- V. *On the Anatomy and Development of Comys infelix, Embleton, a Hymenopterous Parasite of Lecanium hemisphaericum.* By ALICE L. EMBLETON, *B.Sc.*, 1851 *Exhibition Science Research Scholar; Associate of the University of Wales (Cardiff College).* (Communicated by Dr. DAVID SHARP, *F.R.S., F.L.S.*)

(Plates 11 & 12.)

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I. INTRODUCTION.

THE subject treated of in this paper is of interest both to the biologist and to the economist. *Comys infelix* is a very small Hymenopterous fly belonging to the family Chalcididæ, the members of which have long been recognized as beneficial from an economic point of view, inasmuch as they are great destroyers of the Coccid pests that are so inimical to cultivation in all parts of the world. Biologically this species of Hymenoptera claims attention by virtue of its remarkable life-history, the early stages of which are passed inside a scale-insect, while the imagines, male and female, lead a free life after emergence from the Coccid. In spite of their two-fold importance, little is known about these insects, and their life-histories remain obscure. Recently Bugnion (9) has published the results of his researches on the development, anatomy, and habits of *Encyrtus fuscicollis*, a form allied to *Comys infelix*, though with very different habits. He mentioned the fact that many embryos of this species were to be found enclosed in a capsule, or tube, in the interior of the host—a caterpillar, but he did not thoroughly elucidate the matter. Since Bugnion's paper was published, Marchal (39, 40, 41) has discovered that his species (now called *Ageniaspis fuscicollis*, Dalm.) offers in its development an example of the phenomenon so rare in zoology, and of extreme interest from a philosophical point of view, of dissociation of the embryo. In an early stage of the development, the embryo breaks up and forms from fifty to a hundred embryos. The development of this insect is being studied by this accomplished French savant, and we anticipate most interesting results. He suggests that the species of *Ageniaspis* afford

examples of chronic segregation, the individuals being separated in the times of their appearance in conformity with the habits of the species of which they are parasites. No morphological differences have yet been detected between the "seasonal races" in this case.

Apart from the investigations of these two naturalists, there has been, within the last few years, work done on the *Encyrtinae* by the American school of entomology, especially by Dr. L. O. Howard and Dr. Ashmead, but their studies have not been directed to investigation of the ontogeny.

I propose, therefore, in this paper to record the results obtained after work for eighteen months on the Chalcid, *Comys infelix*; from the nature of the case there are necessarily some points which are left obscure.

As the species I am dealing with has at present only been characterized by a few diagnostic words, it may perhaps be well here to give very briefly the distinguishing features serving to identify it among other species of the genus—especially to distinguish it from *Comys bicolor*, which it resembles to some extent. At first I took it to be that species, but further investigation pointed to the conclusion that I was dealing with a new species. I submitted it to Dr. L. O. Howard, who confirmed my opinion, as did also Mr. P. Cameron and Mr. R. Newstead.

COMYS INFELIX, Embleton (Trans. Entom. Soc. London, 1902, ii. pp. 219–229).

A small fly, 2 mm. in length, 3.75 mm. across the outstretched wings. *Colour* extensively black, but variegated, the head and thorax dark brown, abdomen black; the coxæ of the *first legs* are silvery white, the other parts fuscous and the tarsi black; tibial spur normal; in the *second legs* the coxæ are black, the femora white shading to black, the tibiæ being expanded at the distal ends, and bearing a long, powerful spur; the *third legs* have white coxæ, brown femora, and dark brown tibiæ with a normal spur, the tarsi begin white and then shade to black at the tip; the tarsi are all five-jointed. The *antennæ* are black, club-like at the tips, compressed in the female, but subcylindrical in the male; there are eleven segments, all more or less clothed in fine hair; the funicle is six-jointed, while the pedicel is shorter than the next segments. Between and rather behind the two large dark *eyes* are three *ocelli*. The *scutum* is raised and triangular, bearing an apical tuft of long dark setæ, directed backwards. The *fore wing* is mottled in blackish fuscous patches. The *abdomen* is short, and united to the thorax by an inconspicuous petiole; laterally the abdominal segments become "looped up" over a small oval hinged plate on which are four long setæ. The *ovipositor*, almost entirely hidden, is composed of two large expanded chitinous plates, and a central sting made up of two pointed rods.

II. NATURAL HISTORY.

(a) *Classification*.—The creature belongs to the subfamily *Encyrtinae*, according to Howard in Comstock's report (10). The distinguishing characters of the Chalcididae as given there are as follows:—Tarsi five-jointed; middle tibiæ with a very stout spur at

the tip. The *Encyrtinæ* come under this family and are distinguished from the *Aphelininæ* by the fact that the antennæ are more than eight-jointed. It is perhaps best to quote the more detailed diagnosis of the distinguishing characters of the *Encyrtinæ* as given in Comstock's report :

"Subfamily *Encyrtinæ*.—Tarsi five-jointed ; middle tibiæ somewhat dilated towards the tip, and furnished with a long stout spur ; antennæ more than 8- usually 11- or 10-jointed. Parapsides of the mesoscutum not separated by furrows ; mesothorax prominent, broad in the middle ; vertex with an acute occipital margin ; abdomen usually short and sessile. The members of this tribe are small active Chalcids, which, while by no means confined to Coccids as hosts, still are much more often parasitic on insects of this family than upon those of any other. Dr. Mayr (42), in his paper upon the European *Encyrtinæ*, tabulates the species according to their hosts, and we may briefly condense by saying that one species is parasitic upon an Hymenopterous insect, two upon Coleoptera, four upon Lepidopterous eggs, sixteen upon Lepidopterous larvæ, four upon Diptera, while forty species are parasitic upon Hemiptera, of which thirty-nine infest bark-lice, the remaining one being found upon two species of Aphides. Ratzeburg (46) mentioned two species of *Encyrtinæ* parasitic upon Hymenoptera, four on Coleoptera, four on Diptera, twelve upon Lepidoptera, and no less than twenty-five upon Hemiptera. Even these facts, however, cannot be taken as fairly indicating the proportion of these insects which are parasitic upon the Coccidæ, since the latter family has heretofore been so little studied in comparison with other groups, that doubtless many of its parasites have never been reared. When as much biological work shall have been done upon it as, for instance, upon any one of the families of Lepidoptera, we may expect to find that the proportion of *Encyrtinæ* parasitic upon insects of other families will become dwarfed by comparison."

"Genus *Comys*, Förster (19, 20, 21).—Antennæ rather long, eleven-jointed ; funicle six-jointed ; pedicel slightly shorter than the succeeding joints, from joint three the joints of the flagellum gradually decrease in length, with the female they become more and more compressed towards the tip of the club, with the male remaining subcylindrical. Head and face coarsely punctured. Mesoscutum without silvery white hair. Scutellum three-cornered, with a somewhat rounded tip, near which is a tuft of erect, long, stiff dark hairs. Ovipositor entirely, or almost entirely, hidden. Fore wings brownish on the distal half, the nearly clear basal half having a brownish cross streak ; marginal vein shorter than stigmal ; post-marginal and stigmal long. Males very similar to females, antennal characters giving the only absolute distinction ; wings sometimes clear, and sometimes brownish as with females."

(b) *Mode of Occurrence, &c.*—*Comys infelix* was first noticed in August, 1901, on an *Asplenium* fern parasitized by *Lecanium hemisphaericum* * var. *filicum*, and by *Chionaspis aspidistræ*, Signoret. I observed that *Comys infelix* emerged from the *Lecanium*, with

* I notice that some of the most recent writers (in 1902) have called this Coccid *Saissetia hemisphaerica*. I have not been able to discover why this alteration has been effected, if it is so, for the name *Saissetia* was used in Mollusca in 1900, and is therefore preoccupied.

which the fronds of the fern were covered; a small round hole was left in the dorsal shield of the scale as the only indication of its destruction by the fly; neither then nor since have I found more than one fly emerge from one host or victim. From the small white *Chionaspis* a very minute fly hatched out in abundance; it is apparently *Aspidiotiphagus citrinus*, Howard (.35 mm. in length), but I have not at present been able to continue the work on this species.

I soon discovered that the same kind of fly existed in the *Lecanium* when this occurred on other ferns—viz., *Aspidium falcatum*, *Asplenium* spp., *Pteris* spp. (?): usually the *Pteris* was most abundantly stocked with the scale; it also occurs on *Beaumontia*.

It is an interesting fact that the flies hatched out all through the year, though in fewer numbers in the winter, but appearing in great profusion in spring and early summer; similarly the earliest larval stages were most common in late summer and early autumn, but it was always possible to obtain the different stages all the year round. This continuity of production may merely be the result of the artificial conditions under which the insects live, for the palms and ferns which their hosts inhabit are all hot-house varieties experiencing fairly constant conditions as regards food-supply, warmth, and moisture, whereas in a state of nature they might be subject to seasonal changes. I have never found the parasite on ferns growing out of doors, and the *Lecanium* itself is considered to be exclusively a greenhouse species in Europe and America.

The females are much more common than the males, which appear comparatively rarely, and then only in small numbers; so far, I have found them in the spring and early summer. I shall subsequently mention that this disproportion of the sexes in *Comys infelix* is very great, perhaps a thousand females to one male: this is the only circumstance I have noticed that suggests the natural time of emergence, which, if this may be relied on, is the first warm weather of spring. It was at this period, too, that the females were produced in greatest numbers; the sporadic appearance of other examples is therefore quite probably due to the unnatural conditions of existence as stated above. The male is so rare that I have had but little opportunity of observing it, and owing to this rarity my remarks may be considered to apply only to the female except when the other sex is specially mentioned. During the time when the flies were so abundant, I kept them under cages with flowering *Genista* plants and some parasitized ferns. They were always most active in the direct sunshine, and in the first week of March, when I had a cage of them in the sun, I observed pairing to take place for the first time; subsequently I observed it repeatedly.

I was not fortunate enough to observe oviposition, but I will quote an account given by Mr. R. Newstead (43 a) (which he has kindly placed at my disposal) of the occurrence in an allied form—*Blastothrix sericea*, Dal. “On the 17th of October, 1901, after long and careful watching, I observed for the first time one of the chalcidid parasites in the act of laying eggs in the body of a coccid. When first seen, the parasite was running swiftly from place to place, evidently searching for a suitable host; its antennæ were bent downwards almost at right angles to the long scape forming their basal half, and were moved up and down rapidly and alternately, the tips each time

touching the path of the insect as it progressed. Many coccids were examined, and, when a suitable one was found, the parasite turned its head towards the anterior extremity of the coccid, and, resting with all its feet upon the body of the latter, inserted its ovipositor into the centre of the thoracic area; it then slowly moved its abdomen up and down, and apparently laid its eggs in the puncture; the parasite then withdrew its ovipositor, and, turning round abruptly, feeling its way again with its antennæ, seized with its jaws the lips of the wound made by its ovipositor, and distinctly closed them upon it and apparently pressed the edges together; finally it passed the palpi over the wound, and then left the coccid to its fate."

These insects do not—as is the case with so many species—seek the light; on the contrary they prefer the shadow. I tested this many times by having them in a glass vessel, of which one half was illuminated and the other half shaded; they always left the light for the darkened end. This behaviour is all the more unexpected seeing that in the sunlight their activity was always so marked, but it may be that they were resting and therefore preferred to be in the dark. For the most part, they sit inactive on the plant on which they are bred; they seldom offer to leave it, flying but rarely and then only under the stimulus of strong sunshine; such flights are short, never exceeding the distance between one fern-frond and the next. Their most usual mode of locomotion is walking at a relatively rapid rate, supplemented by sudden jumps, effected doubtless by the powerful tibial spurs of the second legs; by this leap they often cover a distance of one or two feet. This rapid running movement gives them a certain likeness to ants, which they resemble curiously in colour and size, for their wings are carried folded flat upon the dorsal surface and are inconspicuous. The antennæ are constantly feeling and moving, as is also the case with ants, and at first sight this motion is sufficient to suggest the resemblance.

(c) *Economic Aspects*.—From an economic point of view *Comys infelix* is of signal importance inasmuch as it destroys one of our most injurious scale-insects. Coccidæ attack a great many plants of commercial value and do immense damage; usually the horticulturist combats their ravages by means of spraying with insecticides, but the question of parasites is of the greatest importance. In a preliminary paper on the "Economic Importance of the Parasites of Coccidæ" (17), referring to *C. infelix*, I have said that "as far as I can judge from the facts that have come under my observation, I am led to rate very highly the value of these parasitic Hymenoptera as destroyers of Coccid pests. In the case of *L. hemisphæricum*, King's statement that it is one of the commonest pests in greenhouses applies to the district round Cambridge as well as to the United States, and the pest is satisfactorily controlled by the parasite. If the parasite is not found in other districts where the scale is injurious, it should be introduced there. Considerable difficulty has been experienced in the attempts to distribute the predaceous enemies, but in the case of the internal parasites, the task is much simpler, and success will be easier to attain, for it is only necessary to transmit a small plant bearing a few parasitized Coccidæ. From my work on this species I am led to believe that the *Encyrtinæ* are remarkably tenacious of life in their early stages." As regards the quarantine regulations that are so strictly enforced in many parts of the world, I

remarked that "the creatures may be imported on merchandise or by insects as well as on plants. Neither should it be forgotten, that if a pernicious scale be once introduced, then the parasites that may be contained in the scales are excluded. To avoid this, a knowledge of the marks by which parasitized scales can be distinguished from others, is really essential in the carrying out of the quarantine regulations" . . . "it is of utmost importance that, previous to any attempt to destroy the Coccidæ, it should be ascertained whether internal parasites are present or not. If they are found in large proportion, then time should be allowed before any insecticide be used, so that the parasites may emerge from all those individuals containing them, so as to allow the beneficial creature to be perpetuated and increased. After the emergence of the flies, then the Coccidæ, if any such there be, may be killed by using those insecticides which are especially adapted to the particular case." There seems, however, to be some difference of opinion on this subject of the importance of Hymenopterous parasites, but I find myself more and more convinced of the views expressed in the preliminary paper, because of the simple fact that having had this scale-insect under observation for a long time I can testify to the well-nigh total destruction of it by *Comys infelix*. I can readily understand the reluctance of those who have not had this advantage to admit the fact, when I recall that there may be a thousand scales on a plant, and that though nearly every one may be really parasitized and consequently utterly destroyed, there is nothing to reveal this. One must first understand the signs of parasitism in the scale before being able to appreciate the work done by the fly. In economic work of this description it is therefore of the utmost importance that the marks of parasitism should be recognized. I have shown a plant covered with parasitized *Lecanium* to people used to making biological observations, and they could not believe that the scales were parasitized and destroyed until they saw the fly actually emerge, and that although the parasitism was nearly complete.

It is necessary, in dealing with all insect pests, to use much vigilance and caution, but at the same time to combat them whenever they appear; but this can only effectually be through a proper knowledge of their habits and life-histories, for it is possible, as already stated, to do harm by destroying some beneficial creatures which live upon the pest. In countries which have been under cultivation for centuries a balance between the destructive and beneficial forces has been produced by adaptation, and in this way the destructive species are kept in check; it is therefore essential that care be taken not to remove any of the factors which help to maintain this necessary and delicate equilibrium. It is, at the same time, of utmost consequence that as soon as an injurious creature makes its appearance, it should be watched carefully; in the event of a species coming into the country, in the very early stages it may be dealt with successfully by resorting to hand picking, giving it, if possible, no chance to become established. An added danger to the introduction of an injurious species from another country, is the fact that in its native land it is accompanied by some enemy which keeps it in check; but when it sets up in the new home, it is free from this restraint and spreads enormously in consequence. In the case of parasites of injurious creatures it often happens that they can also be introduced with ease, if, for example, they happen to be beetles, flies, birds,

lizards, &c. It is a recognized method to reduce a pest by introducing some enemy from another country. This has been done in America against injurious scales, by introducing little Chalcid flies from Europe.

Thus the basis of economic entomology is life-history work, which has wider bearings than merely following and observing the different stages in the life-cycle of an insect, for all these separate pieces of work on life-histories contribute towards the solution of the great biological problems of distribution, adaptation to environment, parasitism, and even add to the data on the questions of heredity and variation*. In order to arrive at any knowledge of how to control injurious insects, it is obvious we must first learn the facts of their life-histories, together with a knowledge of the distribution, food, enemies, climatic needs, &c., until its limitations can be outlined with approximate correctness—then any steps taken to deal with it will probably be successful. This subject is at present warmly debated in various parts of the world, and some contend that in the long run it is better to trust to Nature than to extensive artificial operations. My contention is, that we may only trust to Nature when we have obtained a knowledge that will warrant us in so doing, and that will probably enable us to restore natural conditions when they have been abruptly infringed.

Since my paper, above referred to, was published, Professor Antonio Berlese, of the R. Scuola di Agricoltura, at Portici, has taken up this question and published two important papers on the method of Economic Zoology; and as he takes the same view of the subject as I have done, I hope he may be successful in his effort to attract greater attention to the economic importance of the parasites of Insects.

III. DEVELOPMENT, AND STRUCTURE IN EARLY STAGES.

(a) EGG.

I have examined the ovaries of a large number of the flies immediately after their emergence from the scales: though I cannot † say how long the specimens had been in the imago condition inside the host, I found the eggs were present in the tubes in an already advanced stage of development (Pl. 11. figs. 2-5). It usually happened that the ovaries became crushed so that the eggs were most of them free. I have not been able to decide definitely whether the different stages of growth of the eggs are connected with different positions in the egg-tubes; but probably it is so, the egg nearest the oviduct in each tube being the most advanced. Except those in the very earliest stages, the eggs had the appearance of two masses of yolk connected by an isthmus; it is clear that this isthmus ultimately becomes the appendage of the perfected egg, which, as will be seen

* A German economic entomologist, Dr. L. Reh, of Hamburg, is at present engaged in enlightening public opinion as to the value of knowledge of this sort.

† The reason why I am unable to say when the imago condition is reached, is because the creature is inside the Coccid, and to expose it is to destroy it, and so no individual case can be traced. This difficulty will always be met with, and is insurmountable. From external signs it is possible to tell roughly when the creature pupates, because then it turns black, and this can be detected through the shell of the Coccid. But there is no such clue to the time when the imago condition is assumed.

from Plate 11. figs. 6, 7, 8, is of a very remarkable form. It was difficult to decide in certain cases whether this neck was or was not equally connected with both masses; if so, it certainly soon becomes the exclusive property of the mass that will become the egg. There is a considerable difference in the two masses, more especially as regards the contents. The future egg-mass is almost oblong in shape, while the other portion is spherical and smaller; the granules in the former are larger and more concentrated than in the latter. It is a fact of interest and of some significance that the two masses or parts of the egg always respond in strikingly different ways to various staining reagents; for instance, when treated with methyl green in acetic acid and mounted in dilute glycerine, the true egg-mass and isthmus show a clear green-blue colour, while the other mass is purple. I observed that this stain behaved with similar distinction in other cells belonging to different parts of the body, the nuclei presenting the same colour as the egg-mass, and the cytoplasm of the cells the same as the yolk-mass. I could find no nucleus in the egg.

In the earliest stages the egg is an oval body containing coarse granules; this stage is followed by one in which a slight constriction is observable in the middle; this gets more and more marked until the condition of two masses connected by a fine isthmus is assumed. All these stages are found within a membranous covering (Pl. 11. figs. 2-5). In the latest stages a curious structure is present on the neck part of this dumbbell-shaped egg; it is a valve-like projection, pointing towards the yolk-body like a lip. There is still a connection between the two masses (Pl. 11. figs. 6-9), but where this lip is situated there is an appearance of fine papillation or striation on the wall of the tube. At the distal end of the yolk-mass there is evidence of some thickening of the wall, but I cannot find any definite structural peculiarity beyond this. This dumbbell-shaped condition measures .35 mm.

I also examined flies which I had kept alive for a week or two on flowering plants, and in them I found eggs as stalked bodies; that is, the yolk-mass had disappeared, and left only the true egg-mass with the isthmus appearing as a stalk. This appendage ends as a curious forked apparatus, representing the valve or lip present on the connecting tube in an earlier stage. The papillated appearance is now more conspicuous; in the neck of the stalk, at the point where it forks, there is a plug of protoplasmic matter (Pl. 11. fig. 7). From this stage, though I could not observe the act of oviposition, I traced the egg to its destination in the body of the scale, where it is always situated on the right side of the anus (if one looks at it dorsally, towards the head). The form of the egg now is identical with that when last seen in the fly; it measures .25 mm., and always has the plug of matter in the stalk. In older Coccids, where the young larva is present, then the tail of the larva is seen to be capped with the remains of the stalked egg-case, the body of the egg having split into two when the larva emerged. This stalk measures .05 mm.

To summarize the processes I have described, I may say that the mass of matter from which an egg is developed becomes constricted in the middle until it finally assumes a dumbbell form; *i. e.*, two masses are connected by an isthmus. In this condition, changes between the two masses take place by means of the isthmus, as the result of

which, one mass becomes predominant and forms the egg; a portion of the isthmus remains attached to the egg as its stalk or appendage.

It is desirable to call attention to this, as I am not aware that any form of oogenesis quite similar to this has been described. I may add that, when I had made only a few observations, I thought it probable that the original mass of formative material divided into two, and that we might find ourselves in the presence of a condition suggesting an initial stage of dissociation of the embryo, but I was soon convinced that this was not the case. The fact that chemical stains and reagents acted differently on the two masses is of importance, indicating an essential dissimilarity in the nature of the two halves.

(b) LARVA.

In tracing the early life-history of the fly a serious practical difficulty is met with, inasmuch as it is impossible to follow the same individual through the different stages, for to be able to observe it in the scale it must be exposed, and thus killed. In this way there is no certainty regarding the exact continuity of the observations; I have endeavoured to obviate this as much as possible by examining a great number of the parasitized scales in all stages of growth and at all times of the year; even so, I am sorry to say that there are some links missing from the chain.

General points.—In preparing these larvæ for the microscope, the best results were obtained with those which had been removed from the Coccid, and then suspended on a watch-glass in the vapour of osmic acid over the mouth of a bottle containing a .5 per cent. solution. In a minute or two the larvæ look brown; they are then washed carefully in water and mounted in glycerine. Others were mounted in Canada balsam, but in these preparations some shrinkage always occurred. Some I stained with borax- or alum-carmin, but the osmic acid preparations possessed many advantages. This applies also to the later stages in the metamorphosis before the pupal stage is reached, when the creature becomes black and chitinous.

i. *First observed Stage.* (Plate 11. figs. 10, 11, 12, 13.)

External form.—I refer to this as the first “observed” stage, because it is probable that the larva immediately on hatching may be different from the youngest specimens I have succeeded in finding; the hypermetamorphosis may be greater even than that which I shall describe.

The larva of the fly is found in the younger Coccidæ as a soft white tapering maggot .75 mm. in length; the head is not differentiated in any conspicuous way from the rest of the body, the anterior end being merely bluntly rounded. Behind what may be called the “oral segment” are thirteen segments, including the bifurcated tail-segment; this segment is a most unusual structure, for the body terminates in two long tapering tails, each with a tracheal trunk continuing to its tip, suggesting that this is an adaptation subserving respiration. These delicate prolongations are always embedded near the anus of the host, and very frequently are capped with the old egg-case. The question of the respiratory significance of this apparatus will be discussed later.

Tracheal system.—The main tracheæ run in two lines parallel with the sides of the body; being full of air, they can be seen plainly through the semitransparent body-walls; anteriorly they are connected by a transverse commissure in the second segment behind the head; there is also a posterior connection.

Bugnion (9) states that there are nine pairs of stigmata in the larva of *Encyrtus fus-collis*, occurring in the segments two to ten. Reinhard (47) has counted the same number in *Pteromalinae* larvæ (*Decatoma*, *Callimone*, *Eupelmus*, *Pteromalus*). Laboulbène (35) describes also nine in the larva of *Pimpla Fairmairei*; but Ratzeburg (46), in the larva of *Anomalon circumflexum*, a parasite of *Bombyx*, found no stigmata at all, which he says is due to the fact that the larva lives inside the caterpillar. In the larva of *Comys infelix* at this stage I have been unable to detect any stigmata, though I have employed many methods in preparing the larvæ for the microscope, but always with negative results. Possibly the tail-apparatus takes the place of stigmata, for it is a most remarkable arrangement, and suggests a parallel with the metapneustic tracheal systems of some Dipterous larvæ in which there exist only a terminal pair of spiracles. In some metapneustic Dipterous larvæ a pair of anterior spiracles appear later; this is then called an amphipneustic larva. The arrangement in which the normal stigmata are present is called peripneustic.

Alimentary system.—In the bluntly rounded anterior end there is a circular mouth with a soft rim or lip (Pl. 11. fig. 11); inside there are two chitinous mandibles, each being a simple tooth or claw, one of which overlaps the other; these mandibles possess a powerful muscular apparatus. From the mouth, the alimentary canal runs to the tail; immediately behind the mouth there is a funnel-shaped pharynx, leading through an œsophagus to the stomach, in about the third segment. On either side of the stomach is a gland, probably possessing a salivary function (Pl. 11. fig. 13); these glands open into the pharynx. The alimentary tract is straight, apart from the stomach, which is sac-like and fills the larger part of the body-cavity, and contains fat-globules and other dark-coloured granules; it looks darker than the rest of the body, which is white, and, under a high power of the microscope, is seen to be granular. There is a short intestine behind the stomach, but at this stage it is not connected with the anus.

ii. Second Stage.

External form.—The body now measures 1.75 mm. As the two-tailed larva grows its contents get more and more aggregated into ball-like masses. The body becomes rounder and thicker, while the tails atrophy (Pl. 11. fig. 13), till the stage is reached (fig. 14) in which the posterior end is rounded, but the two tracheal trunks are still visible projecting out of the body as withered ends not yet quite cast off.

Tracheal system.—Apart from the difference in the tail-apparatus, the two main tracheæ remain unaltered except for the fact that in each segment they give off a group of secondary branches. In this stage I have found the anterior and posterior commissures still present; in front of the anterior connective the main trunks continue, ultimately ramifying in the head; behind the posterior commissure the trunks are

continued, finally projecting out of the body as withered atrophied remains of the tail-apparatus (Pl. 11. fig. 14). Between these two transverse connectives are eight pairs of side branches, more marked than the finer anastomosing branches of tracheæ that, as stated, are given off in each segment. Of these eight pairs of conspicuous side branches, the first and last have each a definite spiracle, but the six pairs between have no spiracles, or else they are so small as to be unfunctional. This is an interesting condition between the peripneustic and the amphi-pneustic arrangements.

Alimentary system.—The mouth and mandibles show no alteration, and the alimentary canal is unchanged except that its contents are more marked in colour and quantity, and that the communication with the anus is now probably established. The coloured refringent granules in the stomach are most noticeable.

iii. *Third Stage.*

External form.—The larva now has become more swollen and measures just over 3 mm. in length (Pl. 11. fig. 15), and it is only very occasionally one finds traces of the tail-tracheæ outside the body.

Imaginal discs.—It is now possible to discern in outline the early rudiments of the future organs of the imago: these rudiments Weismann called “imaginal discs”; Künckel d'Herculais (34) called them “histoblasts,” and Miall refers to them as “imaginal folds.” Gradually they assume a form (Pl. 11. fig. 15) in which the *antennæ* can be seen as a pair of plate-like bodies near the mouth. Behind and almost above these is a pair of circular discs from which the eyes will arise. The buds which will ultimately form the buccal folds are also discernible. The leg-rudiments (Pl. 11. fig. 15, *l.*¹⁻³) come behind the eyes, and on the outer margin the wing-rudiments are plainly traceable. Nearer the posterior end of the body are two oval masses of cells, representing the future sexual glands (Pl. 11. fig. 15, *s.g.*)—ovaries or testes; and following closely on these are three pairs of bud-like bodies, which are the rudiments of the sting (Pl. 11. fig. 15, *st.*¹⁻³).

Tracheal system.—The tracheal trunks still have a lateral course, connected by an anterior and posterior transverse commissure. The stigmata are as in the preceding stage, but in connection with each of the four spiracles described as functional in that instar, there is an apparatus by which intercommunication is apparently set up between the respiratory systems of the host and parasite (Pl. 11. fig. 15). From each of these four spiracles there is a double tracheal tube running out into the host's body; these two branches become subdivided and ramify in the host-tissue, and by this means, it seems, the parasite obtains its air-supply. Whether these ramifying tracheæ originate from the tracheal system of the Coccid host, or from that of the parasite for whose benefit we may presume they are functioning, is quite obscure. If the former be the correct interpretation, we must conclude that the host develops a respiratory system for the benefit of the parasite that is destroying it. If, on the other hand, the structures originate with the parasite itself, we have to deal with the remarkable fact that they constitute a tracheal system entirely outside of the creature to which they belong. Bugnion says that in

Encyrtus fuscicollis the tracheæ of the host ramify on the tube containing the parasite, and serve for respiration of the young *Encyrtus*. The only other case I can find bearing on this point, is that described in 1837 by Dufour, of *Andrena aterrima* and a parasitic Dipterous larva*. Dufour claims that two of the host's tracheæ grow into the body of the larva, which is thus supplied with air; but there seems some doubt about the inter-relationship in this case.

As this instar passes into the next, the posterior pair of external tracheæ become marked by the appearance of three red-brown plate-like structures on each side of the body of the larva (Pl. 11. figs. 16, 17, 18, *pl.*); they are situated at the point where the radiating external tracheæ are united with the body-wall. These curious plates are present in the pupal condition, but are left behind when the pupal skin is cast.

Thus we see, in summarizing the facts recorded above, that in the larval condition respiration is at first carried on by means of a bifurcated tail-apparatus in which the two lateral tracheal trunks are continued; in this condition there are no spiracles, but later on the two tapering tails atrophy, and spiracles are developed. This condition is superseded by an arrangement of tracheæ ramifying outside the parasite, in the body of the host; there are now 8 pairs of stigmata, and the posterior pair of radiating tracheæ arise in the 9th segment behind the head.

Before the next (or prepupal) instar is reached, a process of histolysis takes place by which the internal organs are completely broken down, to be built up into the pupal tissue by means of a process of histogenesis, or regeneration.

In this instar, or at any rate during the later period of its existence, the larva appears to possess a membranous coat, or sheath. It is to a membrane of some kind or other that Bugnion refers in the passage quoted above as to the respiration of the larva of *Encyrtus fuscicollis*: he states that the embryos are all in one long common capsule, and he is of opinion that this is a product of the egg; but the case differs so widely from that of *Comys infelix*, that his facts cannot be of much service in making a parallel argument. As to the nature and origin of this sheath in *Comys infelix*, I am quite in doubt. Subsequently, as we shall see in the next instar, there exists a well-defined and ample membranous sheath, but whether the membrane observed in the third instar is really the same as that found later, or not, I cannot say with any certainty; no actual ecdysis has, however, been observed, and I think it is probable that the sheath is a larval skin retained on account of the respiratory apparatus attached to it externally. The question is complicated by the appearance in the next (or prepupal) instar, at the base of this respiratory apparatus, of additional structures in the form of certain oval red plates (Pl. 11. figs. 16, 17, 18, *pl.*), which appear to be applied to the sides of the body at the spot where the tracheæ radiate out. If these were developed outside an old skin, it would be a very remarkable fact: I have alluded to the possibility that these respiratory structures are really formed by the host, and in that case there would be no difficulty in understanding that they undergo further development even on the separated skin of the parasite.

* Cf. Cambridge Natural History, Insects, ii. (D. Sharp), p. 26, fig. 13.

I have been unable to settle this question, for in order to do so with any finality it would be necessary to find the creature at the exact time when the change is taking place, and this would entail the examination of a vast number of individuals, and as each examination involves a careful dissection of the small host first, the time required would be considerable.

It is at this point in its life-history that the creature turns completely round inside its host.

iv. *Prepupal Stage.* (Plate 11. figs. 16, 17.)

External form.—A great change has taken place between this and the preceding condition, transforming the larva into the prepupa, or pseudonymph. In this instar the creature is still creamy-white, like the larval forms already described; it is, however, enclosed in a membrane (Pl. 11. figs. 17, 18, *m.*), which is probably the remains of the original larval cuticle, and the parasite is now head to tail in the Coccid, instead of head to head as was the case in the larval condition; its dorsal surface is now closely pressed to the inside of the dorsal surface of its host, whose body it now almost completely fills. The appendages, &c., of the imago body are well defined, though still imperfectly developed in this instar (Pl. 11. fig. 17). The head is differentiated from the rest of the body, the antennæ and eyes being clearly outlined, while the thoracic region has become more rounded. The rudiments of the legs and wings are folded across the ventral surface, and the segmentation of the abdomen is distinct, so that the creature now exhibits very definitely the form of the perfect insect. Internally, the organs have undergone less change as a result of the histolysis and subsequent regeneration. Packard (44, p. 67) has called this form the *semipupa*, and Siebold's term *pseudonymph* applies to the same instar; the nymphal form is attained after an ecdysis.

Tracheal system.—There are in this instar four large stigmata—three situated in the thoracic region and one in the abdominal segments, with six smaller abdominal stigmata which may not be functional, for only traces of the first five can be seen in the imago, and the seventh has entirely disappeared, or has fused with the sixth to form the large functional spiracle which is so conspicuous.

Situated on each side of the abdomen there are three oval red plates (Pl. 11. figs. 16, 17, 18, *pl.*), referred to above. These appear to be connected in some way with the respiratory function of the creature, for they are placed at the base of the large forked tracheal tube, which at that point effects its union with the body, or, in other words, branches out of the body at that point, to ramify over the membrane which encloses the insect. This membrane has been discussed when the preceding instar was being considered. Each of these curious plates is an oblong body applied closely to the outside wall of the abdomen; under a high power of the microscope, one of these plates is seen to contain red globules, of different sizes. It is not easy to determine what the function of these structures can be, but I suggest that they have some connection with respiration, seeing the radiating tracheæ arise at the same place as these anomalous plates. Nothing of this nature has been recorded by Bugnion as occurring in *Encyrtus ruficollis*, nor can I find elsewhere any statement bearing on these curious structures.

v. *Pupa*. (Plate 11. fig. 18.)

External form.—The pupa measures 2.25 mm. in length. The earliest pupal form is not of a uniform black colour, the dorsal surface alone being black. The fully formed pupa is, however, completely black and chitinous, though still enveloped by the cuticular membrane whose origin has been already discussed. The first organs to assume their final colour are the eyes and ocelli, which early become charged with dark red-brown pigment, at a period when the rest of the body is creamy-white; gradually the colour deepens all over the thorax and abdomen, though the head, apart from the eyes and ocelli, remains almost transparent for a considerable time. When the body has become uniformly black, the creature is in an inert, passive condition, unlike the preceding larval stages, in which slow movements from side to side take place as a result of external stimulus. But after a time this black, inert pupa becomes the perfect insect, and breaks through the enveloping membrane (Pl. 11. fig. 18, *m.*) and the old pupal cast skin, and with its mandibles cuts a small round hole in the dorsal shell of the Coccid, and escapes, to lead its free existence.

Tracheal system.—The abdominal plates (fig. 18, *pl.*) and the radiating tracheæ are still present, but when the imago emerges they are left behind with the old sheathing membrane. The pair of tracheæ which radiate out from the head region never develop these oval red plates at their bases; it may be that these plates are more connected with excretion than respiration. The nymphal respiratory arrangements are apparently very transitory.

In order to obtain, if possible, more detailed and exact knowledge of the larva and pupa while still within the host, I cut the undissected host into a series of sections with the microtome. To do this I tried various methods for softening and cleaning the chitin, but the most successful results were obtained when I employed eau de Javelle or eau de Labarraque, as suggested by Looss. The chitin in this way was rendered transparent and permeable to reagents. I first hardened the specimens, and then left them in 25 per cent. eau de Javelle for 18 to 24 hours, afterwards washing out thoroughly with water. They were then dehydrated, embedded in paraffin, and good sections were obtained; sometimes I stained, before embedding, with alum-carminé or picro-carminé (five to six days), but usually I found it best to stain the sections when on the slide.

But though the sections were good, there was little or nothing to be made out by this method of investigation, which was not seen better in macroscopic dissections; except, of course, histology, but that I have been content to omit.

IV. ANATOMY OF IMAGO, ♀.

(a) *Measurements*.—Length (without antennæ) 2.5 mm.; length of thorax .9 mm.; width of head .75 mm.; width of thorax .74 mm.; width of abdomen .74 mm.; length of abdomen .85 mm.; length of antennæ 1.25 mm.; extent of fore wing 1.5 mm.; extent of hind wing 1.25 mm.; width of fore wing .62 mm.

(b) *Antennæ* (Pl. 11. figs. 19, 20; Pl. 12. fig. 21).—The antennæ are relatively long

and club-like, composed of eleven segments, the funicle being six-jointed, while the pedicel is shorter than the succeeding segments. From the third segment, the joints which go to make up the flagellum decrease in length, but increase in width and become, in the female, compressed towards the tip; in the male they remain almost cylindrical. Except for the pedicel the whole organ is clothed with fine black hair. The antenna is light brown at its base, shading to black in the flagellum.

(c) *Head* (Pl. 12. figs. 26, 27).—The surface of the head and face is curiously sculptured and punctured; it is golden-brown, almost black beneath the eyes, which are very dark and composed of fine facets devoid of setæ. Between, and slightly behind, the eyes are three ocelli, the two basal being nearer the true eyes than they are to one another.

(d) *Mouth-parts*.—The maxillary palpi are the most conspicuous parts, being black and projecting laterally. The *maxilla* (Pl. 12. fig. 24) consists of a stout tooth made up of three joints, the second bearing the *palp* on its outer surface and a small club-like organ on its inner surface; there is next a broad flattened part of two halves; the palp comprises four pieces, and ends in a curious club-like structure with long setæ on its inner face and tip. The *lower lip* can be seen as a median structure below the mandibles (Pl. 12. figs. 22, 23); laterally it has a foliaceous setose apparatus united basally by a triangular membrane, to which is attached a labial palp on either side; this is made up of three segments. The *mandibles* are very simple, curved, plate-like organs, with setæ; they are approximately triangular in outline, the apices curving inwards, the bases being just above the maxillary palpi (figs. 22, 25). Overhanging the whole mouth-apparatus is an upper lip, with a setose edge (fig. 22, *u.l.*).

(e) *Thorax*.—Except for the shining black *collar* (Pl. 12. fig. 29, *c.*) the thorax is yellow with conspicuous darker patches of pigment and black hairs. The *pronotum* (Pl. 12. fig. 29, *pr.*) is almost circular; laterally it carries the small dark tegulæ. Behind the pronotum is the raised *scutellum* (fig. 29, *sc.*), a triangular area with the apex pointing backwards, and terminating in a tuft of long stiff black hairs, arising apparently in two longitudinal rows. The mesonotum and metanotum are black and glossy, the former serving as attachment for the fore wings, and the latter for the hind wings and third legs (Pl. 12. fig. 28). The thoracic spiracles are arranged in three pairs (Pl. 12. fig. 29, *st.*¹⁻³); the mesothoracic are in a suture, only seen by looking from the side; the metathoracic are conspicuous (figs. 28, 29).

(f) *Fore wing* (Pl. 12. figs. 19, 20).—The wings are mottled with black fuscous areas, and are covered with fine hairs, forming a fringe round the distal margin. At the base of the short incurving vein is a group of dark setæ, with a second group just behind. From the description of the genus as given in Comstock's report, quoted above, and from my figures, it will be easy to see the disposition of the wing-veins.

(g) *Hind wing* (Pl. 12. figs. 19, 28).—These wings are smaller and more delicate than the fore wings, and are not mottled, being uniformly transparent and clothed with fine short hairs.

(h) *First legs* (Pl. 12. fig. 31).—The *coxæ* are silvery white, while the *femora* are dark, separated from the coxæ by two *trochanters*; the *tibiæ* are slender and fuscous,

the spur being no longer than the first tarsal joint; the *tarsi* comprise five segments, the last being the *claw*, made up of two hooked down-curving setæ. The whole leg is covered with short dark hairs.

(i) *Second legs* (Pl. 12. fig. 30).—These differ from the first only in colour and in the length of the tibial spur. The *coxæ* are black, the two *trochanters* rather paler, while the *femora* are almost white; the *tibiæ* are yellow, and dilated distally; the *spur* is long and powerful, and by its means the creature performs the characteristic hopping movements; in preserved specimens the second legs project beyond the third (Pl. 12. figs. 19, 20, 30).

(j) *Third legs* (Pl. 12. fig. 28).—The small rounded *coxæ* are silvery white, the *femora* are brown and the *tibiæ* black, while the *tarsi* are almost white, the tip of the claw being black. The spur is of normal size, as in the first leg.

(k) *Abdomen* (Pl. 12. figs. 32, 33, 34, 35, 36, 37).—The abdomen is of a deep glossy black, with numerous long dark hairs, and ventrally a soft down of short hairs. There are seven segments succeeding the petiole. The structure of the exoskeleton of the abdomen in the perfect insect is not easily ascertained, for there are many obscure points, and it was only after dissecting a great number of specimens that I was able to arrive at even an approximately correct knowledge in this matter. After trying many methods, I found that the most satisfactory specimens were those that had been macerating for a day or two in water, until they were quite soft and greatly distended; in such preparations the black abdominal plates stand clear of each other with the swollen white internal tissue showing between: this was most useful, for in such a condition one could clearly and unmistakably make out the relative positions of the parts before dissection. Another advantage is that the pieces of the exoskeleton can be removed one by one if great care be used, and the whole series put together again on a slide and mounted in Canada balsam (Pl. 12. figs. 34, 35, 36, 37). An alternative method, which often proved very helpful, was to leave the flies in 10 per cent. (or 5 per cent.) KOH for 24 hours, when all the soft parts are destroyed, the chitinous parts remaining uninjured and in a condition in which they can be easily separated from one another; when properly washed, dehydrated, cleaned, and mounted in Canada balsam, the structure is seen to even better advantage than in the former method, for the chitin has become, to some extent, transparent. Nevertheless, the difficulty always remains that curved and rounded pieces of the armature must be flattened when mounted, rendering some distortion unavoidable. This difficulty is met with chiefly in the matter of obtaining a correct interpretation of the structures which go to make up the petiole (figs. 34, 35, 36, 37): This has a dorsal and a ventral face, each composed of two small chitinous plates, of which the dorsal pair is much the thicker and stronger, being always conspicuous in mounted preparations, while the ventral pieces need careful search before they are discovered. In these flattened mounted specimens, the dorsal factors of the petiole appear as a dark mass situated between the side wing-like parts of the abdominal plate immediately behind the petiole (figs. 34–37). In life these two lateral flaps of the abdominal plate curve round the abdomen to the antero-ventral face, leaving the petiole standing out in front; its dorsal elements also curve round, forming a sort of short tube,

the remaining (ventral) face of which is completed by the ventral pieces of the petiole. This dark basal portion of the petiole-ring is made up of two separate elements, meeting in the middle line, where they are very narrow; at the sides they are much deeper (Pl. 12. fig. 36), so that, in outline, the two together are cup-like in mounted specimens, with an almost straight base resting on the segment behind the petiole; the two sides are prolonged to form blunt points, which articulate with the propodium and make a concavity between, filled by a pallid membrane, like a semicircle between two horns. The (anterior) rim of this semicircle is a clear strong chitinous band. The chitin of these parts is smooth, and devoid of surface reticulations such as mark the abdominal plates. Ventrally (Pl. 12. figs. 36, 37) the structure of the petiole is very similar to that seen on the dorsal side, but the chitin of which these parts are composed is thin and reticulated, making them obscure and difficult to detect. Another difficulty too in investigating the ventral structures arises from the fact that these almost transparent parts often remain attached to the metathorax, and so get lost. But with careful manipulation it is seen that they are borne between two lateral horn-like projections of the segment abutting on the petiole, and that their anterior edge is not concave as in the dorsal region, but straight or slightly convex. The two strong outstanding points from the ventral abdominal segment apparently form the articulation, and in the natural position would point towards the dorsal surface on the face that meets the thorax; they would not point up and forward, as is necessarily the case when the parts are flattened-out under a cover-glass. This petiole, therefore, differs greatly from what prevails in either the Aculeate Hymenoptera or the Ichneumonidæ. Dorsally, behind the petiole there are seven separate plates (figs. 34, 36). Each plate, except the last, is made up of a median area connecting two lateral flaps. In the first of these (and what must be looked upon as the true second segment), the lateral parts are broad and wing-like, their function being to fold round the anterior face of the abdomen, curving towards the ventral surface; this segment bears no trace of a spiracle.

The 2nd, 3rd, 4th, and 5th plates form a progressive series, each with an atrophied spiracle. The flaps are bent back more in each segment (Pl. 12. figs. 34, 36) until in the 6th this curvature reaches its maximum, for the side parts are very slender until near the tips, where they expand. At this point there is the only functional spiracle in the abdomen: it is a large circular orifice (Pl. 12. fig. 40) surrounded by a chitinous ring; in the clear centre can be seen a tongue-like structure; the large trachea can be traced running from this spiracle into the body. The median part of the seventh plate is slender and deeply concave in front. The last dorsal plate has no lateral expansions; at its points on either side is situated a remarkable organ, which, for want of a better term, I refer to as the "tactile plate"; it is over this that the preceding plates have been looped, as it were (figs. 33, 34, 36, 39). This organ consists of a pear-shaped plate (figs. 42, 43) placed transversely to the length of the body, the pointed end being on the inner side; the plane of the plate is at right angles to the dorsal surface. The plate itself consists of a membrane stretched over a loop-like ring of chitin and supplied strongly with nerves; at its pointed inner end there is a solid chitinous rod, which, in the natural position of parts, points forwards at right angles to the length of the oval plate;

this rod is almost the same length as the plate, to which it is attached by a hinged joint, as may easily be proved by moving the rod to and fro on the plate-rim. The plate itself carries four long setæ, the two inner being the biggest, and the outer the smallest. It is hard to say what is the function of this curious apparatus. I have watched the living insect walking about for hours on a fern-frond, hoping to get some clue as to the use of this "tactile plate"; I have examined its structure microscopically, but cannot be certain of its function. In life, the long hairs were always standing out conspicuously from the side of the abdomen, and occasionally it seemed they were brought into a more erect and bristling attitude, but beyond that I observed nothing.

Turning now to the ventral elements of the abdominal exoskeleton, it is found that there are six large segments (Pl. 12. figs. 32, 35). Behind these there are two small sub-circular pieces, one on each side of the base of the sting, and two large pieces still further behind these, nearer the middle line close to the apex of the ovipositor; probably these are the vestiges of the seventh and eighth segments. The ventral plates are almost all alike, except that the one adjoining the petiole has the two horns pointing forwards (*cf.* petiole). The others all have the lateral parts rounded at the ends, and the surfaces are reticulated and bear fine hairs, becoming more numerous on the posterior segments. The last of the ventral series of plates covers the ovipositor, which is almost entirely hidden in life, though sometimes in a lateral view the tip may be seen protruding slightly (fig. 33).

I find but little information in books as to the structure of the abdomen of Chalcididæ. More attention has been given to the external anatomy of the Aculeata, but the structure of the abdomen in *Comys infelix* is so different from that of the Aculeates that the homologies of some of the parts are still an enigma to me. Bugnion, who dealt with the anatomy of a form allied to *Comys infelix*, left the difficult points of the morphology untouched; and he is also silent as to some of the important points of simple anatomy of this part of the body.

Ovipositor (Pl. 12. fig. 41).—The ovipositor or sting has been largely studied in the Aculeata, but I can find little information about it in the Chalcididæ. Certain portions of this organ in *Comys infelix* are so different anatomically from the sting of the Aculeates that it appears at first sight almost hopeless to homologize the two by mere comparison, and it is necessary to thoroughly understand the development to arrive at really permanent results. As regards this a preliminary difficulty exists: it is now generally admitted that the sting of the Aculeates is developed from appendages situate in the pupa on the eleventh and twelfth body-segments, the segments themselves being subsequently very highly modified to form parts of the complex apparatus. Bugnion has figured the ovipositor of *Encyrtus fuscicollis*, and it agrees largely with what I find to exist in *Comys infelix*; he also figures the buds of the appendages in the larva, and shows that they arise in three different segments, viz., the three in front of the anal segment. If this is correct, great caution is necessary in comparing a sting formed by appendages of three segments with a sting that is developed from appendages of two segments only. I have no information to give on this point in *Comys*, and shall therefore briefly describe the structures I have figured.

The ovipositor is furnished on either side with two large expanded chitinous plates; these are held together anteriorly by a three-cornered nodule of chitin (Pl. 12, fig. 41). Of these two pairs of plates, the inner is the larger; each half carries a fringe of short bristles round the distal border. The outer edge of this plate is strengthened by a thickening of the chitin; this thickening leaves the margin and turns into the middle of the plate before it reaches the extremity. Where these two inner plates articulate with the triangular nodule, there arises a curved rod which runs round and back, meeting its fellow of the opposite side in the middle line; these two curved bars end near the extremities of the inner plates, and they form the pointed stinging-apparatus of the ovipositor. A little below the level of the articulating nodules, these two curved rods converge together and are embraced by a thin membranous sheath; at this point the enveloping sheath expands into a pair of oval claspers or clamps, through which the rods of the sting run. The membrane is continued on as a covering or director to the sting-points. At first I was uncertain as to whether these rods were separate from the membranous sheath or not, but later on I found it was possible to dissect them out as perfectly free structures, grooved to the tip from the point where they become swathed in the sheath.

As regards the origin of the parts of the ovipositor—or sting—in Hymenoptera, there seems to exist a considerable amount of confusion in the literature on the subject; the point on which I find authors disagree is as to whether the three pairs of buds (or imaginal discs) present in the larval condition belong to two segments or to three. Bugnion says they arise in three different segments representing three pairs of appendages, and he figures them accordingly; he says: “la *tarière* (gorgeret, stylets et valves), représentant également trois paires d’appendices, dérive de six petits disques qui se montrent dans la seconde moitié de la période larvaire, de chaque côté de la ligne médiane, à la face inférieure des trois derniers segments.” . . . “J’ai observé moi-même la formation des six disques de l’armure génitale chez les larves d’*Encyrtus*, la transformation de la partie centrale de ces organes en petits bourgeons digitiformes, puis la division des deux bourgeons intermédiaires en quatre (?), mais il ne m’a pas été possible de suivre leur développement ultérieur.” He seems to be in some doubt as to the division of the median pair into two pairs of buds. Kraepelin (33), in *Apis mellifica*, states that in the earliest instar “an der Bauchseite der drei vorletzten Segmente findet man um diese Zeit je ein Paar länglich runder Wülste, welche, von Tracheen umspinnen und augenscheinlich der Hypodermis entstammt, man nach Weissmann’s Definition als Imaginalscheiben zu bezeichnen das Recht hat.” . . . “Bald zeigen diese Wülste weitere Differenzirungen, namentlich die des dreizehnten Segmentes. An letzteren gewahrt man nach kurzer Zeit eine Längstheilung, derart dass jeder Wulst nunmehr aus zwei nebeneinander liegenden cylindrischen Zapfen besteht, deren basale Theile unter sich wie mit dem correspondirenden Wulst der andern Seite verbunden sind. Die Wucherungen des zwölften Segmentes sind zu länglichen, gekrümmten Zapfen geworden, während die des elften Ringes zwei rundliche mit je einem langen Faden in Verbindung stehende Blasen repräsentiren.”

But Dewitz (16) also worked at the development of the sting in *Apis mellifica*, and he asserts that the three pairs of sting-rudiments arise from two segments, and his figures show this very unmistakably. He says: "auf der Bauchseite der beiden vorletzten Segmente, dem 11. und 12., sieht man die erste Anlage des Stachels als 6 kleine Wärzchen, von deren 4 dem vorletzten, 2 dem drittletzten Leibesringe angehören. Die beiden letzteren krümmen sich bei ihrem späteren Wachsthum mit den Spitzen nach den Seiten und sie sowohl, als auch die 4 übrigen liegen unmittelbar unter der Oberhaut in kleinen Höhlungen." He finds the development is similar in *Locusta viridissima*, and also in *Vespa vulgaris*, of which he remarks: "die beiden vorletzten Segmente, das 11. und 12. hinter dem Kopfe zeigen wieder die 6 Stachelwärzchen in kleinen Vertiefungen unter der Oberhaut liegend, welche ebenfalls aus Imaginalscheiben entstanden sind."

Janet (31), too, supports the view that the parts of the sting arise in two, and not in three segments; his remarks apply to *Myrmica rubra* and are as follows: "sur le 11^e anneau il y a deux appendices qui sont les rudiments des stylets. Sur le 12^e anneau nous voyons le rudiment de la glande à venin, deux appendices qui se souderont plus tard en une pièce unique impaire et donneront le gorgeret et, enfin, sur les côtés du gorgeret, deux appendices qui deviendront les valves protectrices de l'aiguillon." His figure shows this very clearly.

Packard (44) quotes these writers, but seems to be unaware of any discrepancy; he reproduces the figures of the development of the sting in *Bombus*, as given by Dewitz, showing that only two segments are involved, but he says, "as shown, then, by our observations and those of Dewitz, the rudiments of the ovipositor consist of three pairs of tubercles, arising, as Kraepelin and also Bugnion have shown, from three pairs of imaginal discs, situated respectively on the seventh, eighth, and ninth uromeres, or at least on the three penultimate segments of the abdomen." So far as my observations go, they show that there are three pairs of tubercles, but that they arise in *two*, and not in *three*, segments, there being two pairs in the posterior segment.

Regarding the ultimate fate of the sting-buds, Kraepelin remarks that the parts arising from the first of the three pairs that he admits to be present go to form the oviduct and passages; but it is very difficult to suppose that the external buds figured by Bugnion on the corresponding segment could become transformed in such a manner, for it would involve a complicated process of invagination.

I have been unable to find anything further relating to the development of the sting in Hymenoptera; Zander's (66, 67) papers are on the morphology of the adult structures, and do not consider the larval condition. One of the most recent papers (Anglas, 1) on the metamorphosis of the wasp does not deal with the sting origins at all.

V. ANATOMY OF IMAGO, ♂. (Plate 12. figs. 44, 45.)

The male of this species differs in several respects from the female. It is smaller than the largest females, being about the same size as the smaller specimens; it looks somewhat longer than it is in reality on account of the fact that the wings, when folded on

the back, extend a short distance beyond the end of the body; this is true for the hind wings as well as for the fore wings.

In colour, the male fly differs considerably from the female. The body is entirely black, except several white joints of the legs. The thorax and head are dull black, and not golden brown as in the female. The antennæ are completely black, and do not end in a club-like dilatation, for the component segments are almost equal in size. The antennæ of the male fly can also be distinguished from those of the female by the fact that they possess a conspicuous covering of fine black hairs, relatively long; the elbow, too, is not so strongly marked as in the female antenna. When the male is looked at from the side, it is seen that the antennæ are arched upwards and forwards, the tips curving down again.

The wings are, proportionately, much larger than in the female; they differ also in not possessing the shaded fuscous patches so noticeable in the other sex; they are, on the contrary, of a shining iridescent colour, having an almost metallic appearance. The group of hairs so marked on the surface of the female fore wings, is absent in the male, in which the entire surface of the wing is covered with a soft down of fine hairs.

The legs are similar to those of the female, the second pair being furnished with the large tibial spur so characteristic of the species.

The abdomen is relatively smaller than that of the female, but, as regards the arrangement of the segments and of the curious lateral plates, the form is identical. The reproductive apparatus differs entirely from that seen in the female. In the natural condition, there is a small pointed process projecting from the tip of the body, on either side of which can be seen a little wing-like organ. When dissected out, the male organs are found to be composed of a central hollow piece, or penis (Pl. 12. fig. 45, *p.*, *h.*), in which run the ducts communicating with the glands. On each side there is a jointed, hooked rod, ending in three sharp teeth. Outside these parts, laterally, there is another rod-like organ, which ends in a long spike, or seta. The tip of the penis has curious little papillæ, which are the openings of the ducts leading from the gonads.

Note.—While performing the work recorded above, I have been fortunate in having the valuable help of Dr. D. Sharp, who has, with constant generosity, given me the benefit of his knowledge and experience; I am, therefore, only too happy to take this opportunity of acknowledging, with gratitude, the essential service he has rendered.

Balfour Laboratory, Cambridge,
May 14th, 1903.

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VII. EXPLANATION OF THE PLATES.

PLATE 11.

- Fig. 1. Portion of fern-frond attacked by *Lecanium hemisphaericum* var. *flicum*, the Coccid being parasitized by *Comys infelix*.
- Figs. 2, 3, 4, 5. Early stages in the development of the egg within the egg-tubes of *Comys infelix*.
- Fig. 6. Fully formed egg previous to the disunion of the two parts, showing the valve-like apparatus on the connecting neck. A=true egg-mass; B=yolk-mass.
7. Egg after losing the yolk-mass; the valve-apparatus is retained as a bifurcated foot to the stalk which is plugged with a quantity of protoplasmic matter. Egg-cases like this are found in the host's body, and are often seen capping the tail of the larva.
8. Valve-apparatus more highly magnified.
9. Egg before the separation of the two masses, drawn on $\frac{1}{2}$ mm. scale. Length = .35 mm.; length of stalk after separation = .05 mm.
10. First observed larva with the bifurcated tail. Length = .75 mm.
11. Mouth and mandibles of first larva, with buccal glands. 12. Posterior segments of same.
13. Larva just before the second instar, in which the tails are atrophying.
14. Second instar in which the tails remain only as withered ends of the tracheæ. *sp.*¹⁻²=spiracles.
15. Third instar showing imaginal discs. *l.*¹⁻³=leg-buds; *st.*¹⁻³=sting-buds; *s.g.*=sexual glands.
16. Prepupa *in situ* in the host (*h.*). (The insect is represented in an inverted position.)
17. Prepupa removed from host but still in its sheathing membrane (*m.*). *pl.*=oval red plates.
18. Pupa in membrane. Length = 2.25 mm.
19. *Comys infelix*, ♀, dorsal view. Length = 2.5 mm. 20. The same, ventral view.

PLATE 12.

- Fig. 21. Ventral view of head.
22. Mouth-parts *in situ*. *u.l.*=upper lip; *md.*=mandible; *p.*=maxillary palpi.
23. Labial palpi. 24. Maxilla and palp (*p.*).
25. Mandible, drawn on scale of $\frac{1}{20}$ mm. Length = .18 mm.
26. Surface of face, with two ocelli and part of an eye. 27. Surface of the eye.
28. Hind wings, 3rd legs, and 3rd thoracic spiracles (*sp.*³).
29. Dorsal view of thorax. *c.*=collar; *sp.*¹⁻³=spiracles; *pr.*=pronotum; *t.*=tegulae; *sc.*=scutellum.
30. Second leg with tibial spur.
31. First legs with thoracic segment of attachment.
32. Ventral view of abdomen of specimen distended with water, showing relative positions of parts.
33. Lateral view of abdomen as seen in life, showing sting.
34. Dorsal plates of abdomen and petiole.
35. Ventral plates of abdomen flattened, showing petiole and sting.
36. Dorsal plates and petiole, flattened.
37. First ventral plate and petiole.
38. End view of the tip of the abdomen, showing the arrangement of the plates round the anus.
39. Tactile plate, *in situ*.
40. Large functional spiracle on the 7th dorsal plate.
41. Sting-apparatus.
- Figs. 42, 43. Tactile plate and hinge.
- Fig. 44. *Comys infelix*, ♂, dorsal view.
45. „ „ „ skeletal parts of the reproductive organs. *p.*=penis; *h.*=hooks.

A.L.Embleton del.
A.R.Hammond lith.

West, Newman imp.

A.L. Embleton del.
A.R. Hammond lith.

West, Newman imp.

COMYS INFELIX.