in front of her. In this position, she works her abdomen first vertically downwards and then somewhat forwards, so that its apex is from one-half to three-quarters of an inch below the surface. She now lays her eggs steadily, working hard all the time and rolling each egg separately in the sand, which adheres to its sticky surface so as to form a protective covering. In captivity large Mason jars were used, in which we placed an inch or more of sandy soil. Sometimes the females would work down to the glass bottom, and in such cases a number of the eggs would become glued to it, and could not be removed without damage.

The sand sticks so tightly to the egg that when I first tried fixing them in Bouin's fluid I was quite unable to remove it, even after weeks of immersion in the fixative. This difficulty was overcome last year by giving some of the females sugar, instead of sand, in which to oviposit. Eggs were laid freely in the sugar, but the latter did not stick to them. Owing to their white colour, they could not be easily seen. I therefore dissolved the sugar, spoonful by spoonful, in water, when the eggs would float up, and could be taken out by means of a brush and placed on strips of paper, to which they adhered slightly. A number of these were kept for a month, to see whether this treatment had caused any damage; but they all hatched out quite safely.

The number of eggs laid by a single female varies from about 200 to close on 300. From 2nd to 6th November 1918, I counted the eggs laid by one female each night. Each of these five females was exhausted after one night's work, and did not lay any more eggs the following day. The counts were 195, 206, 253, 242 and 289 respectively; the last female was exceptionally large. This gives a total of 1,185 eggs from five females, or an average of 237. Each female worked steadily for some hours, until quite exhausted; so that it would appear to take over one minute to lay each egg and roll it thoroughly in the sand.

The Egg (text-fig. 1).

The eggs are of a creamy white colour and somewhat soft consistency, in shape broadly oval with slightly flattened ends; length, 1·7 mm.; transverse diameter, 0·9 mm. The micropyle is situated at the anterior end, and consists of a minute slightly raised disc-like projection, as shown in text fig. 1*a*. The surface is quite smooth, without any sculpture whatever.



a. *b*.

Fig. 1. *Ithone fusca*, Newm: *a*, two eggs (× 20) showing micropyles; *b*, larva hatching from egg (× 11).

When sifted out from the sand in which they have been laid, the eggs are found in the form of small sand cocoons, mostly of oval shape, but sometimes quite irregular, owing to the adhesion of one or more larger particles of the soil. Their general appearance can be gathered from text-fig. 1*b*. If put away in a dry pill box, without either soil or moisture, they hatch quite readily. The embryonic period lasts about one calendar month. The emerging larva makes a hole in one side of the egg, not far from the end, and comes out head first, curving over on itself ventrally as it emerges. When its head, thorax, legs and about six abdominal segments are free, it rests for a short time in the position shown in text-fig. 1*b*. Finally it struggles free from the egg-shell and at once begins to burrow down into the soil.

The Larva.

Owing to the fineness of the larval exuviae or pellicles, it has not been possible to observe the actual series of ecdyses of the larvae. This in any case would be most difficult to do, as they all take place deep in the soil. Also, as great changes in size occur, not only during the course of a single ecdysis, but also in the comparative sizes of different individuals during the same ecdysis, I have had to determine the number of instars by morphological methods. I found that measurements of any sort were not to be relied upon, as this larva is so soft-skinned that even the prothorax and the back part of the head swells during the progress of each ecdysis. The only safe method seems to be a careful study of the chaetotaxy and of the form of the spiracles. By making careful preparations of a number of larvae of all sizes in caustic potash, I have been able to determine that there are certainly *five* instars. This is remarkable, since all other Planipennia have only three or four. The changes in the general shape of the larva, the form of the head, prothorax and legs, the form of the mouth-parts and antennae, are all so slight as to be practically useless in this connection. As regards the spiracles, these are circular in the newly-hatched larva. During each instar, they become more and more oval; until, in the last larval instar, the whole series is of a very elongate oval shape, as shown in Plate iv, fig. 7. Correlated with the changes in the form of the spiracles is a much more definite change in the chaetotaxy. The newly hatched larva possesses, with the exception of the specialised end-segments of the abdomen, only long slender *primary setae* (macrotrichia) and an abundant armature of minute microtrichia also. At the second instar, a number of *secondary setae* of macrotrichial type, but smaller than the primary setae, occur; these increase rapidly in number with each instar, until they completely hide the original primary setae, which can only be found for certain in one or two special areas where the differentiation of the two types of setae remains marked.

For the determination of the correct instar, I found the metathorax the most useful segment. It has the double advantage of having a chaetotaxy closely comparable with that of an abdominal segment, and secondary setae formed on a short, rather stout model, quite unlike that of the primary ones. Consequently the primary setae can be picked out through all instars, and the invasion of the secondary setae on to the specialised clear areas, or *pinacula,* which originally carried certain groups of primary setae only, can be followed up with precision. On the abdominal segments, the secondary setae, though at first somewhat smaller than the primary, are of the same slender form, and by the third instar there is so little difference in size that the task of picking out the one from the other is quite hopeless.

A point of great interest in this larva is the fact that the primary setae can most certainly be homologised with those of the Lepidopterous larva, as I have also found to be the case with the larva of the Mecopteron *Chorista* (though this result has not yet been published). The attention of Lepidopterists is drawn to this fact, which emphasises, by a further striking character, the close affinity that I have already insisted upon as belonging to the whole of the Panorpoid Orders. It also throws some light upon the vexed question of the seta named *theta* in Fracker's nomenclature, which only occurs in the second instar of HEPIALIDAE, and is therefore considered as sub-primary by that author (**1915**, p. 34). This seta is absent throughout in *Ithone,* so that no evidence is forthcoming for its existence in the Planipennia. Its late arrival, therefore, in the Lepidoptera is probably due to its having been added to the original chaetotaxy after the definite evolution of the Lepidopterous larval type.

A short account will now be given of each larval instar, with special attention to the changes in spiracles and chaetotaxy.

First Larval Instar (Plate iv, fig. 2; text-figs. 2–5).

The newly hatched larva is actually about twice as long as the egg in which it was confined; though, owing to its curvature, it does not appear so long as this. The head and prothorax are of about equal size, and considerably larger than the other segments. The general form is melolonthoid; the larva is obviously adapted only for a burrowing existence, being very awkward and ungainly if placed on a flat surface. In attempting to walk, it keeps its abdomen arched, but presses its thorax down flat; in such an attitude, it can only make slow and very awkward progression.

But as soon as it is placed on loose soil, it begins to burrow with remarkable rapidity, passing the grains of sand backwards between its strong burrowing legs, so that its mode of progression much resembles that of climbing over a continuous succession of moving particles. It works steadily downwards through the top layer of dry soil, until it reaches the zone of slight moisture, where it passes its existence. During

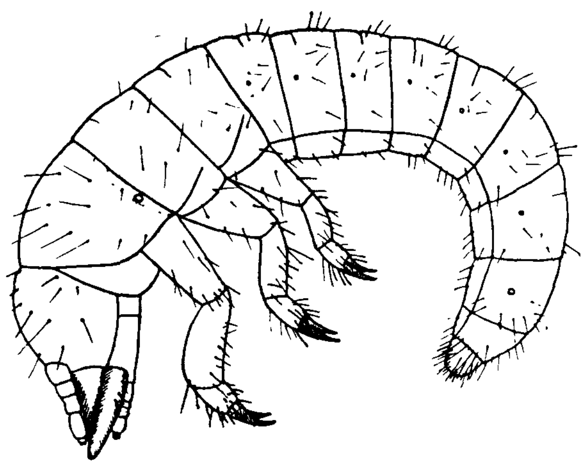


Fig. 2. *Ithone fusca*, Newm., first larval instar, newly hatched, lateral view (× 40).

dry weather the larvae could be found from 18 in. to over 2 ft. below the surface ; but after rains they work upwards, always keeping close to the same zone of slight moisture, at about the same level as the Coleopterous larvae on which they prey. In exploring the soil for food, they often work spirally, turning round and round with a screw-like progression, and thus examining a very great volume of soil in a small space. As they are quite blind, and have excessively short antennae, it is doubtful by what sense they become aware of the presence of their prey, unless by actual contact. In this connection, we do not know for what purpose they emit the strong odour of citronella which is characteristic of them. It may possibly serve to prevent them from coming in contact with one another and so attacking one another in mistake for Coleopterous grubs.

The following is a detailed description of the newly hatched larva : *Head* moderately large, broader than long, somewhat narrower than the very wide prothorax. *Epicranium* smooth, shiny, cream-coloured, carrying about 11 setae on each side of the middle line. *Compound eyes* and *ocelli* entirely absent. *Antennae* very short, with only five segments, as shown in text-fig. 3*a* ; they are inserted on the epicranium somewhat behind and above the bases of the mandibles, with their bases wide apart. The basal segment is about as broad as long, the next somewhat shorter, the 3rd little more than half as long as broad, the 4th as long as the basal segment, slightly broader than the 3rd, the 5th a small knob seated on the apex of the 4th, and carrying four or five sensory setae ; there are also two or three longer tactile setae upon the 4th segment distally. These antennae are superficially like the labial palpi, but the latter have their bases very close together. Between and in front of the antennae the epicranium dips downwards as a narrow *frontal shelf*, separated from which by an indistinct suture is the *clypeo-labral plate*, which projects between the bases of the mandibles, with a nearly straight front edge, carrying four strong setae. The *mandibles* and *maxillae* are of the most extraordinary form, even for a Planipennian larva. In this Order, as is well known, the two pairs of jaws become highly specialised to form a pair of sucking-jaws on each side of the head, the maxilla, or rather its galea (the palp and lacinia being absent) becoming an elongated lancet which slides to and fro beneath the somewhat more strongly built spear-like mandible ; the upper surface of the maxilla and the lower surface of the mandible are grooved, so that a complete tube is formed between them, and along this tube the juices of the victim are sucked by pharyngeal action. But in the larva of *Ithone*,

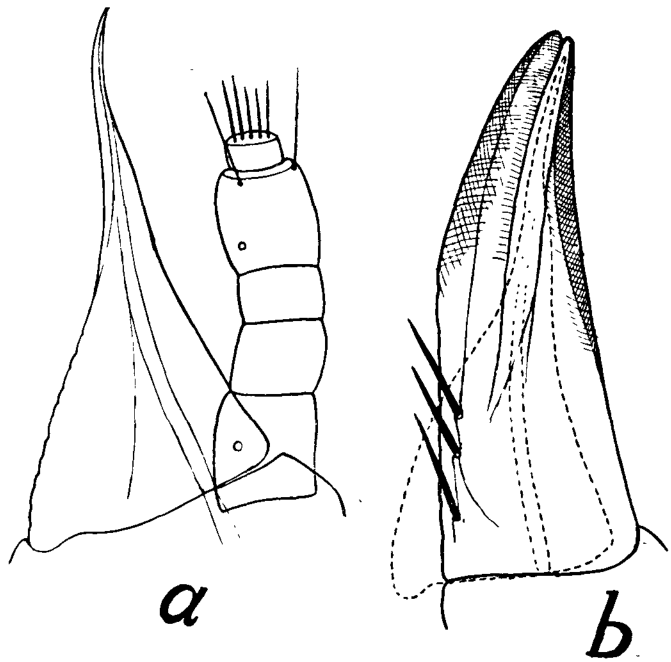


Fig. 3. *Ithone fusca*, Newm., first larval instar : *a*, left mandible and antenna ; *b*, left maxilla, with the position of the mandible dotted in (× 180).

probably owing to the peculiar habit of always striking *upwards* at its victims, the functions of mandible and maxilla appear to be almost reversed, and their structure completely so. On first examining one of these larvae, one is struck by the fact that it is the *lower* jaw which is strongly chitinised, and which carries, on its upper surface, a deep groove in which the exceedingly slender apical part of the upper jaw works to and fro. The muscles of the mandible are weakly formed, and there is little sign left of the original ginglymus joint connecting it with the head ; on the other hand, the sides of the head below the bases of the maxillae are swollen out, and even become corrugated in the last instar, to accommodate the powerful muscles which work the maxillae themselves. It seemed to me at first probable that mandibles and maxillae had indeed changed places through some strange new conformation of the head ; but a number of careful dissections show that this is not so, for the mandibles can be clearly seen to be attached in their proper places close to and below the bases of the antennae, while the maxillae are always closely associated with the labium. Text-fig. 3*b* shows the slender mandible *in situ* in the groove of the stoutly built and strongly chitinised maxilla below it. The *mandible* itself (text-fig. 3*a*) is attached to the head by a very broad leaf-like base, and is somewhat triangular in shape ; the distal half is excessively slender, with the sharply pointed apex curving slightly inwards. A narrow groove runs from apex to base, on the underside. It is only heavily chitinised towards the apex and along the distal part of the two edges. The *maxilla* (text-fig. 3*b*) consists of a single strongly chitinised piece, probably the galea, inserted on a fairly broad base, which appears to represent the stipes and cardo fused together. It is shaped rather like an elongated tooth, the outer edge being curved, the inner straight. The extreme tip is notched, forming the entrance to a deep groove, which can be traced with ease along most of its length. On the outer edge, near the base, three strong setae are developed. The labium (text-fig. 4) consists of a pair of four-segmented palpi with their bases set closely together on the

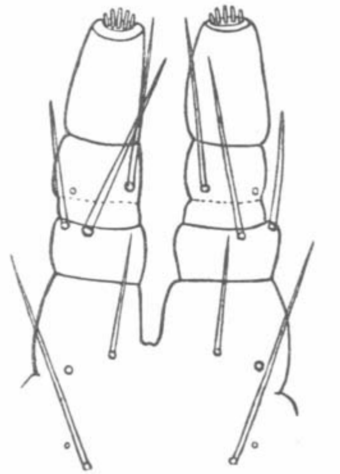


Fig. 4. *Ithone fusca*, Newm., first larval instar, labium ($\times$ 208).

underside of the head, below and between the two maxillae ; there is no separate basal piece visible. The 1st segment is about as long as wide, the 2nd a little narrower, only slightly more than half as long as wide, the 3rd very slightly narrower still, as long as wide, and with its basal 3rd just slightly constricted off from the rest by a faint suture ; this suture indicates the line along which this segment divides into two at the next instar, when the palpi become definitely five-segmented. The 4th or terminal segment is somewhat acorn-shaped, nearly twice as long as broad, and longer than the basal segment ; at its apex it carried a set of five small sensory organs in the form of short, stiff, cylindrical chitinous projections. Large tactile setae are situated as shown in text-fig. 4.

Thorax : *Prothorax* about as long as head, but broader, with a large shield-like pronotum, quite smooth and devoid of microtrichia, but carrying 10 primary setae on either side, as shown in text-fig. 2. A conspicuous *spiracle*, the only one present on the thorax, is to be seen rather low down at the back of the prothorax on either side, in the softer portion lying just in front of the mesothorax ; it is circular, with a small central aperture, and measures about 0·03 mm. in diameter. *Meso-* and *metathorax* about equal, each shorter than the prothorax, but of about the same breadth ; primary setae as shown in text-fig. 2. Each of these segments shows signs of a transverse division on the notum by a slightly impressed line at about two-fifths of the segments' length from the anterior border, similar to that shown in abdominal segments 1–7. *Legs* very strongly formed, of burrowing type, with large coxae, stout, somewhat curved, forwardly projecting femora, and short tibio-tarsi carrying large digging-claws curved backwards. The forelegs are the largest and possess the strongest claws ; the middle legs are considerably shorter, the hind-legs slightly smaller than the middle ones. The coxae of the forelegs are inserted fairly close together, those of the other two pairs much further apart.

Abdomen greatly curved, broadest at base, tapering gradually towards apex. First eight segments clearly marked, each with its pair of small circular spiracles, of which the first seven are only about half as large as the prothoracic, the 8th a little larger than the others; 9th and 10th segments smaller, not so clearly separated from one another; apex very hairy. Primary setae as shown in text-fig. 2. The 10th segment ends somewhat conically in a small *anal papilla*, on which three weakly formed triangular flaps conceal a slight depression. Within this, in a carefully cleared slide, an exceedingly minute round hole can be seen, which is probably the opening of the silk glands, the original anus having been modified for this purpose.

Chaetotaxy: The primary setae of the head, prothorax, and last two segments of the abdomen are on different plans from one another and from the rest of the segments, and are not here discussed further. Those of the first eight abdominal segments, meso- and metathorax are arranged on a closely similar plan, which is comparable with that of the primary setae in the larvae of Lepidoptera, as set forth by Fracker (1915). This author names the setae by Greek letters. His method will be adopted here; but in order to make the chaetotaxy simpler to understand, I shall also arrange the setae in groups to which positional names can be given, on the following plan:—

Position.	*Names.*	
	Anterior Seta.	*Posterior Seta.*
Dorsal	α (absent)	β
Latero-dorsal	γ	δ
Lateral or Peristigmatic:—		
Upper	ε	ρ
Lower	η	κ (μ)
Latero-ventral	ν	π
Ventral or Coxal:—		
Upper	τ	ψ
Lower	ω	σ

By using this table, each seta receives, besides its Greek name, a *positional name* which may be found more useful, if somewhat longer; *e.g.* β becomes the *posterior dorsal seta*, η the *lower anterior lateral seta*, and so on.

Fracker, in his work, indicates twelve primary setae for a typical segment in the first instar of the Lepidopterous caterpillar. These are: alpha, beta, gamma, delta, epsilon, rho, eta, kappa, pi, nu, tau and sigma. He also indicates three others as subprimaries, which are setae arising at the first ecdysis; they are theta, mu and omega. Of the twelve primary setae, only one, alpha, appears to be absent from *Ithone*, while another, tau, only appears on the metathorax. Of the subprimaries, theta is never present in *Ithone*, thus supporting Fracker's contention that its absence from the first instar in HEPIALIDAE shows that it is not a true primary seta; mu is present only on the metathorax; and omega occurs on both metathorax and abdominal segments. It would thus appear that omega is really a primary seta for *Ithone*, and takes the place of the more dorsally situated tau, present in the Lepidoptera. This could be easily understood if both omega and tau were actually primary setae for the ancestral Panorpoid type, the upper seta being suppressed in *Ithone*, the lower in Lepidoptera. The seta which I have called psi appears to have no homologue in Lepidoptera.

Text-fig. 5 shows the chaetotaxy of the metathorax and first two abdominal segments of *Ithone* in diagrammatic form. From the mid-dorsal line to the dotted lateral line above pi, the microtrichia are exceedingly abundant, being only absent from certain areas around the primary setae which correspond with the hardened plates or *pinacula* of Mecopterous and Lepidopterous larvae, but which, in *Ithone*, are simply clear, unhardened areas. Each primary seta has a small circular area surrounding it, except in the case of eta and kappa, around which there is a larger pinaculum enclosing both, and represented by a dotted line in text-fig. 5. On the meso- and metathorax, there is also a much larger pinaculum enclosing gamma, delta, epsilon and rho. I have used the condition of this pinaculum as a convenient diagnostic character for determining the first three instars, as may be seen from text-figs. 5–7. Below the dotted line microtrichia are very weakly developed for a space, this area always including pi ; but, lower down, they again come more into evidence.

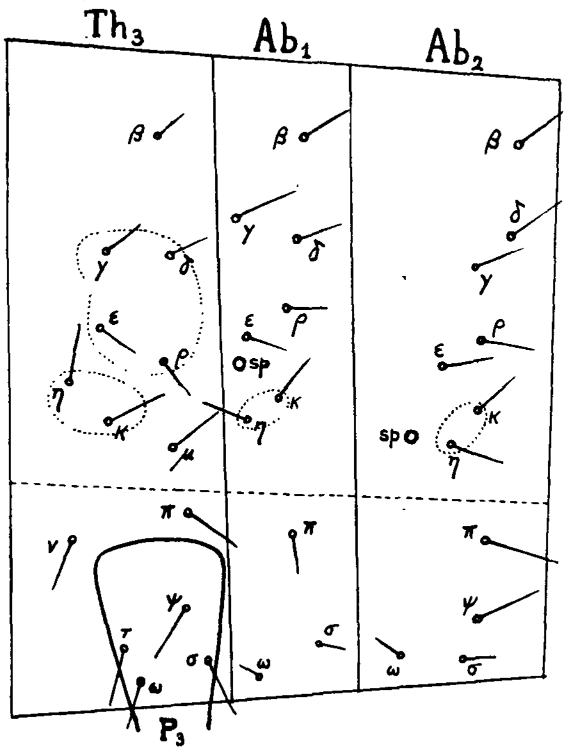


Fig. 5. *Ithone fusca*, Newm., first larval instar ; diagram of chaetotaxy of metathorax (Th_3) and first two abdominal segments (Ab_1, Ab_2), to show positions of primary setae, with Fracker's notation ; P_3, coxa of hind leg.

Secondary setae of the type which appears on the metathorax in the second instar are already present on the anal papilla at the first instar, and the end of the abdomen is conspicuously more hairy than the rest of it ; so that we are justified in considering segment 10 as already specialised in this larva.

During the first instar, the larvae grow considerably, the prothorax and back of the head swelling out with the other segments. But this instar can always be recognised by the comparatively large size of the head, the small, circular spiracles, and the presence of the primary setae only on the thorax and first eight abdominal segments.

Second Larval Instar (Plate iv, fig. 3 ; text-fig. 6).

The second larval instar superficially resembles the first, except for its larger size and the comparatively smaller size of the head in relation to the prothorax. The head is more swollen below the bases of the maxillae, and there is a distinct beginning of the tendency, so noticeable in the later instars, for the mouth-parts to turn upwards. The labial palps are definitely five-segmented. The three pairs of legs are more nearly equal in size than in the first instar. The spiracles are greatly enlarged, and of a broad oval shape, with the aperture in the form of a wide slit ;

the prothoracic spiracle now measures 0·1 mm., while that of the first abdominal segment measures 0·06 mm. in length, the breadths being about two-thirds of these measurements in each case. All the segments show a new development of fairly numerous secondary setae of macrotrichial type, but not so long as the primary setae. On the pro- and mesothorax these setae are nearly all very slender, less than half as long as most of the primary setae; the pronotum remains shield-like and smooth, without any microtrichia, but the mesonotum has the microtrichia very strongly developed, as have all the succeeding segments. The secondary setae on abdominal segments 2–8 are slender and comparatively short, like those of the

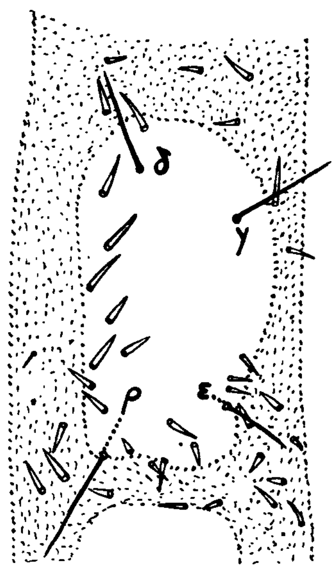


Fig. 6. *Ithone fusca*, Newm., second larval instar; large pinaculum of metathorax, showing invasion of secondary setae (× 112).

pronotum; those on the first abdominal segment are slightly thicker, and those on the metanotum are very distinctly thickened, so that they can be distinguished at a glance from the primary setae, which remain in position. The invasion of these setae upon and around the large pinaculum of the metathorax, which encloses the four primary setae gamma, delta, epsilon and rho, is shown in text-fig. 6.

Third Larval Instar (Plate iv, fig. 4; text-fig. 7).

The third instar is again considerably larger than the second, but owing to actual differences in the sizes of individual larvae, measurements cannot be relied upon to determine the correct instar. The head is again smaller in comparison with the prothorax than in the second instar, and the turning-up of the mouth-parts is distinctly more noticeable. Antennae and labial palpi remain five-segmented. The spiracles are now very oval in shape, the prothoracic spiracle measuring 0·16 mm., and being only half as broad as long, while the first abdominal spiracle is 0·10 mm. long, and a little more than half as broad. Transverse striation of the lips of the spiracle and of its internal opening is now apparent. The most noticeable change in this instar is the very large invasion of secondary setae on all the segments; the condition of the large pinaculum on either side of the metathorax is shown in text-fig. 7. It is no longer possible to pick out the primary setae with certainty on the abdominal segments, as the lengths of the secondary setae are by now very nearly the same.

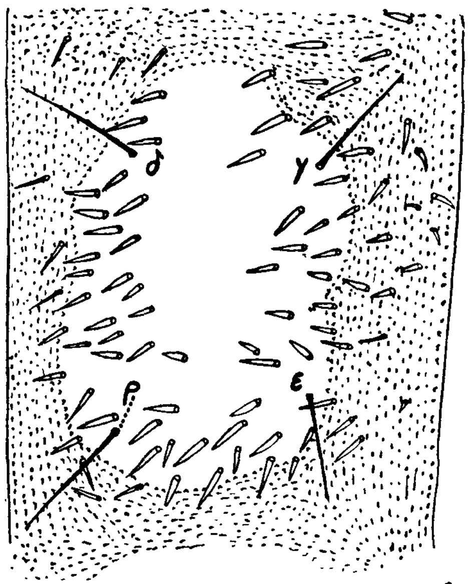


Fig. 7. *Ithone fusca*, Newm., third larval instar; large pinaculum of metathorax, showing the great increase in the number of secondary setae (× 112).

Fourth Larval Instar (Plate iv, fig. 5; text-fig. 8).

In this instar, the head is further reduced in size in comparison with the prothorax, and is now less than half as wide as the latter, and considerably shorter, as can be seen from text-fig. 8. The turning-up of the mouth-parts is very noticeable, as is also the development of the swollen ventral portion of the head beneath the maxillae.

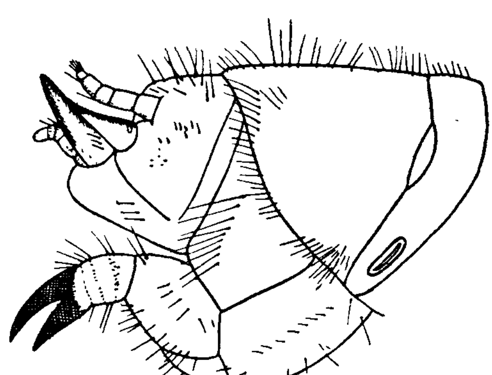


Fig. 8. *Ithone fusca*, Newm., fourth larval instar; lateral view of head and prothorax (× 20).

The upper claw of the fore tarsus is now about as long as the maxilla; in all previous instars it is considerably shorter. The primary chaetotaxy has disappeared, or can no longer be recognised; the setae on the head and prothorax are shown as in text-fig. 8, while those on the remaining segments are very minute and abundant. The most striking change is in the size and shape of the spiracles. The prothoracic spiracle is now twice as long as in the previous instar, measuring 0·32 mm. in length ; its breadth is only one-fourth of its length, and the internal aperture has become a very narrow and elongated slit. The first abdominal spiracle is 0·19 mm. long, somewhat broader in proportion to its length than the prothoracic. Transverse striation or ribbing of the lips is clearly noticeable. Antennae and labial palpi remain five-segmented, but the terminal segment of the latter turns downwards. There is a slight indication of the beginning of a division of the tibio-tarsus into three segments.

Fifth (last) Larval Instar (Plate iv, figs. 6, 7 ; text-fig. 9).

The last instar closely resembles the preceding, except for its greater size. The head is still further decreased in breadth and length in comparison with the huge prothorax ; its breadth is now barely one-third of that of the latter. The antennae are usually five-segmented, but I have occasionally noted six segments in this instar ; the two end segments tend to turn upwards. The labial palpi are still five-segmented,

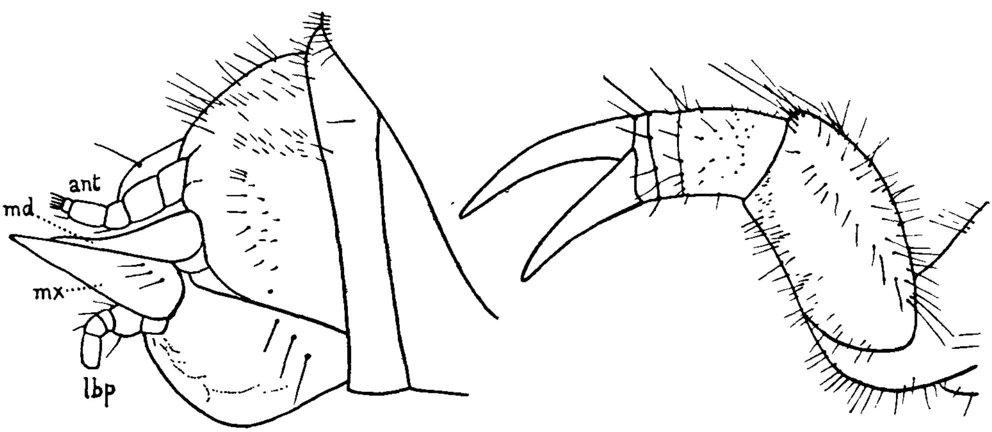


Fig. 9. *Ithone fusca*, Newm., fifth larval instar; lateral view of head and foreleg, with mandible, maxilla and tarsal claws left unshaded (× 20).

with the two terminal segments turning sharply downwards. The ventral portion of the head is now greatly swollen and corrugated for the attachment of the maxillary muscles. The upper claw of the fore tarsus is definitely longer than the maxilla, and the tibio-tarsus shows distinct signs of division into three segments, of which the basal one is twice as long as the other two together. The whole series of spiracles now appears as a row of transverse slits, very much longer than broad. The prothoracic spiracle is 1·13 mm. long, the first abdominal 0·60 mm. ; the internal apertures are very narrow slits extending nearly the whole length of the spiracle. The edges of the internal apertures can be seen to be curved over and definitely marked with transverse ribs, as are also the lips of the spiracle itself. The 9th abdominal segment carries a ring of conspicuous dark hairs, not noticeable in the previous instar.

Formation of the Cocoon (Plate iv, fig. 9).

When the larva is full-grown, it ceases to feed for some considerable time, and makes its way down to a somewhat lower level where the soil is slightly moister than that in which it lives as a larva. Having chosen a suitable place, it hollows out an elongated oval cell in the moist soil, by continually coiling itself round and round, bringing its head forward close to the ventral side of its abdomen, and then turning right over and repeating the same performance. When this cell is securely formed, by continuous pressure on the soil, the larva lies upon its back, and proceeds to weave the cocoon from the anal opening in the same manner as other Planipennia. The complete process has not been observed, but I was fortunate enough to see one larva with its cocoon partly formed, in which the separate fine layers of silk were clearly visible. The cocoon, when completed, is elongate oval in shape, a little less than thrice as long as wide, with almost parallel sides and well rounded ends. It is of a dead whitish colour and a papery consistency, the texture reminding one more of that of some Hymenopterous cocoons than of those of other Planipennia. The insect spends on an average about six weeks in the cocoon; during the first half of this period it remains a larva, and then changes into a pupa.

The earliest cocoon found by me was on 12th September, but most of the larvae spin up during the succeeding fortnight. The earliest emergence of the imago noticed during the same year was on 30th October. The period spent in the cocoon is thus seen to be about six weeks on the average, or a little over.

The Pupa (Plate iv, figs. 10, 11; text-figs. 10, 11).

The pupa is a soft-bodied *pupa libera* of elongate form, having the rather small head turned down ventrally in front of the somewhat larger prothorax, which lies about at right angles to the main axis of the body. The rest of the thorax is curved round dorsally to join the long, straight, stout abdomen, which is only slightly curved

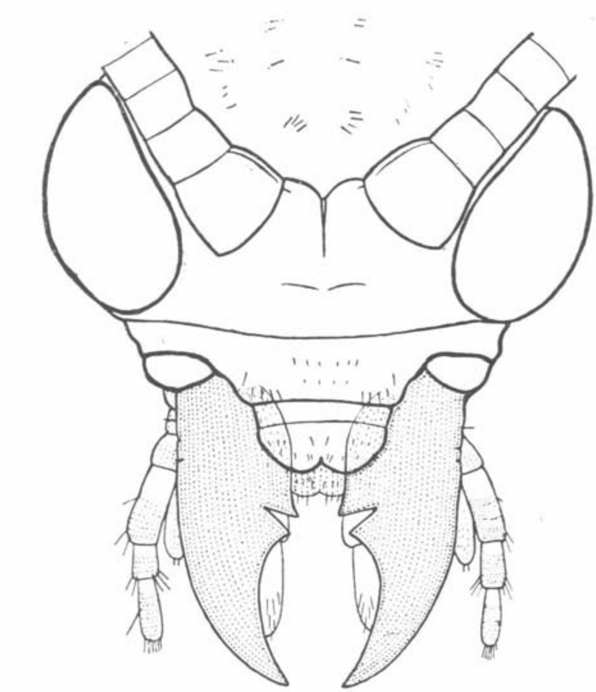


Fig. 10. *Ithone fusca*, Newm., pupa; front of head, showing compound eyes, bases of antennae and mouth-parts (× 20).

ventrad at its anal end. The wings are folded down sideways against the thorax, the tip of the forewing reaching only to about the middle of the 3rd abdominal segment. The antennae are curved at first upwards and backwards so as to pass over the bent knees of the three pairs of legs, and then curve round so as to lie close alongside the front border of the wings. The legs are hunched up so that the knees are drawn back to the level of the eyes, the tibiae and tarsi lying ventrally along the first four abdominal segments. The whole pupa is at first of a soft creamy white colour, except for a slight darkening of the anal end, and the mandibles, which are a rich brown. This is well shown in Plate iv, fig. 10. The head, legs and abdomen are freely movable, and the mandibles are also capable of movement in one plane only. The pupa is able to lift its head up to a considerable extent; this attitude is shown in Plate iv, fig. 11; but it usually rests with its head downwards as in fig. 10.

Text-fig. 10 shows the structure of the front part of the head. There are no *ocelli*, but the *compound eyes* are well developed, and placed far apart, with the large bases of the *antennae* between them. The latter consists of about 54 segments, of which the basal one is larger than the others; the moniliform appearance of the antennae is well seen in Plate iv, fig. 10. The *frons* is clearly divided from the *epicranium* by an impressed transverse line; the middle portion of the *frons* projects forwards slightly as shown in text-fig. 10. Attached to this middle portion is the clypeo-labrum, which is now clearly divided into a smaller upper *clypeus* and a larger lower *labrum*, the free margin of which is well rounded, and notched in the middle. The huge *mandibles* (shaded in text-fig. 10) project downwards in the form of two broad-bladed, strongly curved and sharply pointed knife-like appendages, having the lower half of the inner margin convex, the outer half strongly concave, and the angle between them deeply notched so as to form two strong teeth placed close together. Their length is 1·8 mm., more than thrice as long as the imaginal mandibles which form within their bases. Their function is to tear open the cocoon for the exit of the pupa; it is also possible that they may assist the pupa in its progression through the soil, the legs being almost useless for this purpose.

The *maxillae* are fully formed, as shown in text-fig. 11*a*, with broad, short cardo and stipes, lacinia, galea and palp complete. The *lacinia* (*lc*) is a broad, flat process, with its oblique distal margin fringed with numerous short hairs. The *galea* (*g*) is a narrower, somewhat oval process, with three small hairs on its rounded apex. The *palp* (*p*) is fairly long, five-segmented, the basal segment being very short, the 2nd twice as long, the 3rd as long as the first two taken together, the 4th about as long as the 2nd, and the 5th as long as the 3rd, but narrower, with bluntly rounded apex carrying a set of rather short bristles; the 4th segment carries a set of longer hairs apically.

The *labium*, with attached *hypopharynx*, is shown in text-fig. 11*b*. The *labium* itself consists only of a broad, short base carrying two large, three-segmented *palpi*, in which the basal segment is the shortest, the other two being about equal. Setae are scattered about on the 2nd and 3rd segments, and the latter carries a set of stiff apical bristles. The *hypopharynx* (*hp*) consists, as in other Planipennia, of a short, bilobed tongue-like process projecting above the basal piece of the labium; each free lobe carries a few short setae.

A day or two before the imago emerges, the pupa turns a dark smoky colour, while the wing-sheaths gradually darken until they become quite black and shiny. During the later part of pupal life, the formation of the parts of the imago within those of the pupa can be watched with ease. From a pupa still more than a week from emergence, and not yet darkened in colour, I was able to draw out undamaged the whole of the imaginal antennae, mouth-parts and legs. As a full account of the imago has already been given in my previous paper, reference should be made to it for a comparison of the pupal parts with those of the imago itself. In general, the pupal parts are much paler, somewhat larger, and much more stoutly built than those of the imago, but their general shape is the same; the only exception is that of the mandibles, already noted. Some details of interest were noted in the formation of the legs, as shown in text-fig. 11 *c*, *d*. The tibial spurs are large and fleshy in the pupa, the imaginal spurs being much longer and narrower, as shown in *d*. The pupal tarsus consists of six segments, the last of which is a swollen bulb, shallowly divided into two rounded apical lobes. From this segment there develop the two claws (*cl*) and the empodium (*em*), as shown in *c*. The lengths of the tarsal segments of the imago are much greater than those of the pupa, especially the 5th, so that the boundaries of the separate segments do not correspond. The brushes of strong hairs on the segments of the imago are pressed against the sides of the pupal segments.

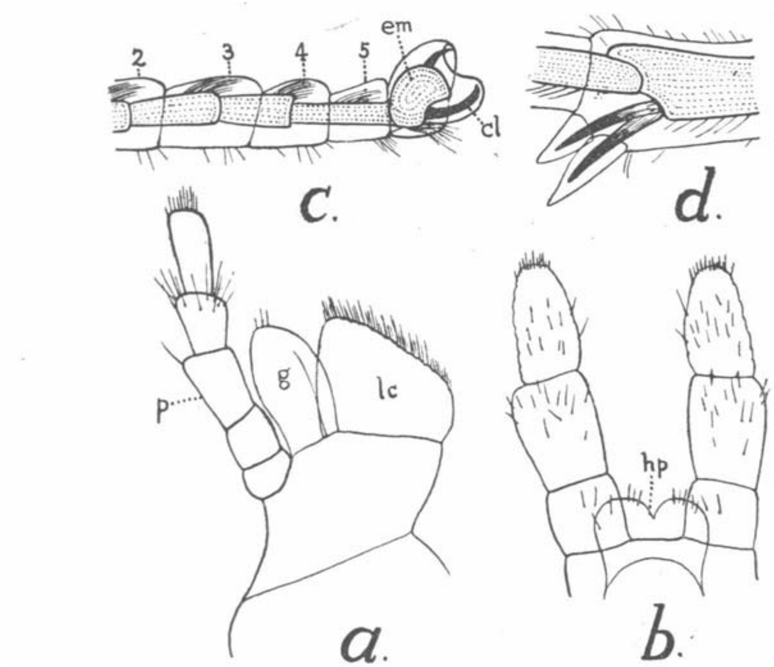


Fig. 11. *Ithone fusca*, Newm., pupa; *a*, maxilla (× 30), with galea (*g*), lacinia (*lc*), and palp (*p*); *b*, labium and hypopharynx (*hp*) (× 30); *c*, portion of hind tarsus of late pupa, showing the arrangement of the segments of the imaginal tarsus within, and the formation of the claws (*cl*) and empodium (*em*) from the terminal pupal segment; *d*, end of hind tibia of late pupa, showing formation of tibial spurs of imago (× 20).

The cocoon is cut open at about one-fifth of its length from the head end. This cut is quite irregular, and appears to be made by the mandibles first pushing their sharp points through the envelope, and then catching the torn edge between the two pairs of teeth and ripping it sideways until the top of the cocoon is entirely torn off. (The tear visible in the cocoon in Plate iv, fig. 9, was not made by the insect.) As the imagines emerge from the ground about sundown, it is to be supposed that the pupa, after getting free from the cocoon, comes to rest at some point in the soil where the warmth of the sun is noticeable, and waits until a slight cooling takes place before the imago discloses itself. Most of the cocoons being from a foot to more than two feet down in the soil, it would appear impossible for the pupa itself to be able to sense the position of the sun at such a depth.

This brings the account of this remarkable life-history back to the point at which it was begun. It now remains for me to discuss the feeding habits of the larva, and to point out its probable value in the field of economic entomology as an enemy of Grass-grubs.

Feeding habits of the Larva.

Mr. Gallard and I have both satisfied ourselves that the natural food of this larva is the Scarabaeid grubs which it superficially resembles. A dissection of the larva shows that it has no true mouth, and that only liquid food can be taken, in the same manner as in the case of other Planipennian larvae. No faeces are formed, and the structure of the hind gut and anus shows that this part has become specialised for the production of silk only. The question, then, was as to what was its natural food. A collection of all the forms of animal life inhabiting the sandy soil in which *Ithone* lives yielded only the following results: (*a*) cocoons of Thynnid wasps; (*b*) larvae and pupae of Brachycerous Diptera, chiefly Asilidae; (*c*) larvae and pupae of Coleoptera, chiefly Scarabaeidae; (*d*) occasional burrowing Lepidopterous larvae, chiefly those of Hepialidae.

That the larvae of *Ithone* do not normally feed upon (*a*) or (*b*) is obvious, these two groups being themselves predacious, and most probably attacking *Ithone* itself as well as other larvae. In fact, a Thynnid cocoon has recently been obtained by me from a live *Ithone* larva which was put away in a jar of soil some weeks previously. Of (*c*) and (*d*) we can say at once that the latter are far too uncommon to supply the amount of food necessary for the large number of *Ithone* larvae present in the soil. The only food that is present in the requisite amount is the Coleopterous larvae, of which more than ninety per cent. consist of Scarabaeid grubs, more or less closely resembling the larva of *Ithone*. One of these, shown in Plate iv, fig. 8, is so like *Ithone* when first dug up that we came to call it the "false *Ithone*"; we have not succeeded in rearing it to determine to what species it belongs.

On several occasions I placed a number of Scarabaeid larvae in soil in a large jar and then turned out a few *Ithone* larvae on top of the soil. The *Ithone* larvae at once burrowed rapidly down, and kept working away round and round the jar. Approaching a Scarab larva, they appear always to burrow down below it, and then work up towards it from below. I have not actually succeeded in seeing an *Ithone* larva attack any of its victims, but have no doubt that it is done by an upward stroke, judging by the formation of its mouth-parts. On examining one jar of larva the following morning, I found all the Scarab larvae killed, one having been sucked almost dry, another partly sucked, and the rest having one or more clearly marked wounds which had caused their death. One *Ithone* larva was also wounded, and died later; this may have been from an attack by another *Ithone* larva, or possibly the wound was caused by the jaws of the Scarab larva which it was attacking. Mr. Gallard had also observed, on more than one occasion, the death and partial sucking-out of Scarab larvae to which *Ithone* larvae have been given access.

We can only conclude that the principal diet of the larva of *Ithone* consists of Coleopterous larvae, chiefly those of Scarabaeidae; though this does not preclude the probability that they also attack Hepialid and other larvae when hungry.

The Economic Value of the Ithonidae.

The family Ithonidae is widely spread throughout Australia, being found from Queensland down into New South Wales and Victoria, and across the central desert into Western Australia. One species, *Heterithone pallida*, Till., is common in many localities in Tasmania. The larvae must, therefore, be capable of standing great extremes of temperature in the soil. The insects are most abundant along the sandy foreshores and wherever the soil is of a light, loose texture suitable for easy burrowing. These are also the conditions which best suit the various species of Grass-grub. But, just as Scarabaeid grubs are also to be found in heavier soil, so there is evidence that *Ithone* also exists there, though not so abundantly. One species has been taken on Mount Tambourine, where the soil is of volcanic origin; the larva of another has been found by Mr. Gallard in a heavy loam at Epping. Isolated records of the occurrence of the imago come from many parts of the interior of Australia also, so that the insect is by no means confined to the coastal strip.

Grass-grubs are a serious pest in many parts of the world, and any addition to the list of their enemies should be very welcome. In New Zealand, much damage is caused at times by these pests, which do not seem to have any enemies there except a few introduced birds. In attempting to control this pest, there appears to me to be three lines of attack, viz., Ithonidae, Scoliidae and Thynnidae. It would be unwise to rely upon one only, when all three are available. One must, however, take into consideration the popular objection to the introduction of any new large wasp into a country devoid of them. I have therefore started my attempt to reduce this pest by introducing *Ithone* into New Zealand. Last October I went across to Sydney, and, with the help of Mr. Gallard, secured, as already related, some 7,000 fertile eggs of *Ithone fusca*, 5,000 of which were sent to New Zealand. These have been distributed in lots of 500 to the following centres: Wellington, Auckland, Christchurch,Wanganui, Hokitika, Blenheim ; and, within Nelson province, Murchison Mapua, Richmond, Tahunanui, Dun Mountain (250). Besides these, 750 eggs have been sown in specially prepared grass plots liberally supplied with *Odontria* grubs in the grounds of the Cawthron Institute, and covered over with bird-proof netting. These will be opened up and examined during the coming winter, to see whether the *Ithone* larvae have succeeded in establishing themselves under the new conditions of food, climate and soil. Plate v shows these plots in their present condition (17th March 1922), with the Insectarium in the background.

Cawthron Institute, Nelson, N.Z.
17th March, 1922.

Literature Quoted.

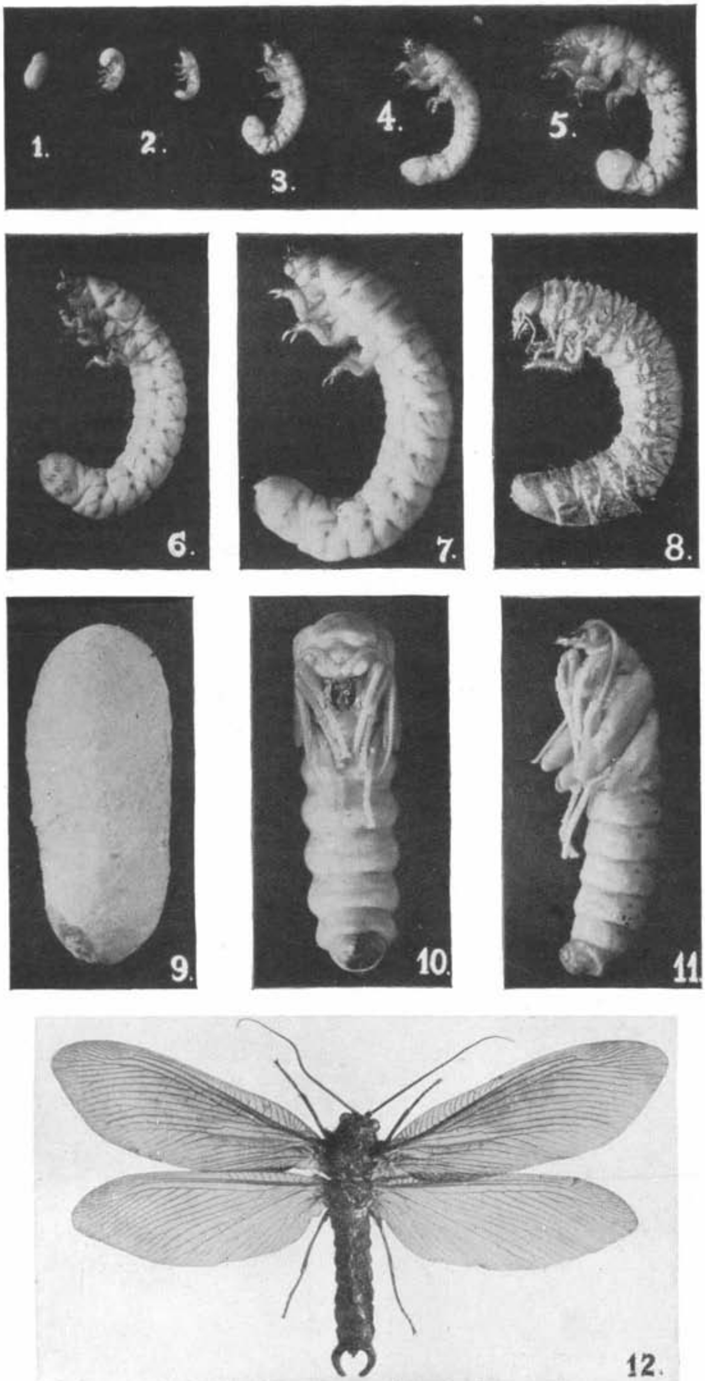
Fracker, S. B. (1915). The Classification of Lepidopterous Larvae.—Illinois Biol. Monographs, ii, no. 1, July 1915.

Tillyard, R. J. (1919). Studies in Australian Neuroptera, no 8. Revision of the Family Ithonidae, etc.—Proc. Linn. Soc. N.S.W., 1919, xliv, pt. 2, pp. 414-437.

EXPLANATION OF PLATE IV.

Life-history of *Ithone fusca*, Newman.

Fig. 1. Egg (× 3).
,, 2. Two newly hatched larvae (× 3).
,, 3. Larva, second instar, approaching ecdysis (× 3).
,, 4. Larva, third instar (× 3).
,, 5. Larva, fourth instar (× 3).
,, 6, 7. Two larvae of fifth or last instar (× 1·9).
,, 8. Scarabaeid larva found with *Ithone* larvae, and superficially resembling it; last instar (× 1·9).
,, 9. Cocoon (× 1·9).
,, 10. Pupa, front view (× 1·9).
,, 11. Pupa, side view (× 1·9).
,, 12. Male imago (× 2·2).



Life-history of *Ithone fusca*, Newman.

A view of the prepared grass plots containing grass-grubs and sown with *Ithone* eggs, in the grounds of the Cawthron Institute. Insectarium in the background.