ART. XV.—*Embryological Structure of New Zealand* Lepidoptera: *Part I.*

By AMBROSE QUAIL, F.E.S.

[*Read before the Wellington Philosophical Society, 12th March, 1901.*]

Plate IX.

THE subject has of recent years received the attention of capable authors in England and America, and some notes on the embryology of *Lepidoptera* of general interest, if applied to local species, may be of use to New Zealand students in directing attention to its scientific importance.

The number of eggs laid by *Lepidoptera* varies inversely in proportion to specialisation. Assuming primitive productivity to be great, *Hepialidæ*—an ancient group—deposit their ova indiscriminately at random amongst the herbage in great quantity, probably thousands in some genera. The development of ornamentation of the ovum, the degree of development attained within the ovum by the ensuing larva, may cause greater assimilation of egg-producing matter per ovum, hence a reduction in the number of ova laid per species.

It is characteristic of *Arctiidæ*, *Noctuæ*, *Geometræ* to attach ova in batches to branch, twig, leaf, or what not, and, generally speaking, in these groups the number of ova is limited, in some species to a hundred or so. Among *Rhopalocera* the position is usually selected and ova deposited singly, and the number deposited is small.

Individual species in any group may be noted to have a greater productivity than is usual, but some female *Lepidoptera* develope a greater capacity for egg-production at the expense of imaginal structures; thus reduction may be counteracted and rate of productivity maintained. Apterous female *Orgyia*, *Hybernia*, &c., are extreme examples of such.

Ova of *Hepialidæ* (*Porina* and *Charagia*) are smooth and of spherical shape. This may not indicate generalisation, since *Psychidæ* (*Œceticus*) ova, though smooth, are longer than broad, and have equal claim to be considered a primitive egg-shape; there is little doubt, however, that the smooth egg is more primitive than the sculptured egg. Eggs of certain groups are laid on the side (lateral); among these a Tineid egg (fig. 3), with obscure sculpture, is a more ancient type than such lateral eggs as have parallel ribs, and are also probably more primitive than Geometrid eggs, with distinct hexagonal sculpture—*Selidosema*, *Asaphodes* (fig. 4). Eggs of certain groups are attached on end (vertical); among these the

smooth round eggs of *Rhapsa scotosialis*, flat on attached surface, are more primitive than Arctid (*Nyctemera*) eggs, which are similar in shape but with hexagonal sculpture, or typical *Noctuæ* (*Melanchra insignis*) eggs, more flattened at the base, with parallel corrugations converging to the centre. *Rhopalocera* ova have elaborate sculpture (figs. 1, 2).

The eggs of *Lepidoptera* most frequently have hexagonal figures raised on the surface; more highly specialised forms, with parallel ribs, appear to be derived from the hexagonal by the decadence of the transverse sides of the hexagons and greater development of the longitudinal sides. I have, in fact, examined a Tineid egg which seems to actually illustrate the process. Egg-shells with hexagonal patterns are probably similar in composition to beeswax, recent experiments* having proved the natural formation of "crystalline" hexagons in the pure beeswax upon which bees build up the cells of honeycomb; the size of the hexagons has been varied experimentally, according to the thickness of the wax, "from those of nearly an inch across to others of microscopic dimensions," and a variety of these "crystalline" bodies has been formed by the treatment of certain "waxes with other fats, oils, and waxes." It may be noted that the ovum of *Vanessa gonerilla* (fig. 1) has an ornamentation which is not hexagonal, and the secretion by which the ovum is attached at its base to the leaf upon which it has been deposited is of irregular "crystalline" formation, but nevertheless largely hexagonal. Certain Tortricid ova look like mere splashes of white, green, or brownish matter, due apparently to a secretion which covers them, which is likewise characterized by "crystalline" hexagons.

The larvæ of *Lepidoptera* are composed of fourteen bilaterally symmetrical segments, which comprise the head=1, thorax (pro-, meso-, post-)=3, abdomen=10. The head near the mouth has six ocelli on each side. In their imago stage *Lepidoptera* have compound eyes (except, perhaps, female *Psychidæ*); near the ocelli in front are antennæ, broad and fleshy organs very unlike those of the imago; at either side of the mouth are the jaws, and below are the maxillæ and the labium (lower lip), with its minute palpi and terminal spinneret, from which the larva produces its silken threads. The thoracic segments have legs which ultimately become the imaginal legs, and certain abdominal segments have fleshy ventral extensions terminated by one or more rows of hooks; these are termed prolegs (claspers on 10), but Dr. Sharp† has proposed a more appropriate term, "abdominal feet." These

* C. Dawson, F.G.S., and S. A. Woodhead, in "Natural Science," vol. xv., p. 347.

† "The Cambridge Natural History," vol. vi.; Insects (part ii.).

are not retained in the imago. The spiracles (breathing-organs) are lateral, one each side of the prothorax and first eight abdominal segments; those of the prothorax and 8th abdominal segments are often larger than the spiracles of any other segment. The absence of spiracles from meso- and post-thoracic segments may be associated with the ultimate development of the imaginal wings.

The thoracic and abdominal segments are made up of minor subsegments, and the skin is frequently covered wholly or in part (figs. 12–14) with minute hairs, and in more or less fixed position there are certain pimples (termed "tubercles"), which form the base of longer and stouter hairs (termed "setæ"). The position of the tubercle setæ affords a basis for classification. The arrangement of the tubercles of prothorax is mostly scutellar—*i.e.*, on the dorso-lateral plate or scutellum—and always differs from the arrangement of the tubercles on meso- and post-thorax.

[Since the above was written Dr. G. Harrison Dyar, writing in the "Century" number, vol. xiii., "Entomologists' Record," states: "I now agree with Dr. Hofmann that the thoracic and abdominal setæ are homologous," a conclusion reached by the present writer independently but not stated, as hitherto Dr. Dyar had not formed that opinion. The nomenclature of the thoracic (below the scutellum) and abdominal setæ should correspond.]

I have noted elsewhere* a probable generic distinction among *Hepialidæ* (*Porina* and *Charagia*) in the arrangement of the prothoracic scutellar setæ, and have noticed considerable diversity in the position of the prothoracic tubercles in most groups of *Lepidoptera*. The more fixed position of the abdominal tubercles appears to be of little value in differentiating genera, though of great significance in classifying larger groups.

The arrangement of the meso- and post-thoracic tubercles differs from the abdominal, though more approximate than those of the prothorax; the abdominal segments are practically duplicates—except 9 and 10, which are always modified. Newly hatched larvæ usually have the primitive arrangement of tubercles in the group of which they are representative, and also usually have primitive tubercles with single setæ. Multiplication of tubercles (and reduction) and of setæ takes place after the first moult, though sometimes newly hatched larvæ exhibit specialisation.

Abdominal dorsal tubercles: On the back four tubercles are placed, as it were, at the corners of a trapezoidal figure, those in front being near each other, those behind being more

* Trans. Ent. Soc. London, 1900, p. 424.

remote. Such is the normal form in most groups of *Lepidoptera*, and in the nomenclature of Dyar* are known as—i. anterior, ii. posterior, trapezoidal tubercles. Newly hatched larvæ of *Rhopalocera* have the primitive position of the tubercles and single setæ (*Vanessa gonerilla*, figs. 9–11). After the first moult *Vanessa* larvæ acquire by coalescence of the anterior trapezoidal tubercles a single mid-dorsal unpaired tubercle (fig. 12), which, with the other abdominal tubercles, has numerous setæ. The trapezoidal tubercles of some *Psychidæ* (*Œceticus*, fig. 17) are reversed in position in newly hatched and adult larvæ. Some European *Psychidæ* (*Taleporia*) exhibit intermediate and normal position of the trapezoidals. Abdominal tubercles (iii.) supraspiracular, a tubercle always above the spiracle usually somewhat anterior, in *Geometræ* (figs. 5, 6) noticeably so. The primitive condition of the supraspiracular tubercle appears to be with a single seta in most groups—*Rhopalocera* (fig. 9), *Psychidæ* (fig. 16), *Noctuæ* (fig. 13). *Hepialidæ* have two supraspiracular setæ in the newly hatched stage, which, however, appear to arise from distinct separate tubercles. From its minute size the anterior seta suggests the original condition of two supraspiracular tubercles and the gradual loss of one (the anterior) amongst primitive *Lepidoptera* from which *Hepialidæ* were derived; and it is of interest to note that the supraspiracular in *Tinea* (*pellionella*, fig. 15) has two setæ, one of which, as in *Hepialidæ* (the anterior), is very minute. *Tinea* is certainly an ancient group of *Lepidoptera*, and its minute supraspiracular seta, with its less independent base, may represent a further stage in the loss of the ancestral second supraspiracular. Such a form as may be observed in *Arctidæ* of supraspiracular tubercle with numerous setæ (fig. 18) is unquestionably evidence of specialisation. A closely allied genus in the same group (*Nyctemera annulata*) has the supraspiracular and the other abdominal tubercles with primitive single setæ. iv. Postsubspiracular tubercle usually below the spiracle in a posterior position; in some groups is moved up level with the spiracle —*Geometræ* (figs. 5, 6), *Noctuæ* (fig. 13), *Arctidæ* (fig. 18). v. Subspiracular in all groups with which I am acquainted is below the spiracle and usually anterior. vi. A tubercle above the abdominal feet is usually not present until after the first moult in *Psychidæ* (fig. 16) and *Arctidæ* (fig. 18). In –x I have observed an area probably representing this tubercle in the newly hatched larvæ, but the seta is not developed until after the first moult. It may be noted that, whereas in *Hepialidæ* and other groups this tubercle (vi.) is anterior above the abdominal feet, in *Noctuæ* (fig. 13) it is posterior in position.

* Classification of Lep. Larvæ, G. H. Dyar, Ph.D.

vii. The basal tubercles on the base of the abdominal feet and in a corresponding position on the footless segments—*Hepialidæ* (*Porina*)—have three basal setæ (four in adult), but most groups have only two in the early stage (figs. 6, 9, 16, 18). The tendency throughout the *Lepidoptera* seems to have been towards a reduction in the number of primitive tubercles. That the ancient stock probably had a greater number of tubercles is suggested by the supraspiracular of *Hepialidæ* and *Tinea* and the basal setæ of *Hepialidæ*. Such modifications as take place after the moult are specialisations of recent acquirement, and when, as in *Metracias*, such is present in the newly hatched stage it is tolerably certain we have a comparatively recently evolved species. viii. is a tubercle on the ventral surface inner to the abdominal feet and on the footless segments, always present in all groups so far as my observations go.

A good deal might be said of the tubercles on the 9th and 10th abdominal segments, but I have been unable to make determinations of their value, which appears to be of rather a specialised character. There is also a great diversity in the structure of the tubercle setæ (figs. 8, 11, 18); probably the smooth hair-like seta is the more primitive form.

The number of abdominal feet is also various; in most groups there is a pair each on segments 3, 4, 5, 6, and 10. The anterior pair (segment 3) in *Rhapsa* and others are greatly reduced in size—are, in fact, little more than enlarged tubercles in the newly hatched stage. Other *Noctuæ*, as *Melanchra insignis*, have two pairs of feet reduced in size (of 3–4 segments), and not functionally operative in the newly hatched stage. Speaking from memory, some *Geometræ* are similar to *Melanchra* (*Rumia*, of Europe, for instance). Typical *Geometræ* (fig. 6) have abdominal feet between 6th and 7th and on 10th segments—two pairs only.

The number of rows of terminal hooks which more or less completely encircle the abdominal feet is various in different groups and genera of the same group—for instance, *Porina* and *Charagia* (*Hepialidæ*).

Pupæ in all groups of *Lepidoptera* differ greatly in structure from larvæ, and, though functionally quiescent as regards consumption of food and comparatively so in movement, it is in the pupal stage that the imaginal organs are largely developed and larval structures obliterated.

The pupa consists of the same number of segments as the larva, of which 8, 9, 10 abdominal are often consolidated and with difficulty identified. Movement, being practically confined to the segments between the posterior edges of the wing-cases and the consolidated anal segments, is often curtailed in the higher groups.

Imaginal organs are developed within well-marked areas of the pupa. The prothorax is small; mesothorax greatly enlarged at the expense of the other thoracic segments; from the latter and the post-thorax the wing-cases extend laterally and nearly meet together ventrally. On the ventral surface the head is anterior, with protuberant eye-pieces; the proboscis, antennæ, and legs are between the wing-cases. The anterior abdominal spiracles are subdorsal, and the others are lateral.

Rudimentary tubercle setæ correspond to the larval tubercles in position (fig. 19). In some groups, as *Rhopalocera*, prominent protuberances are developed. In most groups the armature of the posterior extremity of the pupæ is most interesting. *Nyctemera annulata* (*Arctidæ*) has a blunt posterior extremity, with about a dozen weak, thin, hooked bristles arranged postero-dorsally (fig. 23). *Melanchra composita* (*Noctuæ*) has a less blunt extremity, terminated by two strong spines, in front of which on each side are a lateral and a subdorsal spine (fig. 21).

The pupa of *Asaphodes megaspilata* (*Geometræ*) has a pointed extremity and two strong spines, and a single weaker spine on each side (fig. 22). *Vanessa gonerilla* (*Rhopalocera*) has the extremity of the pupa extended considerably, with a large number of terminal hooks by which it is firmly suspended from its silken pad.

Species which feed externally during larval existence may be pitted with small cavities or minutely rough on surface of the pupal segments, but have no segmental spines except at the posterior extremity; there may be exceptions, but this is characteristic. Species which feed internally during larval existence—in fruit or wood—or live in cases, have an interesting character in the pupal stage, in segmental spines or hooks, which assist the pupa to emerge from the larval habitat.

Hepialidæ have numerous points or spines (not hooks), which are placed close together along the anterior and posterior ridges of the dorsum of the abdominal segments, and also ventral spines; these are all directed posterior, are not present on the anal segments, which are without terminal armature. *Carpocapsa pomonella* (*Tortricidæ*) has anterior and posterior segmental spines on the dorsum; these spines are a little distance apart, directed posterior, and extend to the anal segments. There are no ventral spines, but the blunt anal extremity has an armature composed of a pair subdorsal a pair sublateral hooks on each side (fig. 24). *Œceticus omnivorus* (*Psychidæ*) is remarkable in the male pupa, which is provided with numerous small hooks on the posterior edge of the 3rd, 4th, and 5th abdominal segments dorsally; these are directed anterior. On segments 6, 7, and 8 a mid-dorsal patch of about twelve very strong hooks are

directed posterior. The anal extremity is blunt, with a pair of strong hooks curved ventrally (figs. 19, 20).

It is unnecessary to refer to the structure of the imago stage, Mr. G. V. Hudson having done so in his work on New Zealand *Macro-lepidoptera*, but in my next papers, if you will have them, I shall give descriptions of the structure and life-histories in detail of those species of New Zealand *Lepidoptera* which I have been able to study and which have not hitherto been published.

EXPLANATION OF PLATE IX.

Fig. 1. *Vanessa gonerilla*, ovum, lateral view; × 50.
Fig. 2. " ovum, apex.
Fig. 3. *Tinea pellionella*, ovum, lateral view; × 100.
Fig. 4. *Asaphodes megaspilata*, ovum, lateral view; × 50.
Fig. 5. " 3rd abdominal segment, larva, first skin, lateral view; × 200.
Fig. 6. " 6th and 7th abdominal segments, ditto.
Fig. 7. " 9th and 10th abdominal segments, ditto, dorsal view.
Fig. 8. " tubercle seta, much enlarged.
Fig. 9. *Vanessa gonerilla*, 3rd abdominal segment, larva, first skin, lateral view; × 200.
Fig. 10. " 3rd abdominal segment, ditto, dorsal view.
Fig. 11. " tubercle seta, much enlarged.
Fig. 12. " 3rd abdominal segment, larva, second skin, dorsal view; × 50.
Fig. 13. *Rhapsa scotosialis*, 4th abdominal segment, larva, second skin, lateral view; × 50.
Fig. 14. " trapezoidal tubercle and skin-growth; × 200.
Fig. 15. *Tinea pellionella*, 3rd abdominal segment, larva, first skin, lateral view; × 200.
Fig. 16. *Œceticus omnivorus*, 3rd abdominal segment, larva, first skin, lateral view; × 200.
Fig. 17. " 3rd abdominal segment, ditto, dorsal view.
Fig. 18. *Metacrias strategica*, 3rd abdominal segment, larva, first skin, lateral view; × 200.
Fig. 19. *Œceticus omnivorus*, 6th abdominal segment, pupa, dorsal view; × 50.
Fig. 20. " 9th and 10th abdominal segments, pupa, lateral view; × 50.
Fig. 21. *Melanchra composita*, 10th abdominal segment, pupa, dorsal view; × 50.
Fig. 22. *Asaphodes megaspilata*, 10th abdominal segment, pupa, dorsal view; × 200.
Fig. 23. *Nyctemera annulata*, 10th abdominal segment, pupa, dorsal view; × 50.
Fig. 24. *Carpocapsa pomonella*, 7th to 10th abdominal segments, pupa, lateral view; × 50.

(The magnification quoted is approximate, not absolute.)