IV. *Studies in the Morphology of the Lepidoptera.*—Part I. By W. HATCHETT JACKSON, M.A., F.L.S., Deputy Linacre Professor of Anatomy in the University of Oxford.

(Plates XV.–XIX.)

Read 21st November, 1889.

THE present paper represents a portion of an investigation which was begun some years ago but was laid aside at the time for want of material; its resumption was prevented by the claims of other and very pressing duties until the summer of the present year. The results obtained are now laid before the Society in the hope that they may prove of interest, and as a first contribution from studies which still remain to be finished. There are, however, one or two points in this first portion which will require some further elucidation; but as a year must elapse before the necessary specimens can be procured, it seems to me that it is better not to keep back what has been done, especially as the points in question are not of critical importance.

Two subjects are here dealt with. The first is the external anatomical marks by means of which the sex of a chrysalis may be determined; the second, the mode in which the azygos oviduct or vagina of the female butterfly with its accessory organs develops between the close of larval life and the assumption of the state of the imago*.

§ 1. *The External Anatomical Characters distinctive of Sex in the Lepidopteran Chrysalis.*

After a search of some extent in the literature which deals with the anatomy of the Lepidoptera, I have come to the conclusion that none of the many authorities who have studied this order of Insecta have ever noticed the fact that the sex of every chrysalis is denoted by fixed anatomical characters†. Yet such is the case. If the dorsal aspect of a chrysalis is carefully examined, it will be seen at once that there are thirteen somites following the head, three thoracic, and ten abdominal, the last somite carrying the cremaster, which represents the anal valve of the caterpillar. The eighth somite, which has a particular connection with the object of this section, may be identified at once for

* A preliminary account of the results of this investigation was sent to the 'Zoologischer Anzeiger' on Oct. 7, and appeared in No. 322 of that periodical for Dec. 2nd, 1889.

† My search in this connection has extended through the works of Kirby and Spence, Burmeister, Westwood, Camerano, Graber, Scudder, and various anatomists, as well as writers of special monographs such as Lyonet, Herold, and Suckow. Figures occur here and there in which the markings distinctive of sex are more or less clearly indicated, but their import has not been recognized. See Addendum, p. 148, *post*, and Zool. Anz. Jan. 27, 1890.

practical purposes without the labour of counting by the fact that its stigmata are abortive as compared with the stigmata of preceding somites. The characters which determine the sex are to be found on the ventral or sternal aspect of the ninth somite in the male, and in the corresponding region of both the eighth and ninth somites in the female. They were first recognized by myself in 1875, and I have used in succeeding years whatever opportunities have presented themselves of verifying their truth not only by the inspection of specimens but also by means of breeding and dissections.

The male sex is indicated by a linear depression in the sternal region of the ninth somite, a depression which represents the aperture of the ductus ejaculatorius of the imago. It presents itself in one of three slightly differing shapes.

(1) It is a fine line situated in a raised area and provided with two oval lips, one right, the other left. This is the form which is seen in *Pieris* and is shown in Pl. XV. fig. 1.

(2) It is a more strongly marked line inclosed in a nearly circular cup-shaped area with edges strongly raised. The sternal region of the ninth somite is a smoother continuation of the lateral portions of the somite. This form is the one seen in the genus *Vanessa* (*V. urticae*, *Io*, *Atalanta*, *polychloros*) and is shown in Pl. XV. figs. 4 and 5. In some specimens the edges of the inclosing area are more strongly pronounced on the right and left, forming a couple of lips, and then the area has a more or less oblong aspect.

(3) It is a very well defined linear depression, guarded by two lips, one on the right, the other on the left. These lips are tumid, broad at their centres, and pointed at either extremity; or, in other words, they are either oval or somewhat triangular, the bases of the triangles being the linear depression itself. The whole structure lies either in the centre of the sternal region or at its posterior limit. Examples are *Papilio Machaon* (Pl. XV. fig. 8) and *Sphinx ligustri* (Pl. XV. fig. 11). The latter figure is taken from a spirit-specimen of an individual killed immediately on pupation; in older living specimens the dark colour and the thickening of the pupal cuticle rather obscure the structure. All the Heterocera which I have examined possess this third shape.

The female sex is to be recognized by the aspect of the sternal regions of the eighth and ninth somites. There are typically and primitively two linear depressions, one in each of the sternal regions named, but they may be hidden or become confluent. These depressions coincide respectively with two pairs of vesicles invaginated from the hypodermis; see *infra*, pp. 159–160. There are several types of structure to be distinguished.

(1) The eighth and ninth sterna are each marked by a short fine longitudinal line, surrounded by an oval and slightly raised area. This type is seen in *Pieris* and is shown in Pl. XV. fig. 2.

(2) The eighth and ninth sterna are marked by a longitudinal line which is apparently continuous. The sternal region of the ninth somite is, as in the male, a smoother continuation of the lateral portions of the somite. This type is seen in the various species of the genus *Vanessa* and is exemplified in Pl. XV. figs. 6 and 7, taken from *V. Io*. The essential difference between it and the preceding type depends on the formation of a median furrow corresponding to the course of the azygos oviduct by

which the two typical linear depressions seen in *Pieris* are effectually obscured. Pl. XV. fig. 15 is a view of the inner aspect of the empty pupal cuticle of *V. Io*, and shows the remnants of the chitinous linings of the duct of the bursa copulatrix (*b*) and of the oviduct (*o*) respectively, at a late stage, however, of growth, and therefore of greater extent than in the newly formed pupa. Still they indicate the existence of the structures evidenced outwardly in *Pieris*, and described in *V. Io* in the second section of this paper (pp. 159–160, 162, 164)*.

(3) In all specimens of *Papilio Machaon* that I have seen the ninth somite is very narrow ventrally and is crossed by a line as in *Vanessa*. The ventral portion of the eighth somite is broader, and a line extends forwards from its hind margin for about one third of its breadth. This type is figured Pl. XV. fig. 9.

(4) All the Heterocera which I have examined are characterized by a peculiarity of the ninth sternal region. It is prolonged forwards to a greater or less extent as a triangular plate invading the eighth sternal region, and it is at the same time not clearly limited from the tenth somite behind; or in other words the intersegmental line between the ninth and tenth somites is not quite continuous from side to side across the ventral line. These features are shown in two of the Sphingidæ, *Protoparce mauritii* (Butler), Pl. XV. fig. 10, and *Sphinx ligustri*, fig. 12, on the same Plate. The figures also illustrate a further peculiarity of the Heterocera. In *Protoparce mauritii* it will be noticed that there are two fine longitudinal lines or depressions, one in the eighth sternum and a second, the shorter of the two, at the apex of the triangular forward extension of the ninth sternum, whereas in *Sphinx ligustri* there is but a single linear depression situated in the sternal region of the eighth somite, inclosed, however, by triangular lines passing backwards. The single depression represents the two depressions seen in *Protoparce*. Of the correctness of this conclusion I have no doubt, for the following reasons:—*First*, dissection of a one day's old pupa of *Sphinx ligustri* has shown me the existence of exactly the same parts that are seen in Pl. XVII. fig. 34, taken from *V. Io*. There is an anterior vesicle with rudiments of a bursa copulatrix and receptaculum seminis, and a posterior double vesicle. The main difference in these organs, as compared with the organs of *V. Io*, is that the anterior and posterior vesicles are closely apposed to one another. The *second* reason is that in the cast pupal cuticle of the same moth, as well as of a *Smerinthus ocellatus*, I have found two bands united at their bases, which are evidently the cast chitinous linings of the ducts of the bursa copulatrix (*b*) and of the oviducal tube (*o*). They are identical with the structures figured in *V. Io* on Pl. XV. fig. 15, and they are shown in figs. 16 and 17 on the same Plate. There is yet a *third* reason, and that is the occurrence of a single or of a double depression in different chrysalids of the same or allied species. Such a variation I have seen only once, and that quite recently, among the very many examples, probably 200 or more, of *Sphinx ligustri* that have passed under my notice. It is figured Pl. XV. fig. 13. A specimen of *Smerinthus oculatus* belonging to my friend Mr. Poulton is a second instance to the point; as a rule, however, this species has but a single depression.

* See p. 155, on pupæ of *V. Io* of undetermined sex.

The same statement is true of *Sm. populi*, but a specimen in the Zeller collection in the British Museum and two specimens in my own possession are exceptions. In the Stephens collection of "Metamorphoses" in the British Museum is a specimen of *Cossus ligniperda* with two depressions distinctly separated. Other specimens that I have seen possess but one. Two specimens of *Zeuzera æsculi* in the same collection differ in a similar way; one has a single depression, the other a double. All examples of *Cucullia verbasci* bred by myself, and they are many, have had but one depression; the sole example of *C. scrophulariæ* seen by me, and it is in the Stephens collection, has two. In the same collection is a specimen of *Thyatira tridens* and another of *Th. psi**; the former has a single depression, the latter a double.

The external anatomical characters distinctive of sex in a chrysalis and above described are very constant, so far as I have seen after many years of observation; and whenever it has been in my power to verify my own conclusions on the subject, no error of determination has ever been detected. There is, of course, a certain amount of variability in minute details, but it is never of such a kind as to prevent the recognition of the sex. For some time past I have been collecting instances of this variability in *Pieris brassicæ*, and on a future occasion I may hope to figure them.

The following table gives a list of the species examined. It relates only to the female. From time to time single examples of individual species have come under observation of which unfortunately no record has been kept. They all belonged, however, to the Heterocera and to the type 4 *b*, *infra*. The numbers prefixed to the names indicate the number of specimens seen by me, and where no such number is given it is to be understood that it has been very great indeed. The letters "B.M." stand for British Museum, *i. e.* the Natural History Museum, as it is now called, and figures following these letters indicate the Museum number. "Z" stands for Zeller collection; "St" for the Stephens collection of Metamorphoses, both in the National collection. I may here express my thanks to my friend Mr. Heron, of the Zoological Department of the Natural History Museum, for his kind assistance, and to Mr. Doncaster, of the Strand, who courteously permitted me to inspect his stock of pupæ.

1. *Pieris brassicæ*; *P. rapæ*; 3 *P. napi*; 1 *Minetra cyaneus* (Moore), from Ceylon, B.M. 83, 52.
2. 137 *Vanessa Io*; *V. urticæ*; 26 *V. polychloros*; 2 *Papilio Alexanor*, Z.; 1 *P. polytes*, from N.W. India, B.M. 84, 38; 1 *Ornithoptera aeacus*, B.M.; 1 *O. (Papilio) minos*, B.M.
3. 28 *Papilio Machaon*; 35 *P. podalirius*; 1 *P. merope*, from S. Africa, B.M. 78, 10; 20 *Thais cerisyi*; 3 *Th. hypermæstra*, B.M.
- 4 a. With double apertures.
 - 5 *Acherontia Atropos*; 1 *Sphinx convolvuli*, St.; 1 *S. ligustri*; 2 *Deilephila euphorbiæ*, St.; 2 *Chærocampa porcellus*, St.; 52 *Ch. elpenor*; 1 *Ch. alecto*, from N.W. India, B.M. 84, 38; 2 *Ch. nerii*, B.M., Z.; 1 *Smerinthus ocellatus*; 3 *Sm. populi*; 1 *Protoparce mauritii*, from Natal, B.M.; 1 *Daphnis Horsfeldii*, Java, from the Horsfield collection, B.M.; 1 *Cossus ligniperda*, St.; 1 *Zeuzera æsculi*, St.; 1 *Cucullia scrophulariæ*, St.; 1 *Thyatira* (= *Acronycta*) *psi*, Z.; 4 *Nyssia zonaria*.

* These are the names given by Stephens; the species are now assigned to the genus *Acronycta*.

4 b. With a single aperture.

2 *Acherontia Atropos*; *Sphinx ligustri*; 2 *Chærocampa elpenor*; *Smerinthus ocellatus*; *Sm. populi*; 29 *Sm. tiliæ*; 11 *Euchelia jacobææ*; 23 *Arctia caja*; 2 *Cossus ligniperda*; 1 *Zeuzera æsculi*, St.; 1 *Stauropus fagi*, St.; 2 *Notodonta dictæoides*; 1 *N. dromedarius*, St.; 1 *Leucania straminea*, St.; *Phalera bucephala*; 1 *Thyatira* (= *Acronycta*) *tridens*, St.; 2 *Gortyna flavago*, St.; *Mamestra brassicæ*; 15 *M. persicariæ*; 1 *Achatia* (= *Panolis*) *piniperda*, St.; 5 *Dianthæcia irregularis*; 1 *Misellia oxyacanthæ*, St.; 1 *Hadena* (= *Agriopis*) *aprilina*, St.; 3 *Hadena glauca*; 13 *H. chenopodii*; *Cucullia verbasci*; 1 *Bucephala* (= *Cucullia*) *umbratica*, St.; 3 *Gonoptera libatrix*; 2 *Selenia illustraria*; 18 *Nyssia zonaria*; 13 *Biston hirtaria*.

The structures to which are due the marks distinctive of sex in chrysalids develop towards the close of the caterpillar's life, and the cuticle that lines them is in continuity with the cuticle of the future pupa. It is conceivable that the cuticle of the caterpillar might in a given instance be sufficiently transparent to permit of their being seen; it is conceivable also, but not probable, that they might happen to develop at an earlier stage of larval existence. Under no other conditions is it possible for them to afford aid in deciding the question to what sex a living caterpillar belongs. It is easy enough to find the answer to the question by dissection, as will appear later on (pp. 158-159 and note), or by inspection in those few instances where the integument is of sufficient transparency to permit the testes and ovaries to be seen, and where at the same time there is a difference of colour in those organs. I have examined, and in vain, for distinctive external anatomical indications of sex, numbers of caterpillars of *Pieris brassicæ*, *Vanessa Io*, *Sphinx ligustri*, and *Phalera bucephala*, and have found none. It seems to me, however, that the larger and longer caterpillars of *Vanessa Io* and the smaller caterpillars of *Sphinx ligustri* belong, as a rule, to the female sex. But I should not like to be too positive without tables of measurements and weights. It is not only possible but likely, however, that instances where size differentiates the sex of the caterpillar may be found. Peculiarities of colouring are said to do so in some cases. For example Weniger has stated, in the 'Entomologist' (xx. 1887, pp. 87-89), that after the second or third moult of the caterpillar of *Attacus yama-mai*, *A. Pernyi*, *A. selene*, and *A. cecropia*, a coloured mark on the sternal region of the eighth abdominal somite affords a certain test of sex. The mark in the female is a "black blotch" in the middle of a yellowish tint, which in natural size is not larger than a large pin's head. The male differs from the female in the fact that the black blotch has in its centre "a dark green spot." In both sexes the distinctive mark disappears when they are killed and "emptied." It is therefore probably due to a peculiarity in the larval cuticle. At least there is no structure belonging to the reproductive organs in both sexes alike which has the position assigned by Weniger. Professor Westwood points out, on p. 193 of his 'Entomologist's Text-book,' 1838, that, according to de Geer, brown caterpillars of the yellow underwing, *Triphæna pronuba*, produce males, green caterpillars, females; and I gather from § 15, p. 20 of Herold's 'Entwicklungsgeschichte der Schmetterlinge' (Cassel & Marburg, 1815), that other instances are given in Rösel von Rosenhof's work 'Der monatlich-herausgegebenen Insecten-Belustigungen,' published at Nürnberg in 1746-61, and illustrated with a large number of plates. This work I have seen, but

want of time has prevented my searching its pages so as to point out the proper references*.

ADDENDUM.—Since this paper was read I have found that the anatomical sexual distinctions of chrysalids were known in part to O. Wilde, and are briefly mentioned in his work 'Systematische Beschreibung der Raupen unter Angabe ihrer Lebensweise und Entwicklungszeiten,' Berlin, 1861. There is a copy of this book in the Insect Room at the Natural History Museum, where it was shown me by my friend Mr. Heron. In many of the plates to the *second part* sexual signs are affixed to some of the figures of the chrysalids. The cremaster appears to differ in some cases in the two sexes, just as do the antennæ. On p. 4 of the Introduction, Wilde states that the male pupa possesses "in der Mitte der Bauchfläche *des letzten Ringes* zwei kleinere, durch eine Längsfurche getrennte Höckerchen, während diese Stelle bei der weiblichen Puppe geglättet, dagegen aber hinter dem Einschnitte zwischen dem 7ten und 8ten Ringe, über der Mitte des letzteren, eine seichte, mehr oder weniger deutliche, kurze Längsfurche wahrnehmbar ist. Die Unterscheide entspreche der verschiedenen Lage der Fortpflanzungsorgane bei den beiden Geschlechtern." Wilde appears to have been acquainted with only one type of the Heterocera, at least in the female, viz., the one with confluent apertures. A comparison with the foregoing account will show that there is a greater variety in the sexual marks than he supposes, and that he has not placed them with complete accuracy, owing probably to his not knowing the true number of segments in the abdomen.

A second authority has noticed the sexual apertures of chrysalids. Dr. Haase of Königsberg has been good enough to draw my attention to J. T. Ch. Ratzeburg's work 'Die Forst-Insecten,' Th. ii. (Berlin, 1840), and to give me a reference to its pages. On p. 6, Ratzeburg compares the segments of the pupa with the segments of the caterpillar, to which he assigns, by the way, 9 abdominal segments (p. 4). Speaking of the last *three* larval segments, he says, "Letzere scheinen in der Puppe zwar 4 zu sein (also der ganze Hinterleib 10-ringlig), allein das kommt nur daher das der After sich besonders abschnürte. Dicht vor der Afterspalte liegt die Geschlechtspalte. Bei der männlichen Puppe setz sie sich aber bis in den vorletzten Ring fort, während sie bei den weiblichen auf der letzten beschränkt ist (z. B. T. xii. F. 3, 4, p.). So kann also, meine Beobachtung zufolge, männliche und weibliche überall in der Puppe unterscheiden (s. d. zahlreichen Abbildungen)." With reference to this passage I may remark that, as stated later on in the second part of my paper (pp. 151-2), there are really *ten* abdominal segments both in the caterpillar and pupa alike, and that Ratzeburg (like his successor in time, Wilde) was not acquainted with the detailed variations of the sexual apertures of pupæ as described in the preceding pages. He figures in the female only *Vanessa polychloros* and the Heteroceran type 4 *b* with confluent apertures. In his

* Mr. Doncaster tells me that in the Satyridæ the male caterpillar is brown, the female green, and that the male caterpillars of *Orygia antiqua* and *O. gonostigma* have yellow dorsal brushes, the female brown. In all there are 13 or 14 species thus distinguished. Suckow ('Anat. Physiol. Untersuchungen,' Heidelberg, 1818, p. 23) states that the male *Dendrolimus pini* differs from the female (1) by its smaller size, (2) by its lighter, almost smoky grey colour, and (3) by a black-brown band, situated behind the second pair of prolegs, which begins laterally and takes an oblique dorsal course. This band is obscurely marked in the female.

account he also misplaces or misdescribes the positions of the apertures in the two sexes, though the particular figures to which he refers his readers appear to bear out his words. But others of his figures are more correct than his account; *e. g.* Taf. xiv. figs. 4 *p* ♀, 4 *p* ♂, and Taf. xvi. figs. 1 *p*, 2 *p*, 3 *p*, which show the male aperture in the segment in front of the anal segment, and the female (confluent) aperture as situated apparently in the centre of the eighth segment, *i. e.* the segment in front of the one in which the male aperture occurs.

Dr. Haase also remarks to me that the sexes of the Lepidopteran chrysalid have been "long known to all practical Lepidopterists." This may be the case in Germany, but it is certainly not so in England, so far as concerns the sexual apertures of the pupa. Before my paper was read I consulted Professor Westwood and several other practical Lepidopterists, who assured me to the contrary. Moreover, except on the assumption of ignorance, it is hard to account for the complete silence of text-books in general on the subject.

§ 2. *Development of the Azygos Oviduct and its accessory Organs in Vanessa Io.*

It is a well-known peculiarity of the Lepidoptera that the female ducts have two external apertures. The only exception known to me is *Nematois metallicus*, described by Cholodkowsky in the 'Zeitschrift für wiss. Zool.' xlii. 1885. From his account I gather that there is only one aperture in this Micro-Lepidopteran, and that one the posterior of the two usual apertures. All the Macro-Lepidoptera which have been examined possess an aperture which leads into the bursa copulatrix, and is placed on the ventral aspect of the eighth somite, and a second aperture which leads outwards from the oviduct and is placed ventrally to the anus, on the papilla that terminates the abdomen. The aperture of the bursa is the one by which copulation is effected; the oviducal aperture the one by which the ova are always laid. Fig. 19 on Pl. XV. shows the azygos oviduct and accessory organs of *Vanessa Io*, the type I have investigated. It is given more as a standard of reference for the developmental history than for any other purpose. The four ovarioles, cut short, are to be seen on each side (*ov.*, *ov.*); they are attached to the ends of the paired oviducts (*od.*, *od.*) which in their turn enter the azygos oviduct (*od.*)*. This tube terminates by an aperture just below the rectum (*r*). The accessory organs appended to the azygos oviduct are, in order from before backward, a "seminal canal" (*s.c.*), leading to the bursa copulatrix (*b.c.*), a receptaculum seminis (*r.s.*), and a pair of sebaceous glands (*s.gl.*), with a common duct (*d.s.gl.*). Immediately below the termination of the azygos oviduct is a pair of glands supposed to be odoriferous by von Siebold. The left one alone is visible (*od.gl.*). The seminal canal (*s.c.*), it may be noted, opens on the dorsal aspect of the azygos oviduct. It is somewhat

* Four ovarioles on each side is the number typical of Lepidoptera. The only known exceptions are mentioned by Cholodkowsky, in his paper cited in the text (*op. cit.* p. 560). They are the following:—*Psyche helix* with six on each side (A. Brandt), *Sesia scoliiformis* with fourteen (E. Brandt), and *Nematois metallicus* with twelve (one specimen), sixteen (one specimen), eighteen (two specimens), and twenty (six specimens).

dilated at its origin, as in *Euclidia glyphica* and *Plusia chrysitis* (von Siebold, Archiv für Anat. u. Physiol. 1837, p. 420); it is also tortuous in its course. It opens laterally into the duct (*d. b. c.*) of the bursa copulatrix (*b. c.*). In *Danaïs Archippus* (= *Anosia plexippus*) as described by Burgess (Anniv. Memoirs, Boston Soc. Nat. Hist. 1880) it has "near the middle a pear-shaped chamber, the spermatheca or sperm reservoir" (p. 12); and according to von Siebold (*loc. cit.*) it has in Tortrices an appended pyriform vesicle. The bursa is shown as collapsed, and its walls thrown into folds in this figure taken from an unimpregnated female. Its duct is slightly dilated near the aperture, which is shown on Pl. XVI. fig. 25, *a.b.c.* It will be seen from the same figure that the seventh and eighth sterna are fused, and that the eighth sternum is much thickened and, moreover, grooved ventrally. At the anterior end of the groove is an elliptical body, which is glass-like and transparent. It is formed by a hyaline chitinous thickening shown in section on Pl. XV. fig. 20, *e, b*, and guards the bursal aperture from below. Owing to its extreme thickness it must, I imagine, act like a clip on the intromittent organ of the male. The receptaculum seminis commences with a narrow portion, the ductus seminalis (*d.s.*), followed by two irregular dilatations, the equivalent of the capsula seminis (*c.s.*). To the dilatations succeed in turn a slender tube or gland (*gl., r.s.*), which is much longer than the imago itself, and consequently is shown only at its commencement. Von Siebold (*op. cit.* p. 420) states that the capsula is a dilatation of the duct in *Papilio Machaon* and *Hipparchia* (= *Cænonympha*) *pamphilus*. In *Pieris brassicæ* it is, as is usually the case, a pyriform vesicle. It is absent in *Danaïs Archippus* (*Anosia plexippus*) according to Burgess (*op. cit. supra*). The whole receptaculum is called the "einhörniges Absonderungsorgan" by Herold, who regarded it as a gland. Von Siebold, however, has found the capsule filled with sperm after coition (*op. cit.* p. 419) *. The gland attached to the capsule is never absent, and in some instances terminates in a fork (von Siebold, *op. cit.* p. 420), *e.g.* in *Sphinx ligustri*. The paired posterior gland (*s.gl.*) is said by von Siebold (*op. cit.* p. 393) to secrete the substance that coats the ova and glues them to some foreign body. He calls it a sebaceous gland. The two tubular portions, or glands proper, are of immense length and tenuity, and their origins only are drawn in the figure. The two vesicles in which they end are here confluent, but in *Pieris*, as is usual, are completely separate; they have always a common duct leading to the azygos oviduct. The odoriferous glands are not universally present in Lepidoptera. Von Siebold records their existence in *Argynnis melitæa*, *Zygæna*, &c. (*op. cit.* p. 417, or 'Anatomy of Invertebrated Animals,' translated by Burnet, London and Boston, 1854, p. 453, note 22). They are not figured by Herold in *Pieris brassicæ*, and may not exist in that species.

No explanation has yet been given as to how it comes about that there should be two separate apertures to the female ducts of the Lepidoptera, though the existence of the two apertures has been known from the days of Malpighi. De Lacaze-Duthiers has

* The complete absence of the capsula in *Danaïs* (= *Anosia*), as described by Burgess, might seem to militate against Von Siebold's statement. It is no doubt replaced functionally in this butterfly by the dilatation present on the seminal canal, and termed by Burgess spermatheca. He does not, however, mention whether or not he ever found it full of sperm.

devoted a paper to the order in his researches on the female genital armature of the Insecta. Herold has treated of the development of the organs in both the male and female of *Pieris brassicae*, and Suckow has investigated in a similar way *Dendrolimus pini*. Bessels's paper in the 'Zeitschrift für wiss. Zool.' xvii. 1867, deals solely with the testes and ovaries, their development, and the larval ducts in connection with them*.

The conclusions come to by de Lacaze-Duthiers (Annales des. Sci. Nat. (3), xix. 1853) may be shortly summarized to the following effect:—First, the aperture of the bursa copulatrix is in connection with the seventh abdominal sternum, and is a peculiarity of the Lepidoptera not met with elsewhere among Insecta. Secondly, the oviducal aperture is in the eighth somite, the normal position among Insecta; and its proximity to the anus is to be explained by the loss of the somites (ninth, tenth, and eleventh) which very commonly intervene between them. Thirdly, the abdomen is composed of eight somites; in the imago it appears, however, to consist in some instances of nine, even where another species of the same genus has but eight. The explanation is that a delicate lamella may be intercalated between the thorax and the first abdominal somite. The latter, in this case, is connected to the thorax by two processes, one on either side the lamella in question.

All these conclusions appear to be, I regret to say, incorrect. Their incorrectness may be deduced by reference to Pl. XVI. figs. 21, 22, 23, and 24, which represent the abdomen of the caterpillar, of the newly formed pupa, of the chrysalid more than one day old, and of the imago, of *Vanessa Io*. And the figures given not only display the somites of the abdomen, but, as they are drawn to the same scale, they show another point, the change of shape and size undergone by this part of the body in the passage from the larval to the imaginal state. It is a change often overlooked, and the only writer who has lately drawn attention to it is Graber, in his work 'Die Insekten' (Naturkräfte Series, xxii, 1877, pp. 513, 514); but his figures are small and diagrammatic †.

The older authorities on Entomology assign nine somites to the abdomen of the caterpillar. Packard has drawn attention to the fact that ten is the usual number (American Naturalist, xix. 1885, pp. 307, 308). This was the number found by Kowalewsky in the embryo of *Smerinthus populi*, all ten somites bearing feet (Mém. Acad. Imp. St. Pétersbourg (7), xvi. 1871, p. 53, Taf. xii. figs. 8 and 10); but I note in an abstract of Tichomirow's Russian paper on the development of *Bombyx mori* that he found eleven abdominal somites in the embryo of this moth, all provided with feet save the first (Naples Jahresberichte, 1882, Hexapoda, p. 142) ‡. The first eight abdominal

* Cholodkowsky has figured the genitalia in a young stage of *Abraxias (Zerene) grossulariata* (Zeitschrift f. wiss. Zool. xlii. T. xix. fig. 2); and Emerton has published some notes on the changes in the internal organs of the pupa of the Milk-weed Butterfly (*Anosia pleurippus*) in the 'Proceedings of the Boston Soc. Nat. Hist.' xxiii. pt. 4, 1888. But neither of them advances our knowledge of the subject in the least, beyond what was stated by Herold.

† For the remarkable diminution of weight which occurs in the pupa, see Poulton, 'Trans. Entom. Soc.' 1886, pp. 170–179, and Urech, 'Zool. Anzeiger,' xi. 1888, p. 205 *et seq.*

‡ In the embryo of *Gasteropacha quercifolia*, Graber found the abdominal segments at first devoid of appendages. When the latter appear they develop only on those segments in which they persist in the adult. He therefore considers them as *secondary* appendages (Morph. Jahrbuch, xiii. 1888, pp. 609, 610).

somites of the larval *V. Io* have each, as is usual, a pair of spiracles, the ninth has none, the tenth bears the anal valve and anal prolegs. The distinctness of the ninth somite from the tenth was hinted at by Lyonet. The posterior ring, he says, appears "à la vérité souvent, comme ici, composé de deux; mais pour conserver l'uniformité, il convient de ne le considérer alors comme un seul anneau subdivisé" ('*Traité Anat. de la Chenille qui ronge le bois de saule*, 1762, p. 21 of the "description anatomique"). Later on, in treating of the musculature, he speaks of the last ring, his ninth, as consisting of an anterior and posterior part. His figures demonstrate the separateness of the two portions. Sir John Lubbock assigns nine somites to the abdomen of *Pygæra* (*Phalera*) *bucephala*, as is clear from pp. 183, 184 of his memoir relating to the muscles of the caterpillar of that moth (Trans. Linn. Soc. xxii. part iii. 1858), but it does not appear that he regarded the tenth as a separately existing somite. A glance at Pl. XVI. fig. 29 proves at once that the ninth somite in *Vanessa Io* is completely separated from the tenth, and that it has bundles of muscles, fewer in number than the eighth, but strictly conformed to the same type. The latter statement would not be exactly true of the tenth somite. Attention may also be drawn to the existence on the ninth segment of this caterpillar of a latero-dorsal spine, and a tubercle with a small hair-like spine, representing the second row of spines of preceding segments; see Pl. XVI. fig. 21 and its description. W. Müller has drawn attention to a similar fact in the caterpillar of *Acræa pellenæ* as showing the double character of the so-called twelfth (*i. e.* ninth abdominal) segment (Spengel's Zool. Jahrbücher, i. 1886, pp. 529, 530).

In the pupal condition (Pl. XVI. figs. 22, 23) the same number of somites may be traced as in the caterpillar, and it is a curious fact that Kirby and Spence (Introduction, iii. 1826, p. 251) assign ten somites to the pupa, though not to the caterpillar. The two figures of pupæ here given are contrasted in certain respects. Fig. 22 is that of a pupa killed at the moment the suspended larva had begun to cast its cuticle, the operation being completed afterwards by dissection. It is slender, and its somites very distinctly separated from one another. Fig. 23 is that of a chrysalid more than one day old; it shows a stouter abdomen. The intersegmental membranes, which are of considerable extent in this species, are completely folded inwards and hidden; the rings of the somites are thus brought into close contact. This contraction in length and the greater stoutness of body are caused by the excessive shortening of the muscles soon after the assumption of the pupa state. The points to be noted in both figures alike are (1) the presence of eight pairs of spiracles, the first pair hidden by the wings in fig. 23, as is generally the case, whilst the last or eighth pair are, as usual, abortive, a fact evident on comparing Pl. XVI. figs. 27 and 26 with fig. 28 and the description given*; (2) the perfect distinctness of the ninth somite; (3) the replacement of the anal valve by the cremaster (*cr.*); and (4) the formation of the sustentor ridges (*s.r.*) and sustentors of Riley. The distinctness of the ninth somite in the pupa is also shown in the side

* Herold states that the male pupa of *Pieris brassicæ* has eight abdominal somites, the female seven or doubtfully eight; that both sexes have alike six stigmata, the first somite always being devoid of one. He is in error in all these statements. See his 'Entwicklungsgeschichte der Schmetterlinge,' pp. 34, 60, 69 and note, 84, and p. xxiii of description of plates.

views of *Pieris* and *Sphinx* on Pl. XV. figs. 3 and 14. The homology of the anal valve and cremaster was discovered by myself in 1876, but was not published till 1888 ('Forms of Animal Life,' edit. 2, p. 153). Mr. Poulton has confirmed the homology by the presence of a peculiar streak of colour in *Agria tau* (Trans. Entom. Soc. 1888, p. 566). But I have found lately that Riley gave the same homology in his paper "On the Philosophy of Pupation" ('American Entomologist,' iii. 1880, p. 162). Künckel, however, in a brief account published in the 'Comptes Rendus,' xci. 1880, pp. 395-397, just after the appearance of Riley's paper, stated that the cremaster was made by the fusion of the anal prolegs. The truth of Riley's view is proved by Pl. XV. fig. 18, where the cremaster is drawn as displayed by dissection within the anal valve of the larva. The terms sustentor ridges and sustentors are proposed by Riley in the paper just quoted. He homologizes the sustentors with the soles or "plantæ" of the anal prolegs, the sustentor ridges with their limbs. In this homology I believe him to be wrong. The sustentor ridges and sustentors are probably peculiar developments of the *body* of the tenth somite, found only in some Lepidoptera. The eminences on either side the anal furrow (Pl. XV. figs. 1, 4, 8, 11, *r.p.*), or rectal prominences, as they are termed by Riley, represent the prolegs. To this point I hope to return in my next contribution, and will only add here that the anus of the chrysalis lies just below the base of the cremaster, at the dorsal end of a long anal furrow which represents the furrow or depression between the two anal prolegs of the caterpillar.

The abdomen of the imago (Pl. XVI. fig. 24), as compared with the abdomen of both caterpillar and pupa, is not only less in size and bulk, but it appears also to consist of only nine somites, the number usually assigned to it. The first somite is short, its sternum fused to that of the second somite; its tergum is composed of a middle lobe, de Lacaze-Duthiers' lamella (p. 151, *ante*), and of two lateral lobes; its spiracle (*sp.*) is hidden at the bottom of a deep recess*.

The following six somites (2-7) with their spiracles are quite distinct, but the seventh sternum is fused to the eighth, as is more clearly figured in Pl. XVI. fig. 25. The eighth somite (8) has a distinct tergum and sternum, the latter containing the orifice of the bursa copulatrix (Pl. XVI. fig. 25, *a.b.c.*). Its spiracles are lost; indeed the atrophy of the tracheæ which originates from the abortive eighth spiracles of the pupa is nearly complete by the 4th or 5th day of pupal life in *Vanessa Io*. In a male imago of *Sphinx ligustri* I have seen slight scars indicating their position.

There remains the anal cone or papilla (*t.a.p.*, Pl. XVI. fig. 25), which contains the oviducal aperture as well as the anus, and is usually denominated the ninth somite. I shall show further on (pp. 166-7, Pl. XIX. figs. 73, 75, 77, 78) that when the oviducal aperture shifts backward till it is close beneath the anus, an ingrowth or fold of hypodermis takes place surrounding the anus, oviducal aperture, and odoriferous glands. This fold corresponds to a small portion only of the tenth somite, *i.e.* to the anal area. Consequently I believe that it is more correct to maintain, at least with reference to

* The peculiar conformation of the tergum of the first somite is, I believe, due to the presence of strong bundles of muscles which arise from its middle lobe and pass into the thorax. The existence of the spiracles of this somite in the spot indicated was verified by dissection.

Vanessa Io, that the part of the abdomen from the posterior edge of the eighth sternum, and the spot where there is a slight fold in the pleural membrane of either side (Pl. XVI. fig. 25, ×) backwards, represents the ninth and tenth somites of the larva and pupa, now indistinguishable, whilst the terminal cone is a new formation within the area of the tenth somite. The cremaster of the female pupa, it may be added, undergoes complete atrophy, and is not represented in the imago.

It remains to give a summary of what is described by Herold in his 'Entwicklungsgeschichte der Schmetterlinge' (Cassel and Marburg, 1815), and by Suckow in his 'Anatomisch-Physiologische Untersuchungen der Insecten und Krustenthier,' Th. 1 (Heidelberg, 1818), so far as their accounts relate to our purpose.

In the full-grown female larva of *Pieris brassicae*, the species investigated by Herold, the larval oviducts which are continuous with the larval ovaries run backwards near the dorsal middle line; they pass between the tracheæ given off from the seventh pair of stigmata, and are attached to a main trachea of the bundle by a filament; they each turn towards the ventral middle line in the seventh somite behind the seventh stigmata, pass beneath the main longitudinal and oblique muscles of the somite, and are attached close together to the hypodermis (=Schleimnetz) in the middle ventral line at the posterior margin of the seventh somite*. From the attached ends of the larval oviducts start fine longitudinal striæ which traverse the eighth sternal region and connect the larval oviduct to a white mass composed of two oval pieces attached to the hypodermis (=Schleimnetz) beneath the rectum upon the intersegmental membrane immediately following the eighth somite (=auf der hintersten oder letzten ringformigen Einkerbung der Raupenhaut, *op. cit.* p. 10). During the quiescent state preceding pupation the two oval pieces become approximated to the ends of the larval oviducts, owing to a shortening or contraction of the hypodermis (Schleimnetz). As soon as pupation has taken place, they fuse with the oviducts and acquire a soft loose consistence (eine weiche und aufgelockerte Consistenz, *op. cit.* p. 49). During the pupal state the two larval oviducts fuse together at their point of union with the oval pieces to constitute the common (*i. e.* azygos) oviduct, whilst the oval pieces give rise to three processes, a left larger, the rudiment of the bursa copulatrix (Herold's "Samenbehälter"), a right smaller, the rudiment of the receptaculum seminis (Herold's "ein-hörniges Absonderungsorgan"), and a bifid posterior, the paired sebaceous gland (Herold's "zwei-hörniges Absonderungsorgan"). The mass which gives rise to these processes disappears, whilst they increase in size and acquire the form they possess in the imago. Herold nowhere explains how the two separate apertures to the genital duct are acquired; nor can any information be gained from his text or later plates (Taf. xxvii., xxix., xxx., xxxi., and xxxiii.). But he was quite aware of their existence and describes them in his account of the genital organs of the imago with good figures (Taf. iv. figs. 1, 2).

Suckow's investigations were carried out on *Dendrolimus (Odonestis) pini*, or, as he terms it, following Linnæus, *Bombyx pini*. His results agree with Herold's, but certain slight differences may be noted. The two filamentous oviducts are prolonged beyond

* Herold describes the course of the ducts correctly, but the way in which he figures them in his plates (Taf. vii., ix., xi.) is most misleading.

their point of attachment between the seventh and eighth somites as two separate broader and longitudinally striated bands, which end in contact with two small white knobs. They shorten gradually in the quiescent caterpillar, and are thickened at the commencement of pupal life. By their union they form the vagina. The two knobs just mentioned are, at the outset, separated from one another by a slight space, and are fixed to the hypodermis (Schleimnetz). A nerve derived from the terminal ganglion of the chain passes to each of them. Whilst the formation of the vagina is taking place, the knobs approach one another and unite; moreover they are brought by the contraction of the muscles and skin in pupation into opposition with the attached ends of the two oviducts, a statement which seems somewhat at variance with what is said as to the origin of the vagina. They are destined to give rise to four swellings, the rudiments of the bursa, the receptaculum, and the two sebaceous glands. The latter, with a want of consistency, are said to be derived from "the knobs themselves." Suckow, like Herold, does not explain how there come to be two oviducal apertures, though he knew them to be present, nor do his two plates (Taf. v., vi.) afford any clue to a solution of the difficulty.

My own investigations now to be detailed have been carried out entirely on *Vanessa Io*. It was my intention to re-examine *Pieris brassicae*, but unfortunately there was a great scarcity of this butterfly at the beginning of the year 1889, and neither my own exertions nor the exertion of friends could procure a sufficient supply. I hope, however, to supplement next year the material now in my possession, and to give the results in my next contribution. Of *Vanessa Io* a large supply of specimens was obtained on July 10th and 14th from one and the same locality on the banks of the Isis. The history of these specimens may be shortly stated in the form of a table:—

Killed as larvæ by <i>Tachinæ</i>	14
Dissected and preserved as larvæ	44
Killed by accidents in pupation	5
Pupæ of undetermined sex	17
Male pupæ.	123
Female pupæ	137
	<hr/>
	340

In addition to the fourteen larvæ killed by *Tachinæ*, two pupæ subsequently perished by the same means. As to the pupæ of undetermined sex, it may be explained that if a pupa fails to catch hold of its pad of silk and consequently falls to the ground, owing to the strong contraction of the muscles which sets in soon after pupation, the abdomen becomes curved towards the ventral aspect, and the eighth and ninth sterna are drawn beneath the seventh sternum, so that the sexual apertures are completely hidden.

There are two points of biological interest connected with the pupæ to which I should like to draw attention briefly.

The first is the large proportion of females as compared with males, which contrasts greatly with what was found by Bessels in other species. Even supposing that the

seventeen pupæ of undetermined sex were all male, an unlikely occurrence, and it is to be regretted much that pressure of work prevented my examining closely the butterflies to which they gave origin, there would be 140 males to 137 females, *i. e.* about equal proportions of the two sexes *. Another more curious circumstance was noted. The friends who kindly accompanied me and helped me to collect the specimens took their supply from different colonies of caterpillars from those from which I took my own supply. Our several finds were kept in different boxes, and it was found subsequently that the individuals in the several boxes were principally, but not entirely, of one or of the other sex. How far the colonies in which the caterpillars of *V. Io* feed may be derived from different batches of ova I do not know.

The second point relates to the coloration of the pupæ. It is a well-known fact that the pupæ of the Peacock butterfly may be very dusky in colour or green and golden. Every pupa that I saw actually at the moment of casting the larval skin possessed a light green hue; the only noticeable difference between individuals lay in the colour of the cœlomic fluid contained in the wings. The darker the tint the pupa was destined to assume, the darker the green of that fluid. My pupæ fell naturally into three classes.

(1) A large number of caterpillars suspended themselves singly on the food-plants, the common nettle. The part of the nettle, stalk, or leaf to which they were suspended was for convenience removed and pinned to the underside of a box-lid which was then placed over the box. They consequently hung in the dark. The pupæ to which they gave origin were yellow-green, their spines reddish, tipped with black. They had bright golden specks at the bases of the abortive spines of the anterior somites and a few pigmented streaks on the wings. Three caterpillars found by myself and my friend Mr. Latter, suspended to the nettles in the nettle-bed whence we obtained our supplies of specimens, pupated within a few hours of their capture and belonged to this class.

(2) Many caterpillars suspended themselves in larger or smaller groups to the nettles, to the sides of the boxes in which they were kept, or to the muslin covering the open tops of the boxes. The pupæ to which they gave origin differed *inter se*. Those at the

* Bessels gives the following table of the numerical relations of males to females as he observed them (Zeitschrift für wiss. Zoologie, xvi. p. 560):—

Species.	No. of males.	No. of females.
<i>Pontia brassicæ</i>	70	19
<i>Sphinx euphorbiæ</i>	100	35
<i>Gastropacha rubi</i>	40	10
„ <i>potatoria</i>	48	13
<i>Mamestra brassicæ</i>	80	30

The names are as he gives them. I have a number of pupæ of *Pieris brassicæ* (winter brood) at the present time. There are 26 males to 37 females.

Mr. Doncaster, of the Strand, has lately permitted me to go over a number of pupæ. The following notes as to the relative proportions of males and females were taken:—*Papilio Machaon*, ♂ 21, ♀ 28; *P. podalirius*, ♂ 37, ♀ 35; *Thais cerisyi*, ♂ 24, ♀ 20; *Sphinx ligustri*, ♂ 19, ♀ 17; *Smerinthus populi*, ♂ 15, ♀ 20; *Sm. tilia*, ♂ 35, ♀ 29; *Chærocampa elpenor*, ♂ 49, ♀ 50; *Dianthæcia irregularis*, ♂ 12, ♀ 5; *Hadena glauca*, ♂ 8, ♀ 3; *H. chenopodii*, ♂ 17, ♀ 13; *Nyssia zonaria*, ♂ 21, ♀ 22.

outer margins of the groups resembled very closely the pupæ in class (1), whereas those in the centre were more and more dusky according as the group contained more or fewer members. There was in fact a regular gradation in the amount of black pigment present.

(3) A large number of caterpillars which had just ceased to feed were placed at the bottom of an empty wooden box; the box was covered with muslin, and over the muslin was placed the lid of a linendraper's box covered with purple-black paper. The dark side was turned to the caterpillars; the lid overlapped the box by six inches at least on every side, and it was pressed down by a weight. The prisoners were thus in absolute darkness. Without exception they suspended themselves to the muslin, and the pupæ to which they gave rise had extremely dark bodies and peculiar sooty-looking wings. The golden spots at the base of the abortive spines were scarcely visible*.

These experiments on colour-variation, which were quite by the way, seem to me to bear out Mr. Poulton's conclusions, formulated in his paper on "The cause and extent of a Special Colour-relation between certain exposed Lepidopterous Pupæ and the surfaces which immediately surround them," in the 'Philosophical Transactions,' vol. 178, 1888, p. 311 *et seqq.*

Turning now to the development of the azygos oviduct with its accessory organs, I shall divide their history into the following five stages:—(1) the full-grown caterpillar; (2) the formation of the azygos oviduct, which occurs during the quiescent period preceding pupation; (3) the stage during the time in which the bursa copulatrix is still in direct union with the oviduct; (4) the stage in which it acquires its adult indirect union; (5) the formation of the terminal papilla of the abdomen. This mode of division seems to me better than taking stages of so many days old. As a matter of fact different

* My friend Mr. Mitchell was rearing caterpillars of *V. urticae* at the same time that I was rearing those of *V. Io*. He fed them in a dark brown box with a few holes punched in the lid for the sake of ventilation. The holes were small and could have admitted but little stray light. The caterpillars turned to pupæ which were uniformly of a very dark hue with a slightly reddish ground-tint. Among the nettles brought to me I found two pupæ of *V. urticae* of the most brilliant golden and green hue, so golden and green, in fact, that my friend Mr. Poulton declared them both to be ichneumonised. He was right as to one, and wrong as to the other, which produced a perfect butterfly.

The difference noted in the text in the tone of the green colour of the coelomic fluid, in accordance with which the pupæ became light or dark, was very striking. Another point worth recording was the presence, at least here and there, of a red pigment in the hypodermis (as I suppose) of the caterpillar preparing to pupate, but not visible, however, in the newly formed pupæ, and the brilliant ruddy hue of the residue of food in the digestive tract. It has struck me that an examination of the following points might yield interesting results in connection with the variability of the colour of pupæ of *V. Io*:—the spectroscopic quality of the light passing through the larval cuticle; the origin, distribution, and fate of the red pigment of the hypodermis; the effect produced by the evolution of the yellow fat-body which increases so enormously in bulk after the suspension of the caterpillar; the spectroscopic value, if any, of the yellow colour of the fat-body, and of the green-coloured coelomic fluid of caterpillars reared in light and darkness. It is probable that an answer to these points, into which I hope to enquire in the course of next summer, may lead to a comprehension of the physical basis underlying the colour-changes of pupæ. As all the newly formed pupæ of *V. Io* have much the same tint, and the pigmentation is produced rapidly after the assumption of the pupal state, it seems to me that much must depend on the nature of the nutritive material supplied to the pigment-producing cells by the coelomic fluid.

individuals do not develop quite at the same rate. My caterpillars taken on July 10, pupated between July 13 and 17; the butterflies emerged between August 1 and 4, *i. e.* they were 20 to 23 days in the pupal condition, or as a possible maximum 23 days, and as a possible minimum 16 days. The second batch taken July 14 pupated between July 18 and 22, and emerged between August 3 and 7, *i. e.* they were in the pupal state 17 to 21 days, or as a possible maximum 21 days, and as a possible minimum 13 days. It may be added that in both sets of instances emergence was quite irregular, or, in other words, those which pupated first did not necessarily emerge first. It is stated by implication in Buckler's 'Larvæ of the British Butterflies and Moths,' edited by Stainton, Ray Soc. 1886, i. p. 179, that the pupal state of this butterfly lasts 13 to 15 days. The great prolongation of time in some, at least, of my own specimens was due beyond a doubt to the cold weather that set in just after they became pupæ, and the fact that emergence of the whole batch took place within the limits of one week was caused by the sudden heat that began on July 29 and lasted through the first week of August.

(1) THE FULL-GROWN CATERPILLAR.

The larval ovaries are situated in the fifth abdominal somite, and close to the dorsal middle line, as in caterpillars of other species. Their proximal or attached extremities are approximated and they diverge from one another posteriorly. In colour they are whitish, with a yellow tint over their proximal halves, a tint which deepens in intensity during the quiescent period preceding pupation, and during the first few days of pupal existence. They are cylindrical in shape, but when the neighbouring parts of the fat-body are drawn away their outline becomes somewhat irregular owing to traction on the delicate filaments which connect their edges to the adjacent lobules of fatty tissue. Four opaque white lines, the future ovarioles, traverse the larval ovaries lengthwise and converge to their hinder extremities, from which spring the larval oviducts. The latter are very delicate filaments, extremely hard to see. If the caterpillar is still feeding they are generally free for their whole course or involved in the fat-body only here and there, but the nearer the quiescent period approaches, the more involved in it do they become. They run backwards more or less parallel to one another in the latero-dorsal region; they approach and pass between the tracheæ arising from the seventh pair of stigmata, and are tied, each by a delicate filament, to one of the main tracheal stems. They then turn abruptly towards the ventral aspect of the body and are attached to the hinder edge of a trachea. This trachea arises from the seventh stigma on each side, runs inwards beneath the musculature of the seventh somite, and unites with its fellow in the ventral median line. Each oviduct accompanies the transverse trachea of its own size as far as the ventral edge of the ventro-lateral longitudinal muscle-bundles. It then takes a curved course beneath the ventral longitudinal muscle-bundles to the spot where it is attached. This attachment is close to the posterior edge of the seventh somite, internal to, *i. e.* nearer the middle line than the attachments of the ventral muscles. A small space separates the attachments of the two oviducts. These facts are illustrated Pl. XVI. figs. 29, 30, 31, and are explained in the description of the figures. The

attached extremity of a right larval oviduct is figured Pl. XVI. fig. 32. The left oviduct of the same specimen had an exactly similar appearance, and both end in a single root. A delicate and short filament passes from the oviduct near its root to the hypodermis. It seems to consist simply of nucleated connective tissue, and in that case would point to the existence of a superficial coat of cells such as was found by Spichardt to invest the pupal vas deferens of *Liparis dispar*. He states that the coat was absent, however, in the pupæ of *Smerinthus ocellatus* and of other species examined by him, though it appears to be always present in the adult. See Verhandl. des naturh. Vereins der preuss. Rheinlande, 1886, pp. 7, 8, 28, 29. A small trachea also approaches the root of the oviduct, but I do not know its destination. Bessels, in the Zeitschrift für wiss. Zool. xvii. 1867, describes (p. 561) the oviduct as terminating in the hypodermis (Schleimnetz) by four unequal branches each of which "opens" separately; and he makes this mode of termination distinctive of the oviduct as contrasted with the vas deferens, which "opens" by a single slightly broadened out termination. He figures (Taf. xxxiv. fig. 30) the ventral end of the oviduct of *Gastropacha rubi*. The oviducts are at this period, as at a later, solid structures (Pl. XIX. fig. 59) *.

The ventral muscle-bundles leave a small space in the median ventral line uncovered throughout the whole length of the abdomen. The chain of nerve-ganglia overlies this space. The terminal and compound ganglion of the chain is situated about its centre in the seventh somite and forms a very convenient landmark. In the vacant space of the eighth somite, and in its posterior half, is a rounded body divided by a median furrow into two oval halves, one right, the other left, rarely completely symmetrical and alike. A second body is placed in the vacant space of the ninth somite, but in its anterior half;

* The male caterpillar may be at once identified by the following points of structure:—The testes are placed close together dorsally in the same somite as are the ovaries, but each of them is a deep orange-coloured semilunar body divided by three furrows into four segments one behind the other. The convex aspects of the testes are turned towards one another. The rudiments of the four future testicular tubes are placed transversely. The vas deferens originates from the concave aspect of the testis and from its third segment. It passes behind the eighth abdominal spiracle, and then turns round the bundle of tracheæ originating from that spiracle towards the ventral line, but above, not under, the musculature. The two vasa deferentia are attached to the anterior edge of a small disc-like body, which in its turn is attached by filaments to the ventral surface of the rectum, and not to the hypodermis as Herold states of *Pieris brassicæ*. The invagination of hypodermis destined to form the ductus ejaculatorius and accessory glands takes place in the ninth somite, and in the position occupied by the paired posterior vesicles of the female (Pl. XVII. fig. 33).

The testes and ovaries are often dissimilar in colour. Bessels gives the following table (Zeitschrift für wiss. Zool. xvii. p. 553):—

Species.	Ovary.	Testis.	Fat-body.
<i>Liparis dispar</i>	Yellow.	Flesh-red.	White.
<i>Gastropacha potatoria</i>	"	Yellow.	"
<i>Sphinx euphorbiæ</i>	"	Reddish.	Yellow.
<i>Pontia brassicæ</i>	"	Violet.	White.
<i>Cossus ligniperda</i>	White.	White.	"

Sphinx ligustri and *Phalera bucephala* agree, I find, with *Cossus*. In *Pontia* (= *Pieris*) *brassicæ* the fresh fat-body posteriorly to the 6th segment is greenish or olive-yellow, anteriorly to it opaque yellow or green on the dorsal aspect, but on the ventral aspect white. The fat-body of *Vanessa Io* is yellow and becomes orange in the pupa.

it is divided by a furrow into two almost pear-shaped halves, the broader ends of the pears being apposed, their stalks represented by filaments, usually double, rarely single or incompletely double. The two bodies, the anterior in the eighth somite, the posterior in the ninth, are completely independent one of the other; the ninth intersegmental furrow crosses between them. The furrows which divide them into two halves, a right and a left, indicate their bilateral character. In *Pieris brassicae*, which possesses paired bodies of exactly similar character, the furrows are deeper, and in *Phalera bucephala* the two halves are at first independent and separated by a space. They may be originally independent in *Vanessa* and *Pieris*, but if so it is at a stage earlier than any I have seen. Transverse sections of the bodies show that they are formed by wide-mouthed and shallow invaginations of the hypodermis. The filaments attached to each half of the posterior vesicle are also attached at their opposite extremities to the rectum. The anterior filament consists of connective tissue, inclosing a trachea. The posterior consists similarly of connective tissue, but it contains a well-defined band which looks like degenerating muscular tissue. In my specimens no cross striæ are visible in it, and consequently its nature must remain for the present undetermined. Both filaments spread in a radiating fashion over the roof of the vesicle. They atrophy away and disappear entirely by the time the larva becomes a pupa.

The paired bodies of this stage are seen on Pl. XVI. fig. 29, and on an enlarged scale Pl. XVII. fig. 33. The series of sections Pl. XVII. figs. 50 *a*, *b*, *c*, *d*, belong to the earliest stage in my possession, Pl. XVIII. figs. 52 *a*, *b*, *c*, to a later stage. They are taken from the first pair of vesicles and show very clearly their paired character. In certain of the sections (figs. 50 *c*, 50 *d*) a small lateral fold (×) may be noticed. Comparing them with the corresponding sections of an older stage, Pl. XVIII. figs. 52 *a*, 52 *b*, it will be noted first that the lateral folds (×) have increased in depth, and that the vesicle itself is perched upon them, is deeper and somewhat less evidently paired. The lateral folds in question are the first indications of the median portion of the azygos oviduct; at present they extend no further than the base of the vesicle. Figs. 51 *a*, *b*, Pl. XVII., represent sections of the posterior pair of vesicles of the early stage, and they differ but little from the corresponding sections (figs. 53 *a*, *b*, *c*, *d*, Pl. XVIII.) taken from the later stage.

It is generally said that no cell-outlines are distinguishable in the hypodermis of Insecta, and that it consists of a layer of protoplasm with scattered nuclei overlying a homogeneous basement-membrane (see A. Schneider, Zool. Beiträge, ii. pt. 1, pp. 82, 83), but if a reference is made to Pl. XVI. fig. 32, it will be seen that cell-outlines are very distinctly indicated in the hypodermis of the caterpillar of *V. Io*. And it seems to me in consequence that the lines crossing the sections of the vesicles at this stage do really indicate cell-outlines. Further particulars as to this point are given in the account of the next or second stage of the development.

(2) FORMATION OF AZYGOS OVIDUCT.

The formation of the azygos oviduct, and the changes which accompany it, take place during the quiescent period preceding pupation. The characteristics of this stage may be summarized thus. They comprise:—

- (1) Changes in the two pairs of hypodermic vesicles of the larva ;
- (2) The formation of the azygos oviduct and the establishment of the apertures of the bursa copulatrix as well as of the oviduct ; and
- (3) The connection of the paired larval oviducts to the azygos oviduct.

It will be seen therefore that the second stage is one of prime importance in the history of the organs with which this investigation deals.

The first pair of vesicles loses completely all trace of its original paired character. There is a gradual increase in size and at the same time an elongation in the antero-posterior direction. The two ends of the vesicle increase in length and become pointed, especially the posterior end (Pl. XVII. figs. 34, 37, *bc.*, *rs.*). And as the time of pupation approaches, the anterior end becomes more swollen and even slightly bilobed, though this, I am inclined to think, may be an abnormality, whilst the posterior end increases still more in length, and is bent down upon itself to the left side (Pl. XVII. fig. 36, *bc.*, *rs.*). It is readily seen from a comparison with later stages that the swollen anterior end of the vesicle is the future bursa copulatrix, and the pointed posterior end the future receptaculum seminis.

The posterior pair of vesicles also increases in size and in length, and towards the end of this stage gives origin to two posterior tubular processes (Pl. XVIII. fig. 54 *k*, *gl.*). The two processes increase in length and become curved ventrally upon themselves so that they are cut twice over in sections taken from specimens about to pupate (Pl. XVIII. fig. 55 *i*, *gl.*, *gl.*). In fact the external appearance at this stage is very similar to what is seen in Pl. XVII. figs. 38, 39, *gl.*, *gl.* The dorsal median part of each vesicle is converted partly into one of the tubular processes in question and partly into a common or single short anterior portion, which subsequently connects the two tubes with what is now the widely open basal portion of the vesicles from which the extreme posterior portion of the azygos oviduct is developed, see figs. 54 *g*–54 *k*, Pl. XVIII. The basal or oviducal portion closes ventrally, just before the larva becomes a pupa but remains in continuity with the hypodermis. It leaves, when it closes, a small aperture, the future oviducal aperture, at its anterior end (Pl. XVIII. figs. 55 *f*, 55 *g*).

The azygos oviduct is formed in three portions: first, the part underlying the anterior pair of vesicles, which is partly developed in the preceding stage; secondly, the part which connects the anterior vesicle to the larval oviducts, which is established next; and thirdly, the part connecting the anterior vesicle to the posterior vesicles. The two latter parts differ in their mode of origin.

The median portion is completed early in this stage. The two folds noted in the previous stage, one on each side of the anterior vesicles (Pl. XVII. fig. 50, Pl. XVIII. fig. 52, $\times$, $\times$), increase in vertical height, and their lower margins approach and fuse. The closure appears to take place first in front of the future bursal aperture and then behind it.

The development of the second portion is very rapid indeed. The hollow base (Pl. XVII. fig. 50, Pl. XVIII. fig. 52, $\times$, $\times$) upon which the first vesicle is raised extends forwards, but it does so apparently only for a certain distance. At present exact details as to the mode of growth at the apex of this portion are not clear to me. This much is certain that while near the base of the vesicle there is a tube with walls formed of a single layer of cells, the tube as it nears the larval oviducts becomes solid, and is more or less confounded with the hypodermis. My own impression is that there is an ingrowth from the hypodermis of cells which subsequently arrange themselves in the form of a tube; in other words the invagination of cells is at first solid. This impression is borne out by the section shown in fig. 56, Pl. XIX., which comes from a quiescent caterpillar. The cells of the hypodermis are at this time considerably elongated, at least in the posterior portion of the body of the animal. Moreover, they lie sloping forwards obliquely in the region of the oviduct and are consequently always cut at an angle in a transverse section.

The posterior portion of the azygos oviduct develops as a widely open furrow extending backwards from the anterior vesicle to the posterior vesicles, with the basal portion of the cavity of which it is continuous; in fact it is seemingly formed by a continuation of the two folds which elevate the anterior vesicle (Pl. XVII. fig. 50, Pl. XVIII. fig. 52, $\times$, $\times$). By the time the caterpillar is ready to pupate, the furrow is converted into a tube by the fusion of its edges.

The tubular azygos oviduct thus constituted opens to the exterior in two places, by a small aperture beneath the anterior vesicle, which coincides usually more nearly to the base of the receptaculum seminis than to the base of the bursa copulatrix, and by a second aperture just in front of the anterior end of the sebaceous region of the posterior vesicles. A well-marked external or superficial furrow corresponds to nearly the whole extent of the azygos oviduct, even after its complete establishment. The chitinoid cuticle dips into this furrow, which is thus the cause of the longitudinal line crossing the sternal regions of the eighth and ninth somites of the chrysalis.

The facts stated above are illustrated in the series of figures given in Pl. XVIII. figs. 54, 55.

The larval oviducts are taken up by the anterior extremity of the first section of the azygos oviduct. Their ventral ends are at the close of this period perfectly separate from the hypodermis at the spot where the hypodermic ingrowth of cells to form the azygos oviduct becomes connected to them. It seems to me that they grow slightly at their ventral extremities towards one another; for the distance between the two ventral ends in the active caterpillar is certainly diminished in the quiescent caterpillar about to pupate. They are still solid in cross section at this time, and possess a single layer of superficial nuclei (Pl. XIX. fig. 59). A surface view of the ventral ends of the two ducts (Pl. XIX. fig. 58), taken from a caterpillar which had just entered on the quiescent stage, lends support to the idea that the oviducts grow ventrally.

If a section of the hypodermis at this stage, made more or less parallel to the surface, is carefully stained, it will be seen that it consists of distinctly darker areas surrounded by lighter lines. The darker areas, I believe, represent the bodies of the hypodermic cells connected by a small amount of intercellular substance (Pl. XVII.

fig. 47). In cross sections the hypodermis is marked by vertical lines indicating elongate cells; the nuclei are small and stain very darkly (Pl. XVII. figs. 48, 49). A detailed figure of a section through the walls of the azygos oviduct beneath the anterior vesicle is given (Pl. XIX. fig. 64), from which it will be seen that the walls of the oviduct, like the walls of the vesicle, have the same histological appearance as the cells of the hypodermis from the body-wall. In this figure there is also shown a coating or envelope of tissue (*m*) exterior to the layer of hypodermic cells. Similar tissue is found investing more or less the bursa copulatrix, receptaculum seminis, median and posterior portions of the azygos oviduct. It has, under a low power of the microscope, a finely granular look, quite different from that of the fat-body. Under a high power it appears to consist of minute irregularly shaped cells. It is present in later stages, and is found to assume, when a specimen is stained with borax carmine, a pink colour, quite distinct from the more yellow colour of the fat-body. It seems to me, in fact, composed of mesoblast cells derived from the coelomic fluid (?), which give origin finally to the muscular and connective tissue coats of the genital apparatus, the invaginated hypodermis forming only the epithelium.

(3) GROWTH AND CHANGES WITH THE BURSA COPULATRIX IN DIRECT UNION WITH THE AZYGOS OVIDUCT.

The period covered by this stage lasted in my specimens for about four days. The changes in shape and size which take place in the parts already formed will be readily understood from a study of Pl. XVII. figs. 38–45 and the following brief description.

The bursa copulatrix is at first a pyriform vesicle, with no stalk at all worth mentioning. It lies in the middle line and is placed very nearly vertically, a position which is exchanged for one slightly tilted backwards, then for one turning forwards and inclined more or less to the animal's right side, and last of all for one pointing straight forwards on the left side of the animal. The stalk or duct of the vesicle grows considerably in length, and becomes well marked off from the vesicle itself. The latter commences to grow somewhat later, and the sharp distinction between it and its stalk at the place where the two parts unite, may, as in the specimen figured Pl. XVII. fig. 44, be lost to a certain degree. This, however, is not invariably the case.

The receptaculum seminis is at the beginning of this period short and sharply bent down upon itself to the left; but it increases very rapidly in length, and the portion bent down becomes straightened. The whole structure is, in the early part of this stage, strongly inclined backwards, and to the animal's left side, but becomes by degrees more and more vertical. Its base or point of origin is at first placed a little to the left, and slightly behind the base of the stalk of the bursa copulatrix. The two gradually separate, and towards the end of this stage, the point of origin of the receptaculum is very decidedly behind the origin of the stalk of the bursa and on the median dorsal aspect of the azygos oviduct.

The changes undergone by the region of the posterior vesicles which gives origin to the paired sebaceous glands of the imago are considerable. At the beginning of the

stage the oviducal aperture is placed well in front of the anterior tubular end of the sebaceous portion (*cf.* p. 185 on fig. 65), which is separated throughout its whole extent on the ventral aspect from the hypodermis, the space between the two being occupied by intrusive fatty tissue. The two tubular portions, the future glands, lie parallel to one another, are sharply arched and curved upon themselves, and the portion common to them at their point of origin is flattened dorso-ventrally, of fair lateral extent, but of no great length (Pl. XIX. figs. 65, 66). As development proceeds the tubes show a general increase in size, become a little tortuous, but continue to be curved upon themselves. The common basal portion is a little shorter, slightly dilated on each side; the oviducal aperture is more directly beneath it, and consequently the tubular anterior portion of the gland apparatus is nearly vertical and somewhat confused with the azygos oviduct, as is seen from the sections Pl. XIX. figs. 67, 68. All the changes just detailed are more and more accentuated by degrees. The gland-tubes diverge from one another laterally and are directed backwards, but as they lengthen, curve forwards at their apices. The common basal portion is distinctly separated into a right and left dilatation, connected as sections show (*cf.* figs. 67, 68) to the azygos oviduct by a short and distinct tubular duct hidden in the vertical view beneath the common basal portion. The oviducal aperture is now placed immediately below or slightly behind the common basal portion of the gland tubes. Finally, as may be seen from Pl. XVII. fig. 44, the duct (*d.v.gl.*) connecting the two dilatations or vesicles of the sebaceous glands to the azygos oviduct lengthens out, and the azygos oviduct itself extends backwards (*p.od'*), carrying its aperture, *i.e.* the oviducal or posterior aperture, with it.

As to the azygos oviduct. At first, that is to say at the time corresponding to fig. 38, Pl. XVII., no change of any noticeable degree is obvious from what obtained at the close of the preceding stage. Its anterior or bursal aperture lies just below the bases of the bursal and receptacular outgrowths (Pl. XVIII. fig. 55 *d*), its posterior or oviducal aperture is just at the anterior end of the sebaceous apparatus (Pl. XVIII. fig. 55 *f*). Both apertures are very minute and very close together. At the time corresponding to fig. 40, Pl. XVII., its anterior extremity is still solid, but the portion in front of the bursal aperture is rounder in cross section than it was, and separated by a greater distance from the hypodermis, fatty tissue intervening. The portion of the azygos oviduct behind the bursal aperture and in front of the oviducal aperture is now clearly separated from the hypodermis by a space filled with intrusive fatty tissue (Pl. XVII. fig. 41). The oviducal aperture itself is nearly directly below the base of the sebaceous vesicles. At the close of this stage the bursal aperture is connected by a tubular duct (Pl. XVII. fig. 45) to the azygos oviduct, and the oviducal aperture is still further back, situated well behind the base of the sebaceous vesicles (Pl. XVII. fig. 44, *p.od'*).

The paired oviducts increase in size, and at the period to which fig. 40, Pl. XVII. belongs have acquired a distinct lumen (Pl. XIX. fig. 60). The lumen is a fine channel which appears to extend ventrally, or in other words it develops in a direction proceeding from the ovary towards the azygos oviduct. It never communicates with the latter until the parts have assumed the size and proportion shown in figs. 61, 62,

Pl. XIX., which in the case of my specimens indicates a lapse of about three days or rather more from the close of the previous stage. The communication is figured Pl. XIX. fig. 62. I am inclined to think that it is not established sometimes till a yet later period.

There is nothing much to be noted in the histology of the organs during this stage. Their walls are composed of a single layer of cells. The chitinous cuticle lining the azygos oviduct and its apertures to the exterior is very much more distinct than it was; and a delicate cuticle may be traced in the stem of the receptaculum seminis and the vesicles of the sebaceous glands. The minute cells mentioned before (p. 163) as coating the azygos oviduct, especially the portion between the two external apertures, may be traced in a thin coat over the paired oviducts, anterior section of the azygos oviduct, duct of the bursa, stem of the receptaculum seminis, duct and vesicles of the sebaceous glands. There does not seem to be any change in the histological appearance of these cells.

(4) THE INDIRECT UNION OF THE BURSA COPULATRIX WITH THE AZYGOS OVIDUCT,
AND THE DEVELOPMENT OF THE ODORIFEROUS GLANDS.

The bursa copulatrix has up to this time been in direct union with the azygos oviduct. At the close of the preceding stage it assumes, as figs. 44, 45, Pl. XVII. show, a position decidedly to the left of the middle line of the azygos oviduct, a change of position which is shared by the tube connecting the azygos oviduct to the anterior or bursal aperture. The connection between the bursal duct and the oviduct is converted in this stage into a short tube which opens into the azygos oviduct on its dorsal aspect, and into the bursal duct itself laterally. This tube is the future seminal canal. It is shown in fig. 46, Pl. XVII., and in section in fig. 69, Pl. XIX. As may be seen from the latter figure, the course taken by it is not horizontal, but obliquely upwards from the oviduct to the bursal duct. Of the two ends of the tube the oviducal is larger than the bursal. In later stages it assumes an S-shaped curvature, and its oviducal end is frequently markedly dilated. It may be noted that the bursal duct proper is now in the same straight line or in direct continuity with the duct which previously led from the azygos oviduct to the anterior or bursal aperture. The duct last mentioned is derived, in the first instance, not from the anterior paired vesicle of the caterpillar, like the dorsal portion of the bursal duct of the imago, but from the azygos oviduct itself.

Another important feature at this period is the appearance of the two odoriferous glands. The posterior or oviducal aperture of the azygos oviduct continues to shift backwards; it is behind the vesicles of the sebaceous glands and near the anus. Eighteen to twenty sections intervene between it and the bursal or anterior aperture, as compared to four, five, or eight sections, at the assumption of the pupal condition. It is separated from the anus by only six to eight sections. In other words the distance it has gained in one direction it has lost approximately in the other. The odoriferous glands develop as two tubular ingrowths of the hypodermis, one on the right, the other on the left, of the middle line, perfectly distinct one from the other; that is to say, each of

them has its own separate aperture to the exterior. The ingrowths are in front of or anterior to the oviducal aperture, between it and the bursal aperture. They are near the oviducal aperture and underlie the anterior margin of the vesicles of the sebaceous glands. One of them is shown in fig. 74, *od.gl.*, Pl. XIX.

Two points of minor interest may be noted. The stem of the receptaculum seminis constantly bears near its entrance into the azygos oviduct a minute pyriform vesicle (Pl. XIX. fig. 70). This vesicle is evident to the naked eye in dissections belonging to later stages. It is not present in the imago, and it represents transitorily the pyriform capsula seminis of *Pieris* and many other Lepidoptera, which is replaced, functionally at least, by irregular dilatations of the receptaculum in *Vanessa*.

The second point is the almost complete disappearance of the furrow in the ventral hypodermis corresponding to the ventral furrow in the chitinous cuticle crossing the eighth and ninth sternal regions. The hypodermic cells themselves are of much diminished vertical length, and very readily separate from the pupal cuticle. On their outer surface is a darkly staining layer looking like a new cuticle. It is, I believe, a coagulable fluid, for in the next stage it is increased in amount, and in some of the sections the growing scales may be seen imbedded in it. There is also a curious median ridge of elongate hypodermic cells (Pl. XIX. fig. 71) running forwards for a short distance from the bursal aperture, which is now a deep funnel-shaped cavity. The cells of this ridge appear eventually to secrete the thickened glass-like chitin of the globular body covering the entrance to the bursal aperture; see p. 150, *ante*.

(5) THE FORMATION OF THE TERMINAL ABDOMINAL PAPILLA.

At the commencement of this stage, in specimens, that is to say, 24 to 36 hours older than the last described in the previous stage, the two odoriferous glands have increased in length, their apertures have approached one another medianly, or to put it in other words, and perhaps more correctly, the hypodermis forms a prominent ridge to the outer side of both apertures, so that they open into a common depression or pit. To the right and left of this depression there is a slight infolding of the hypodermis ($\times$), the first indication of the formation of the terminal abdominal papilla. These facts are shown in the section drawn Pl. XIX. fig. 75. The infolding becomes a little deeper in sections following the one figured and taken from the same specimen (Pl. XIX. fig. 77, $\times$).

In specimens about 24 hours older still, the changes thus described are much more conspicuous. The apertures of the two odoriferous glands are more deeply placed, and there appears to be a very short common vestibule, as may be gathered from the section figured (Pl. XIX. fig. 76). The condition of the parts closely approaches that which obtains in the imago. The lateral infoldings of hypodermis to form the terminal abdominal papilla are deeper, much more so indeed further back, as may be seen from a section through the anus (Pl. XIX. fig. 78, $\times$). The oviducal and anal apertures are now so close together that the latter is cut through two sections behind the former. It may be added here, to point the contrast, that the anal aperture at the commencement

of pupal life was distant 2 millim. from the bursal aperture, and 1·7 millim. from the oviducal as measured approximately. At this stage it is about 1·75 millim. distant from the former, whilst, as just stated, it is now immediately behind the latter.

A dissection from a specimen slightly older than the one from which the sections were prepared is figured Pl. XIX. fig. 73. It shows the rectum (*r*) above, the oviducal aperture (*o.ap.*) in the middle, and the odoriferous glands (*od.gl.*) below, and the infoldings of hypodermis (*f.f*) surrounding them. The distance from side to side measured from the apex or ridge of one to the other fold is ·75 millim. approximately, and in a vertical direction from just above the rectum to the common base of the odoriferous glands about the same amount. The terminal papilla, which is represented by the area inclosed by the folds, consequently occupies but a small portion of the whole area of the tenth somite of the pupa. In this somite the vertical distance from the base of the cremaster to the spot where the ninth sternum ends between the sustentor ridges is 2·45 millim., and from the ridge of one sustentor to the ridge of the other at the spot where they are widest apart, 2·1 millim. These facts speak for themselves.

The only other points to be mentioned are the following:—(1) The paired oviducts are now very short, have increased in diameter, and their lumina are of considerable size (Pl. XIX. fig. 63). (2) The tubular duct connecting the sebaceous vesicles to the azygos oviduct takes now, as it does in the imago, a decidedly backward course. (3) There is a very well developed and thick coat of minute cells surrounding the median and posterior portions of the azygos oviduct, and the coagulable fluid (?) mentioned before (p. 166) is much increased in amount, and may be seen here and there imbedding the growing scales, and drawn out into irregular bands and filaments by the separation of the pupal cuticle from the hypodermis (Pl. XIX. figs. 72, 77, *cu.l.*).

The formation of the terminal papilla of the abdomen is the last feature requisite to complete the developmental history dealt with in the present paper. The generative organs have by this time almost assumed the proportions they possess in the imago. There is a slight further growth in size, but the final histological differentiation of the organs has scarcely commenced. It is not my purpose, however, to enter here into a detailed investigation of changes of the latter kind.

SUMMARY OF RESULTS.

§ 1. *The External Anatomical Characters distinctive of Sex in the Chrysalis.*

1. The male chrysalis is characterized by a linear depression in the ninth sternal region.
2. The female chrysalis is characterized in one of the following ways:—
 - (i.) By two linear depressions, one in the eighth sternal region, the other in the ninth.
 - (ii.) By a longitudinal furrow crossing the posterior third of the eighth sternal region, and a similar complete furrow crossing the ninth.

- (iii.) By a continuous longitudinal furrow crossing the eighth and ninth sternal regions.
- (iv.) By a triangular forward extension of the sternal region of the ninth somite invading the sternal region of the eighth, together with *either* (a) a linear depression in the eighth sternal region, and another at the apex of the triangular extension, or (b) a single depression close to or in the apex of the triangular extension and produced by a confluence of the two depressions before mentioned.

§ 2. *Development of the Azygos Oviduct and its accessory Organs in Vancssa Io.*

(1) The paired oviducts of the imago are developed from the larval oviducts. The latter are, as stated by Herold, Suckow, and Bessels, attached at their ventral ends to the hypodermis near the posterior margin of the seventh somite, close together and in the median ventral line. They are at first solid, but acquire lumina early in pupal life. A little later their lumina open into the lumen of the azygos oviduct.

(2) The azygos oviduct is derived from the hypodermis; it may be divided into *three* sections, a median, an anterior, and a posterior.

The median section develops as two folds, one on either side of the anterior hypodermic vesicle (5 *infra*). The folds meet ventrally and fuse, leaving, however, an aperture, the future bursal aperture.

The anterior section, the first completed in order of time, appears to develop, so far as its posterior portion is concerned, by the ventral union of two folds extending forwards from the median section; but so far as its anterior portion is concerned as a solid ingrowth of hypodermic cells which becomes subsequently tubular. The anterior end of this section unites with the ventral ends of the larval oviducts while they are still solid.

The posterior section, the last to be completed in order of time, develops as a deep furrow formed by two lateral folds, an extension backwards apparently of the lateral folds, which give origin to the median section. They unite with the base of the posterior hypodermic vesicles (6 *infra*). The future oviducal aperture is left when the base of the posterior vesicle closes.

(3) The anterior aperture of the azygos oviduct or bursal aperture retains a constant position; it opens in the sternal region of the eighth somite. At first it leads directly into the azygos oviduct, but during growth the connection between the two becomes tubular, the tube being formed from the oviduct, and forming eventually the ventral portion of the bursal duct of the imago.

(4) The posterior or oviducal aperture is at first close behind the anterior aperture, but during pupal life shifts backwards and comes to be placed immediately below or in front of the anus.

(5) The bursa copulatrix and receptaculum seminis are both derived from a paired anterior vesicle, invaginated from the hypodermis of the eighth somite in its middle sternal region. The vesicle loses its paired character and overlies the median section

of the azygos oviduct. It grows in length antero-posteriorly. Its anterior end becomes swollen and develops into the bursa copulatrix; its posterior end becomes elongated and pointed, and develops into the receptaculum seminis.

The rudiment of the bursa copulatrix gives origin to the terminal vesicular portion of the organ and to that portion of the bursal duct which is dorsal to the point of entrance of the seminal canal. The bursa and its duct at first open into the dorsal aspect of the azygos oviduct; they then shift to its left side and are continuous with the tubular portion of the oviduct leading to the bursal aperture, which becomes the portion of the bursal duct ventral to the point of entrance of the seminal canal. Finally, the lateral connection between the bursal duct and the azygos oviduct becomes tubular and forms the seminal canal.

The rudiment of the receptaculum seminis is at first bent down upon itself to the left side; it increases rapidly in length and straightens out. It has a transitory pyriform vesicle appended to it. Later on it is differentiated into the three sections recognizable in the imago.

(6) The two sebaceous glands of the imago, their vesicles and common duct leading to the azygos oviduct, are derived from the median dorsal portion of the paired posterior vesicles invaginated from the hypodermis of the ninth sternal region, whilst the common or basal ventral portion of the same vesicles becomes the extreme posterior end of the azygos oviduct.

The anterior end of the dorsal portion retains an aperture into the azygos oviduct and becomes subsequently the tubular duct and the vesicular dilatations of the glands.

The posterior end of the dorsal portion grows out into two tubes, a right and left, the sebaceous glands proper. They are at first curved upon themselves and parallel to one another. As they lengthen they diverge and turn forward.

(7) The odoriferous glands of *Vanessa* originate as separate tubular ingrowths, a right and a left, from the hypodermis just in front of the oviducal aperture. Later on they acquire a common vestibule.

(8) It has been shown incidentally that the caterpillar and the pupa possess ten abdominal somites, corroborating Packard's statement as to the caterpillar.

(9) The terminal papilla of the abdomen of the imago is formed by the ingrowth of two folds of hypodermis, a right and left, inclosing a small portion only of the area of the tenth somite. Accordingly it does not represent a ninth somite, as is generally held; the whole ninth somite and the rest of the tenth somite of the pupa are not clearly marked off from the eighth somite of the imago. The cremaster disappears completely in the course of pupal life. The apparent eighth tergum of the imago probably represents the eighth and ninth pupal terga, and the tenth, if any portion of it is persistent. The pleural region of the ninth pupal somite and of the tenth, so far as it exists, is represented by the soft membrane lying behind the ridge extending dorsally from the eighth sternum of the imago (Pl. XVI. fig. 25 ×). As the bursal aperture lies near the centre of the eighth sternum, this region may possibly include in the imago a portion of the ninth sternal region as well. The softer integument behind connecting it to the base of the terminal papilla would in that case coincide with a portion of the

ninth sternum, and the ventral portion of the tenth somite of the pupa anterior to the place of origin of the terminal papilla.

(10) The eighth pair of abdominal spiracles is abortive in the pupa and is lost in the imago. The other seven pairs of abdominal spiracles persist.

(11) There is a cuticular secretion, apparently fluid, formed by the hypodermis just before the appearance of the scales.

There are a few points as to which further investigation or confirmation is necessary. They are the following:—the nature of the band contained in the posterior filaments attached on the one hand to the rectum, on the other to the posterior paired vesicles of the caterpillar; the exact mode in which the anterior section of the azygos oviduct originates; the way in which it becomes connected to the paired oviducts whether by its growing up to them, or by their growth uniting them to it; the details of the histological process by which the posterior oviducal aperture shifts backwards; the character of the secretion found in the later stages (4 and 5) between the hypodermis and the pupal cuticle. These various points I hope to determine in the course of next summer.

GENERAL CONCLUSION.

The uniformity which prevails in the structure of the genitalia of the Lepidoptera at large, so far as concerns essential features, is so great in the species that have been examined, that it warrants the assumption that a similar uniformity will be found to obtain in the mode in which they develop. It is true that Herold has given a very different account of the development as observed by him in *Pieris brassicæ* to what is stated in the foregoing pages. He has stated that the paired and azygos oviducts in that Butterfly are alike derived from the paired larval oviducts, and that the bursa copulatrix, receptaculum seminis, and sebaceous glands are all outgrowths of a common rudiment placed at the anterior margin of the ventral region of the ninth somite. Suckow's account of the development of the organs in *Dendrolimus pini* is identical in all essentials. But an examination of several full-grown female caterpillars of *Pieris brassicæ* has shown me that the very same rudiments are present in them as have been described in *Vanessa Io* in the present paper. So, too, the full-grown female caterpillar of *Phalera bucephala* and a one-day old female pupa of *Sphinx ligustri* have parts exactly similar to what are shown in Pl. XVII. fig. 33 in *Vanessa Io*. There can be little doubt that Herold's and Suckow's descriptions are erroneous, and that a fair uniformity prevails, at least in the Macro-Lepidoptera, in the mode in which the accessory female sexual apparatus develops.

It is a remarkable fact that very little has been done to elucidate the mode of origin of the secondary genital ducts and their appended accessory organs, either in the male or female, in different orders of Insecta*. Balbiani asserted in 1872, but in general terms

* ADDENDUM.—The statement in the text refers solely to developmental data. The presence of a chitinous cuticular lining appears to constitute a safe anatomical criterion for the purpose of differentiating the portions of the sexual apparatus derived from epiblast or hypodermis from those which are not so derived. See on the subject, as treated from a comparative-anatomy point of view, Palmén's work 'Ueber paarige Ausführungsgänge der Geschlechtsorgane bei Insecten:' Leipzig, 1884.

only, the independent origin of the ovarioles and the efferent ducts of oviparous Aphides (Ann. des Sc. Nat. 5, xv. no. 4, p. 43). But he regarded the vagina as a modified or enlarged portion of the common oviduct (*op. cit.* (5), xiv. 1870, no. 9, pp. 7, 8); he stated, however, at the same time, in the last-quoted memoir (pp. 8–11), that the accessory female organs were outgrowths of the vagina itself, an origin surmised by Weismann in his account of the post-embryonal development of the Muscidae (Zeitschrift für wiss. Zool. xiv. 1864, pp. 296, 297). Witlaczil has described in his 'Entwicklungsgeschichte der Aphiden' the formation of the vagina from an ectodermic invagination, and the derivation of the oviducts from the ovarioles, and in the oviparous female the outgrowths from the vagina which give rise to the accessory organs (Zeitschrift für wiss. Zool. xl. 1884, pp. 599, 605, 606). The same facts have been observed by Anton Schneider in several insects (*Coccus*, *Lepisma*, *Acanthia*, *Chironomus*, *Tenebrio*). His results are stated very briefly and without illustrative figures (Zool. Beiträge, i. 1885, pp. 263, 264). To the ectodermic invagination in both sexes he gives the name of "Herold's duct," and says that it was discovered by Herold in the male and female caterpillars of *Pieris brassicae*. This statement is, however, erroneous; no such discovery was made by Herold, as the text of his memoir or of the abstract of it given p. 154 of this paper will show. The most precise investigations on the subject have been made by Joseph Nussbaum in both sexes of two species of Pediculidæ, *Lipeurus bacilus* and *Goniocotes hologaster*, parasites of the Dove, and in *Blatta orientalis*; but in the last named his observations on the female were only carried out to a certain extent, whereas they were complete in the case of the male. The account *in extenso* of his work was published with figures in the Polish language, to which was added a German summary in 'Kosmos,' Lemberg, 9th yearly issue. From the Naples 'Zoologischer Jahresberichte' for the year 1884, p. 148, Arthropoda, I gather that he describes also in this paper the development of the parts in *Culex*. I have not been able to see it, but in the record mentioned it is stated to be essentially the same as the preliminary paper published in the 'Zoologischer Anzeiger,' v. 1882, pp. 637–643. As to *Blatta* there is a brief account of the development, signed by Nussbaum in Miall and Denny's work on the Cockroach (Studies in Comp. Anat. iii. 1886). The formation of the reproductive organs is treated of on pp. 193–195, and figures given of the developing parts in the male.

Nussbaum's conclusions, as summed up by himself on p. 642 of the 'Zool. Anzeiger,' v. are to the following effect:—

(1) The current impression that the larval ducts unite with one another and give origin to the whole system of sexual ducts is incorrect; they form only the vasa deferentia or the oviducts.

(2) All other parts of the efferent apparatus (uterus, vagina*, receptaculum seminis, ductus ejaculatorius, penis, and appended glands) develop from the hypodermis.

(3) The connective tissue and the musculature of the efferent apparatus are derived from mesoblast cells present in the body-cavity.

(4) The efferent ducts originate as paired rudiments. All azygos parts (uterus, penis,

* The term "uterus" here is applied to what is usually called vagina, and the term "vagina" means, according to Miall and Denny, what is usually called genital pouch, so far, at any rate, as concerns the Cockroach.

receptaculum seminis, azygos glands, &c.) are at first paired. The azygos efferent apparatus of Insects must therefore be deemed as morphologically a secondary and more complicated form.

(5) The male and female efferent ducts are strictly homologous.

(6) The cavities of the oviducts, uterus, vagina in the female, of the vasa deferentia, appended organs and ductus ejaculatorius of the male arise independently and come into connection secondarily.

My own observations on *Vanessa Io*, which are, however, limited to the female, support Nussbaum's conclusions in most particulars. The larval oviducts which seem to come from the same embryonic rudiments, as do the ovaries themselves, are converted into the paired oviducts of the imago, whereas the rest of the efferent apparatus with its appended organs is derived from the hypodermis. The hypodermis, however, only gives origin to the epithelium of the organs; their connective and muscular tissues spring from other cells which appear to be contained in the cœlomic fluid or blood. The rudiment from which the bursa copulatrix and receptaculum seminis are derived is distinctly paired in *Vanessa*, more so in *Pieris brassicæ*, and most of all in *Phalera bucephala*, where the two parts are at first entirely separate. The paired character of the rudiment is lost, and then the bursa and receptaculum grow out, not from opposite sides, so that one of them might be considered as an organ belonging to the left side of the body, the other to the right, but from opposite ends, a very remarkable feature; consequently neither of them belong to one or other side of the body, but both equally to both sides, if regard be had to the primitive condition of the rudiment. Similarly the sebaceous glands, which are paired, are derived from the dorsal portion of a paired rudiment, the two parts of which are widely separated in *Phalera bucephala*. In these organs, however, the paired character of the rudiment is persistent, and the only fusion that takes place is in the portion which forms the vesicles of the sebaceous glands and the single duct that leads from them to the azygos oviduct.

The azygos oviduct itself, however, is not paired either primitively or at a later period, unless the posterior extremity derived from the basal portion of the posterior vesicles may be considered as paired in the first instance. In this respect the development of the organ in *Vanessa* contrasts with the conclusion formulated by Nussbaum. At the same time it agrees with the simple character of the vaginal rudiment in *Aphis* and some other Insecta; only it must be borne in mind that in the Butterfly it is, as will be pointed out presently, a portion only of the anterior section of the azygos oviduct that is really homologous with the vagina of other Insecta, and this portion, as it happens, differs, in part at least, in its mode of development from the rest of the azygos oviduct. Moreover, and this is a second point of difference, the cavity of the azygos oviduct of *Vanessa* is from the first in connection with the cavities of the rudiments of both bursa and receptaculum and of the sebaceous glands. This is not true, however, with respect to the paired oviducts. They are at first solid; their cavities when formed are independent and only come into connection at a later period with the cavity of the azygos oviduct, facts entirely in accordance with Nussbaum's statement on the same point.

But the most curious feature in the developmental history of the Lepidopteran azygos oviduct is the distinct evidence it affords of the fact that it is divisible into sections which must have been successively acquired in the phylogeny of the order. Up to the last stage of active existence the female caterpillar may be said to exist, so far as its genitalia are concerned, in an embryonic condition, one which is persistent only in female *Ephemeridæ* among living insects, as has been shown by Palmén, 'Ueber paarige Ausführungsgänge der Geschlechtsorgane bei Insecten,' Leipzig, 1884. The ovaries and the paired oviducts are alone present, and the latter end ventrally near the posterior edge of the seventh abdominal somite. Were they sexually mature, this is the exact state of things found by Palmén in the female imago of the Mayflies. The prolonged embryonic condition of the parts as they exist in the caterpillar, clearly shows, among other things, that the larva of the Lepidoptera is a specialized form. The next step is the appearance of the rudiments of the accessory organs, and then of a fold on either side of the common rudiment of the bursa and receptaculum. The two folds approach one another ventrally; their edges do not fuse, however, and *before they do so* the first section of the azygos oviduct is established and is in connection, solid connection it is true, with the paired oviducts. The first section may therefore be considered as the homologue of the vagina in other Insecta. The condition now established is very similar to what is found in sexually mature Orthoptera, using that term in the signification to which it is limited by F. Brauer, in his "Systematisch-Zoologischen Studien" (Sitzb. Akad. Wien, xci. Abth. 1, 1885, p. 358), to include only the Orthoptera vera of other authors, minus the *Forficulidæ*. In *Blatta* a short vagina, the uterus, so-called by Nussbaum, connects the paired oviducts to the exterior; it opens on the eighth sternum. The spermatheca opens behind the vaginal aperture on the ninth sternum and the colleterial or the sebaceous glands still further behind. The same arrangement obtains in the *Acrididæ* and *Truxalidæ* according to Berlese (Atti Accad. dei Lincei (3), Memorie, xi. 1881, p. 273), but in the *Mantidæ*, *Locustidæ*, and *Gryllidæ* the spermatheca opens into the dorsal wall of the vagina—in other words, the latter is of greater length (Berlese, *op. cit.* pp. 271-273). The middle section of the azygos oviduct of *Vanessa* persists for some time as an open furrow, and the third section, the last formed, is a furrow in direct continuity with it, extending backwards as far as the base of the sebaceous apparatus. The conversion of the whole furrow into a tube does not take place until pupation is at hand; and when its closure occurs it leaves two openings, an anterior and a posterior, a peculiarity of the Lepidoptera, and one that clearly stamps, from the phylogenetic point of view, the middle and especially the third section of the oviduct as later acquired structures*.

Of the two apertures in question the anterior or *bursal* must be considered as the

* Doyère stated, in the Annales des Sc. Nat. (2), vii. 1837, pp. 203-205, that in the Cicada there is a vestibule into which opens anteriorly the azygos oviduct, and dorsally the spermatheca; it opens itself posteriorly into the base of the ovipositor, and ventrally behind the ovipositor. I have no means of verifying the fact myself, and de Lacaze-Duthiers throws no light on it in his paper on the composition of the ovipositor in the *Cicadidæ* (Annales des Sc. Nat. (3), xviii. 1852, p. 339 *et seqq.*). No later authority seems to have written on the subject.

partial homologue of the vaginal orifice in other orders of Insecta. It opens in the sternum of the eighth somite, the typical position of the vaginal aperture, as disclosed by the researches of de Lacaze-Duthiers. It is only a partial homologue for the following reason. A little consideration shows that the true vaginal aperture is the opening of the first into the second section of the azygos oviduct. The bursal aperture is, strictly speaking, the ventral opening of the second section, and it leads into a tube which has been secondarily developed by the ventral closure of a furrow. Its persistence may be explained on the supposition that it is necessary for copulatory purposes, and points rather to the conclusion that the bursa copulatrix and receptaculum seminis were differentiated structures at a time when the second and third sections of the azygos oviduct were still a continuous open furrow. The lateral position of the bursa and its separation from the azygos oviduct are probably late features in the phylogenetic history of the Lepidoptera, subsequent even to the closure of the furrow.

The existence of a second or posterior aperture is probably to be attributed to the advantage gained by a terminal position for the aperture through which the ova are laid. The remarkable way in which this aperture shifts backwards seems to point very distinctly to this explanation, especially as the Lepidoptera are entirely devoid of the outgrowths which form the ovipositor in some orders, *e. g.* most Orthoptera.

It may therefore be said that there are three stages traceable in the evolution of the genital ducts in the Lepidoptera: an Ephemeral stage, which ends towards the close of larval life; an Orthopteran stage, indicated during the quiescent period preceding pupation; and a Lepidopteran stage, which begins with the commencement of pupal life. As was mentioned before (p. 149) the female genital ducts of *Nematois metallicus* possess but a single external aperture, and the bursa opens into the dorsal wall of the azygos oviduct. It is possible that a better acquaintance with the anatomy of the Micro-Lepidoptera may disclose transitional or primitive states of the organs in question, just as Walter's researches (*Jenaische Zeitschrift*, xviii. 1884) have clearly shown that a primitive biting condition of the mouth-parts exists at the present day in some Micro-Lepidoptera, and more particularly in the genus *Micropteryx*.

There is one other point to which it is worth while drawing attention. What is the significance of the cuticular secretion formed by the hypodermic cells at a certain period of pupal life? Is it analogous to what occurs in the higher Amphibia, lizards and snakes, where certain cells break down completely and provide a liquid which facilitates the process of casting the old cuticular epidermis? If this be the explanation it would naturally be a process occurring at every moult. Whether such is the case with the moults of the caterpillar I do not know, but the surface of a newly-formed pupa is moist with a liquid, and it is the hardening of this liquid when exposed to air that glues the wings and legs to the surface of the body. Or is the secretion to be regarded as a modified cuticle thrown off within the first formed pupal cuticle? It is well known that an Ephemerid casts a thin pellicle after it has escaped from the sub-imago state, and there is some evidence to show that the same process occurs in the Lepidoptera. Professor Westwood drew my attention some time ago to a passage in Curtis's 'British Entomology,' in the description of plate 147, where that most accurate authority records

the fact that he saw an imago of *Acherontia Atropos* moult a complete and thin pellicle *after its emergence* from the pupal cuticle. I have also noted a passage in Packard's 'Guide to the Study of Insects' (9th edit., 1889). It runs thus:—"In the last stage of *Bombus*, just before the imago leaves its cell, the body and limbs are surrounded by a thin pellicle. This pellicle also envelops the moth just before it leaves the pupal state, and is cast off when it moults the pupa skin. This is probably identical with the skin cast by the active sub-imago of *Ephemera* soon after it takes its flight" (p. 68).

The subject is one which I hope to pursue further on another occasion, and will only add here that cast pupal cuticles of *Sphinx ligustri* may occasionally be met with in which a thin pellicle can be raised from the inner surface. An inquiry into this and other structural changes taking place during pupal life in a series of metabolic Insects would probably throw light on the still obscure question of the origin and significance of the quiescent pupal stage.

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DESCRIPTION OF THE PLATES.

PLATE XV.

- Fig. 1. *Pieris brassicae*, male. Ventral view of the four terminal segments (7, 8, 9, 10) of the abdomen. ♂ indicates the aperture of the ductus ejaculatorius. The tenth segment bears the sustentor ridges, *s.r.* of Riley. The centre of the segment is marked by a line, the anal furrow, which corresponds to the furrow between the two anal prolegs of the caterpillar, and leads to the anus at its posterior end. *cr.*, the cremaster; *r.p.*, the eminences representing the anal prolegs. The natural size is indicated in this and nine of the following figures by a line at the side.
- Fig. 2. *P. brassicae*, female. This figure is a corresponding view to the preceding, and the same explanation applies to the letters. ♀ indicates the two female apertures.
- Fig. 3. *P. brassicae*, female. A lateral view of the four terminal segments of the abdomen. The perfect spiracle of the seventh segment, and the abortive spiracle of the eighth segment, are shown. The letters as before.
- Fig. 4. *Vanessa Io*, male. ♂ indicates the aperture of the ductus ejaculatorius. A similar view to fig. 1.
- Fig. 5. *V. Io*, male. Enlarged view of aperture of ductus ejaculatorius. Obj. *aa*, oc. 2, Zeiss, draw-tube full out.
- Fig. 6. *V. Io*, female. ♀ indicates the ventral furrow crossing the eighth and ninth segments in which are situated the two sexual apertures. The latter are minute and not visible. A similar view to fig. 1.
- Fig. 7. *V. Io*, female. Enlarged view of the ventral furrow of the preceding figure. Obj. *aa*, oc. 2, Zeiss, draw-tube full out.
- Fig. 8. *Papilio Machaon*, male. A similar view to fig. 1. ♂ indicates the aperture of the ductus ejaculatorius. *s*=sustentors.

- Fig. 9. *P. Machaon*, female. A similar view. ♀, indicates the female apertures. A fine line sometimes runs forwards to the posterior edge of the seventh segment from the sexual apertures as in fig. 10. *s*=sustentors.
- Fig. 10. *Protoparce mauritii*, Butler, a Sphingid from Natal. Ventral view of the last three abdominal segments. The ninth is seen to be prolonged forwards medianly as a short triangle, at the apex of which is one of the female apertures. It is also not completely marked off medianly from the tenth segment behind. The punctations of the chitinous cuticle are indicated on the right side of the figure. ♀ indicates the two female apertures. A fine dark line, which doubtless corresponded to the anterior section of the azygos oviduct, runs forward from the anterior female aperture to the hind border of the seventh segment. (Specimen in Natural History Museum collection.)
- Fig. 11. *Sphinx ligustri*, male. A similar view to fig. 1. The punctations of the chitinous cuticle are indicated in the eighth and ninth segments. ♂ indicates the aperture of the ductus ejaculatorius and its two triangular lips. *r.p.*, the prominences representing the anal prolegs.
- Fig. 12. *Sp. ligustri*, female. A similar view to fig. 11. ♀ indicates the confluent female apertures.
- Fig. 13. *Sp. ligustri*, female. Enlarged view of the two female apertures (♀) in an abnormal specimen. 8, 9, indicate the segments. It will be observed that the two apertures belong, as in *P. brassicae*, fig. 2, to consecutive segments.
- Fig. 14. *Sp. ligustri*. Lateral view, similar to fig. 3, of the four terminal segments of the abdomen. The seventh perfect and the eighth abortive spiracle are shown.
- Fig. 15. *Vanessa Io*, female. Internal view of the ventral region of the last four segments of the abdomen, taken from a cast pupal cuticle. 7, 8, 9, 10, the segments; *s.r.*, the left sustentor ridge, which is seen to be hollow; the hollow of the right ridge is seen just above. *b.o.*, the cast chitinous linings respectively of the duct of the bursa copulatrix and of the oviducal tube.
- Fig. 16. *Sphinx ligustri*, female. A similar view to fig. 15. The lining of the bursal duct (*b*) is broken and bent down.
- Fig. 17. *Smerinthus ocellatus*. A similar view to fig. 15.
- Fig. 18. *Vanessa Io*. The larval cuticle dissected off and reflected in a specimen about to pupate. The numerals indicate the segments—on the left, of the larval cuticle; on the right, of the contained pupa. *an.*, the cuticular lining of the rectum partially pulled out. *cr.*, the cremaster, which is seen to be contained within the cuticle of the anal valve of the caterpillar. Obj. *a**, oc. 2, Zeiss, draw-tube at 160.
- Fig. 19. *Vanessa Io*. The female organs of the unimpregnated female dissected out and drawn from a left latero-dorsal point of view. *ov., ov.*, the ventral ends of the four ovarioles of each side; *od.*, the two paired oviducts; *od'*, the azygos oviduct which ends immediately below the rectum; *b.c.*, the bursa copulatrix, here empty and therefore collapsed; *d.b.c.*, duct of the bursa; the portion dorsal to the seminal canal is derived from the anterior pair of larval vesicles, the portion ventral to it from the primitive azygos oviduct; *s.c.*, the seminal canal connecting the duct of the bursa to the dorsal aspect of the azygos oviduct; *r.s.*, the receptaculum seminis divisible into the following three regions:—*d.s.*, the ductus seminalis; *c.s.*, the capsula seminis, here two irregular dilatations instead of the more usual pyriform vesicle; and *gl.r.s.*, the appended gland. *s.gl.*, the two sebaceous glands terminating at their ventral ends, each in a thin-walled dilated vesicle; the two vesicles are here confluent; *d.s.gl.*, the common duct leading to the azygos oviduct from the sebaceous vesicles. *od.gl.*, the left odoriferous gland. *r.*, the rectum turned backwards. *t.a.p.*, the terminal papilla of the abdomen, derived from a portion only of the tenth segment of the abdomen. *ch.*, a fine pointed chitinous rod inserted basally into a chitinous ring-like thickening of the terminal papilla, and not shown in this figure; muscle-bundles, running forwards and backwards, are attached to the free apex of this

rod. Together with a similar apparatus on the opposite side of the body, it serves to protrude and retract the terminal papilla of the abdomen. Obj. *aa*, oc. 2, Zeiss, draw-tube in. The figure is reduced $\frac{1}{2}$.

- Fig. 20. Section of the elliptical chitinous body, *e.b.*, guarding the entrance to the aperture of the duct of the bursa copulatrix. It lies in a deep groove of the eighth sternum, and its centre is occupied by a darkly stained mass of hypodermic cells, the cells forming a ridge in the pupa and figured Pl. XIX. figs. 71, 72. The deeper or internal portion of the chitin forming this body, and of the thickened part of the sternum, stains slightly with hæmatoxylin. The soft tissues (hypodermis, &c.) have separated slightly from the chitinous cuticle of the sternum. $\times$, the line points to the spot where the bursal opening is situated in the next section to the one here drawn. Compare fig. 25 of next Plate. Obj. B, oc. 2, Zeiss, draw-tube in.

PLATE XVI.

All the figures in this and succeeding Plates are taken from *Vanessa Io*, ♀.

- Fig. 21. Lateral view of the abdomen of the caterpillar. 1–10, the segments of the abdomen. 3, 4, 5, 6, and 10 carry prolegs; 1–8 possess spiracles, indicated by the dark dots on each of them. It may be noted that the series of large latero-dorsal spines is present on all the segments of the abdomen, including the anal valve. The series of small spines immediately dorsal to the spiracles is represented in the first segment by a tubercle with a small central hair-like spine. A similar tubercle and spine are present on the ninth segment. The series of latero-ventral spines ceases with the eighth segment. The line at the side indicates the natural length of the specimen.
- Fig. 22. Lateral view of the abdomen taken from a specimen of a caterpillar which had just commenced to throw off the larval cuticle; the operation was completed by dissection. The metathoracic wing has been cut away at its base; the leg of the same segment has been left. 1–10, the segments of the abdomen. The tubercles representing the large dorso-lateral larval spines are confined to segments 2–7; in segments 6 and 7 they are deflexed by the stripping backwards way of the larval cuticle. Spiracles are shown on segments 1–8, but the eighth is very diminutive. *s.r.*, sustentor ridge; *cr.*, cremaster. The natural length is indicated by a line at the side.
- Fig. 23. Lateral view of the abdomen of a pupa 24 hours old, to show the remarkable contraction in length and expansion in width which it undergoes, owing to the shortening of the muscles and folding inwards of the intersegmental membranes. 1–10, the segments as before. The first spiracle is completely hidden by the wings, the second and third partially. The eighth is abortive. The line at the side indicates the natural length of the specimen.
- Fig. 24. Lateral view of the abdomen of an imago. 1–8, the terga of the corresponding segments; probably, however, the eighth tergum includes the ninth and what remains of the tenth. The sterna of the first and second, and of the seventh and eighth segments are continuous; but their separateness is indicated in both instances by ridges. Note a fold in the last pleural membrane extending dorsally from the eighth sternum, which probably indicates the posterior limit of the eighth pleural membrane. The pleural membranes are shaded by diagonal lines. The terminal papilla of the abdomen is retracted as it always is in the natural state of repose, but its hairs are visible. The line at the side indicates the natural length of the specimen.

The four preceding figures, 21–24, are all drawn to the same scale,—Obj. *a**, oc. 2, Zeiss, draw-tube in. They consequently show the changes in size which take place in the passage from the full-grown larval to the imaginal condition.

- Fig. 25. Female. Enlarged ventral view of the termination of the abdomen. 7, 8, opposite the corresponding pleura; *sp.*, the seventh spiracles; $\times$, folds in the pleural membrane, probably indicating the posterior limit of the eighth pleura, the remaining and posterior portion of the membrane belonging to the ninth and tenth segments. *t.a.p.*, terminal papilla of the abdomen, which is covered with hairs and has a ventral furrow in which open the odoriferous glands anteriorly, the azygos oviduct in the middle, and the anus posteriorly. The major part of the eighth sternum is thickened and is confluent with the seventh. Its thickened portion has a ventral longitudinal groove lodging anteriorly a transparent elliptical body, which protects the entrance to the duct of the bursa copulatrix, indicated by the letters *a.b.c.* Compare fig. 20 on Pl. XV. Obj. *a** at 5, oc. 2, Zeiss, draw-tube full out.
- Fig. 26. A small portion of the seventh pupal spiracle to show the spinose eminences guarding the aperture; spines and eminences are alike absent in the eighth spiracle. Obj. D, oc. 2, Zeiss, draw-tube full out.
- Fig. 27. Horizontal section through the pupal seventh spiracle and commencement of the trachea, to show the continuously open lumen. Obj. D, oc. 2, Zeiss, draw-tube in.
- Fig. 28. A similar section from the eighth pupal spiracle to show the smooth-walled entrance, collapsed lumen, and blind ending of the trachea. Obj. D, oc. 2, Zeiss, draw-tube in.

The three foregoing preparations were made from a cast pupal cuticle.

- Fig. 29. The ventral and ventro-lateral internal aspect of the seventh, eighth, and ninth segments, with part of the sixth and tenth segments, of a full-grown active and feeding caterpillar. The overlying portions of the fat-body have been completely removed in dissection. 6, 7, 8, 9, 10, the last five segments of the abdomen. The dotted lines indicate the intersegmental divisions. The figures 6, 7, 8 are placed opposite the bundles of tracheæ originating from the spiracles of the corresponding segments. A longitudinal trachea connects the spiracles together. *v.l.*, ventro-lateral longitudinal bundles of muscles present in all the segments, but very thin and somewhat spread out and scattered in the tenth. *v.*, ventral longitudinal muscle-band, similarly present. Various oblique and transverse muscles are seen at a lower level. *n.c.*, the ganglion of the sixth abdominal segment, from which longitudinal commissures pass backwards to the terminal compound ganglion situated in the seventh segment; nerves are given off by this ganglion, of which the median pair are cut short. *od.*, the line points to the larval paired oviduct of the right side, represented by a fine white line passing backwards between the tracheæ originating from the seventh spiracle, to one of which it is attached by a filament. It is seen to turn towards the mid-ventral line in the seventh segment, and is attached to the posterior border of a transverse trachea; it passes under the muscles and at the ventral border of the ventro-lateral muscle-bands quits the trachea and takes a curved course backwards beneath the ventral muscle-band. Its attachment to the hypodermis near the median line and close to the posterior border of the seventh segment is shown. The left oviduct is also partly displayed. The anterior paired oval vesicles are seen in the median line near the posterior border of the eighth segment, and close behind them, in the ninth segment, the posterior paired vesicles, to which are attached on each side a pair of laterally directed filaments. *an.*, placed opposite the anus. *r.m.*, the band of muscle filaments which retains the rectum; anteriorly it invades the ninth segment. Obj. *a**, oc. 2, Zeiss, draw-tube in.
- Fig. 30. The central portion and right half of the seventh segment of the same caterpillar. The terminal nerve-ganglion, with the nerves to which it gives origin cut short, lies in the median ventral line. The longitudinal inner layer of muscles is dissected away, showing the longitudinal and oblique muscle-bands beneath them *in situ*. The transverse trachea and right oviduct are shown as before. Obj. *a**, oc. 2, Zeiss, draw-tube in.

- Fig. 31. A similar preparation to the preceding, but the fat-body is removed and all the main muscles, leaving only some very fine transverse muscle-bands. The anastomosis of the transverse tracheæ of the right and left sides is shown, as well as the course of the larval oviduct. Obj. *a**, oc. 2, Zeiss, draw-tube in.
- Fig. 32. Portion of hypodermis and attachment of right oviduct of an active feeding caterpillar. *od.*, the solid oviduct with faint longitudinal striations and numerous nuclei, elongated parallel to the axis of the oviduct. At its ventral end the oviduct passes into continuity with the hypodermis. A fine clear filament with a few nuclei passes off from the oviduct near its termination to the hypodermis. *tr.*, a minute trachea. The hypodermis is seen in this surface view to consist of a number of nucleated cells, with a small amount of transparent non-staining intercellular substance. The amount of this substance is perhaps slightly exaggerated in this drawing. The cell-outlines are irregular. Obj. D, oc. 2, Zeiss, draw-tube in.

PLATE XVII.

The following figures, 33-46, are drawn under obj. *aa*, oc. 2, Zeiss, draw-tube in.

- Fig. 33. Enlarged view showing the median attachments of the two oviducts, the anterior pair of vesicles in the eighth segment, and the posterior pair in the ninth, of a full-grown active and feeding caterpillar. It is taken from the same specimen as fig. 29. *od.*, the line points to the right oviduct, which is attached close to its fellow. *v.*, the ventral muscle-band of the eighth segment; there is a similar band in the ninth. *r.m.*, the band of rectal muscles. To the posterior pair of vesicles is attached on either side a pair of filaments, of which the anterior contains a trachea.
- Fig. 34. A similar view taken from a quiescent caterpillar. 8, 9, the corresponding segments; *od.*, the paired oviducts; *od'*, the anterior part of the azygos oviduct. The anterior vesicle is no longer paired; its anterior end, *b.c.*, is elongated and rounded, and forms the rudiment of the bursa copulatrix; its posterior end is more pointed and forms the rudiment of the receptaculum seminis, *r.s.*; the anterior vesicle is connected to the posterior, *p.v.*, by the posterior section of the azygos oviduct. The posterior vesicle is elongated, and there is a very distinct median furrow. Its filaments are undergoing atrophy. *r.m.*, the rectal muscles. Note the shortening of the muscle-bands and segments. The azygos oviduct is for the most part a ventrally open furrow at this time.
- Fig. 35. Lateral view of the same specimen from right side. Letters as before.
- Fig. 36. View from above of a specimen similar to that from which fig. 34 is taken. The rudiments of the bursa, *b.c.*, and the receptaculum, *r.s.*, are more pronounced, but the posterior vesicles appear to be somewhat retarded in development. Letters as before.
- Fig. 37. An abnormally elongated and pointed anterior vesicle from another similar specimen.
- Fig. 38. View from above, taken from a pupa *one* day old. The terminal nerve-ganglion with the nerves it gives off is seen anteriorly and in the middle line. Immediately behind it is the rounded apex of the bursa, *b.c.*, and behind that again the elongated receptaculum seminis, *r.s.*, bent upon itself. *gl.*, the right sebaceous gland derived from the posterior vesicle; the corresponding gland on the left is not lettered; the two are parallel to one another. The azygos oviduct is seen behind the bursa extending back to the sebaceous glands.
- Fig. 39. A lateral view of the same specimen from the right side. Letters as before. The bursa, *b.c.*, is pyriform; the left sebaceous gland, *gl.*, is seen arched upon itself, and its anterior end is dilated. This dilatation is the rudiment of the future left sebaceous vesicle. *od'*, the azygos oviduct, which has a considerable vertical depth.
- Fig. 40. View from above, taken from a pupa *two* days old. Letters as before. The bursa copulatrix, *b.c.*, is bent backwards; the receptaculum, *r.s.*, has become nearly straightened, elongated, and

turned to the left side; whilst the sebaceous glands, *gl.*, are no longer parallel to one another, but are still directed backwards.

- Fig. 41. Lateral view of the same specimen from the right side. The duct of the bursa, *b.c.*, has become slightly apparent; there is still a slight hook at the free extremity of the receptaculum, *r.s.*; the sebaceous gland, *gl.*, is much longer, strongly bent upon itself, and the vesicle from which it springs is more pronounced. The azygos oviduct, *od'*., is well seen; it is vertically swollen beneath the base of the receptaculum, *r.s.*, and this is the region where the bursal duct will be specialized. Behind the swelling in question it is seen to be arched, *i. e.* it is completely detached from the hypodermis between its bursal and oviducal openings. It ends abruptly beneath the vesicle of the sebaceous gland.
- Fig. 42. View from above, taken from a pupa *three* days old. The bursa, *b.c.*, is now a stalked vesicle; the vesicle is the bursa itself, the stalk that section of its duct which is dorsal to the point of entrance of the seminal canal. The receptaculum, *r.s.*, is elongated and entirely straightened out; its base of attachment to the azygos oviduct is behind and to the left of the base of the bursal duct. *od.*, the paired oviducts, and *od'*., the azygos oviduct. *p.od'*., the section of the azygos oviduct which is extending backwards behind the sebaceous vesicles; it is only just visible in this view from above. *gl.*, the sebaceous glands, which now diverge from one another, but are directed backwards. Note the want of symmetry between the two glands, and the well-marked vesicles from which they spring.
- Fig. 43. Lateral view of the same specimen from the right side. The two paired oviducts, *od.*, come into sight for the first time in this aspect. The bursa, *b.c.*, and the dorsal section of its duct are well seen; the receptaculum, *r.s.*, is quite straight; the vesicle, *v.gl.*, of the sebaceous gland, *gl.*, is of large size. The ventral section of the future bursal duct, *d.b.c.*, is now a vertically elongate tube, but it is in direct continuity with the azygos oviduct. *p.od'*., the posterior section of the azygos oviduct behind the sebaceous vesicles; it leads to the oviducal opening, which is now distinctly shifting backwards. Compare it in fig. 41.
- Fig. 44. View from above, taken from a pupa *four* days old. The bursa, *b.c.*, is now distinctly on the left side of the azygos oviduct; it is dilated apically, but is not so sharply marked off from its stalk as in fig. 42. *ov.*, the four ovarioles of the right side; *od.*, the paired oviducts, which are much enlarged; *od'*., the azygos oviduct; *r.s.*, the receptaculum, now directed forwards; *gl.*, the sebaceous glands, which are more slender and also turned forwards; *v.gl.*, their vesicles, which are better marked off; and *d.v.gl.*, the common duct leading from the vesicles to the azygos oviduct. *p.od'*., the much elongated section of the azygos oviduct posterior to the entrance of the common duct of the sebaceous glands.
- Fig. 45. A front view or elevation from the same specimen, showing, *od.*, the paired oviducts, *od'*., the azygos oviduct, *d.b.c'*., the section of the bursal duct dorsal to the azygos oviduct, and *d.b.c.*, the section ventral to it. It will be observed how completely these structures are placed to the left side of the azygos oviduct, and how much elongated is the ventral section of the bursal duct. *x*, the line points to the region which will differentiate into the seminal canal. The change is already indicated.
- Fig. 46. Vertical view, taken from a pupa between *five* and *six* days old. *od.*, the paired oviducts greatly increased in diameter; *od'*., the azygos oviduct, now a tube of the same diameter throughout. *d.b.c'*., the dorsal section of the bursal duct differentiated from the stalk of the bursa itself; *d.b.c.*, the ventral section of the same duct differentiated by growth from the azygos oviduct; *s.c.*, the seminal canal or tubular connection between the bursal duct and the azygos oviduct; *r.s.*, the basal portion of the receptaculum seminis, removed by a slight space from the point where the seminal canal enters the azygos oviduct.
- Fig. 47. Horizontal section of hypodermis from the seventh segment of a female caterpillar on the point of pupation. It shows the cells with their nuclei in transverse section and a small

amount of clear non-staining substance between the cells. Compared with fig. 32, which is magnified to the same degree, it is at once evident that the cells are smaller in diameter. Obj. D, oc. 2, Zeiss, draw-tube in.

Fig. 48. Vertical section of hypodermis from the seventh segment of the same specimen. The cells are elongated and close set; their nuclei are nearer their outer than their inner ends. The inter-cellular substance is visible. There is a thin basement-membrane, *b*, and a very delicate pupal cuticle, *cu*. The latter is partly seen from the surface. Obj. D, oc. 2, Zeiss, draw-tube in.

Fig. 49. A similar preparation, similarly magnified, from the cremaster of a *one* day old pupa. The nuclei are at the *inner* ends of the cells.

The six following figures are taken from an active full-grown caterpillar, still feeding, with paired vesicles, in the stage represented fig. 33, Pl. XVII., and are all drawn under obj. B, oc. 2, Zeiss, draw-tube in.

Figs. 50 *a* to 50 *d*. Transverse sections from the anterior paired vesicle.

50 *a*. From the anterior end, second section of the series; the median furrow is seen in the centre.

50 *b*. The next following section; the median furrow is deeper.

50 *c*. The sixth section of the series; $\times$, the lateral fold which is the first indication of the forming middle section of the azygos oviduct.

50 *d*. The next following or seventh section; $\times$, the same fold, which is rather deeper. The left side of this section is partly broken and bent, therefore dotted in. Three more sections, which closely resemble 50 *a*, end the series.

Figs. 51 *a* and 51 *b*. Transverse sections from the posterior paired vesicle of the same specimen.

51 *a*. The first section from the anterior end.

51 *b*. The sixth section of the series; *f*, one of the filaments. This section seems to me slightly oblique to the long axis. The five following sections are very similar, but diminish gradually in size.

PLATE XVIII.

All the sections in this Plate are drawn to the same scale as figs. 50 and 51 in the preceding Plate, *i. e.* under obj. B, oc. 2, Zeiss, draw-tube in.

Figs. 52 *a* to 52 *c*. Transverse sections of the anterior paired vesicle of a caterpillar ceasing to feed and about to suspend itself.

52 *a*. The fourth section from the anterior end; $\times$, the lateral fold to form the middle section of the azygos oviduct. The median furrow is still visible.

52 *b*. The seventh section; $\times$, the lateral fold is of large size, and the basal aperture is somewhat narrowed. The three following sections are similar but larger, and the series then diminishes in size.

52 *c*. The thirteenth section; there is no trace of a median furrow. One more section similar, but much smaller, ends the series.

Figs. 53 *a* to 53 *d*. Transverse sections from the posterior paired vesicle of the same specimen.

53 *a*. The first section of the series.

53 *b*. The third section of the series; the median furrow is very distinct. The next section is similar and larger.

53 *c*. The fifth section of the series; a portion of the roof of the vesicle on the left side is cut obliquely.

53 *d*. The eighth section of the series; *f*, one of the filaments; *m*, the portion of the roof of the vesicle coinciding with the dotted line is converted into the sebaceous apparatus of the adult. Compare figs. 54 *g* to 54 *k* following. The rest of the vesicle forms apparently the posterior end of the oviduct.

Figs. 54 *a* to 54 *k*. Transverse sections through the vesicles and azygos oviduct of a caterpillar about the middle of the quiescent suspended stage, corresponding to fig. 34, Pl. XVII.

- 54 *a*. Transverse section, the sixth of the series, through the azygos oviduct. A small amount of intrusive fatty tissue intervenes between it and the hypodermis, *h*.
- 54 *b*. The ninth section of the series, corresponding to the posterior limit of the anterior portion of the azygos oviduct. The folds are just in contact ventrally.
- 54 *c*. The eleventh section of the series; *b.c.*, the lumen of the bursa copulatrix; *od'*, the lumen of the middle section of the azygos oviduct, still open ventrally.
- 54 *d*. The eighteenth section of the series, taken between the bursa copulatrix and the receptaculum seminis, but nearer the latter. The lumina of the anterior vesicle and the middle region of the azygos oviduct, *od'*, are indistinguishable.
- 54 *e*. The apex only of the twenty-second section of the series, taken through the base of the receptaculum seminis, *r.s.* *od'*, the lumen of the azygos oviduct, which in shape resembles fig. 54 *d*. It becomes gradually diminished in height and increased in width in the following sections.
- 54 *f*. The twenty-ninth section of the series, towards the posterior limit of the hind region of the azygos oviduct, where its height is least.
- 54 *g*. The thirty-second section of the series, through the anterior edge of the posterior vesicle. The narrower upper part above the dotted line appears to correspond with *m*, fig. 53 *d*, and to form a portion of the sebaceous apparatus, *gl.* *od'*, the azygos oviduct open below.
- 54 *h*. The thirty-fourth section of the series. The dorsal or sebaceous portion, *gl.*, of the vesicle is more constricted basally. *od'*, the azygos oviduct open below.
- 54 *i*. The thirty-fifth section of the series. The sebaceous portion, *gl.*, of the vesicle is distinctly divisible into a right and left half, with a median furrow. *od'*, the azygos oviduct as before. *m*, mesoblast cells.
- 54 *k*. The thirty-sixth section of the series. The sebaceous portion of the vesicle is divided into two tubes, *gl.*, a right and a left. The tubes are traceable through the three following sections and the basal or oviducal region, *od'*, through one more in addition.

Figs. 55 *a* to 55 *i*. Transverse sections similar to the above from a caterpillar just about to pupate. The larval cuticle was split in the dorsal thoracic region. The parts evidently resemble very closely in anatomical character fig. 38, Pl. XVII., but are smaller.

- 55 *a*. The sixth section of the series. *b.c.*, lumen of the bursa copulatrix; *od'*, the azygos oviduct; *h*, the hypodermis of the body.
- 55 *b*. The eighth section of the series. The lumina of the bursa, *b.c.*, and of the azygos oviduct, *od'*, are continuous; *h*, the hypodermis of the body-wall.
- 55 *c*. The tenth section of the series. *r.s.*, the lumen at the base of the receptaculum seminis, just open to the lumen of the azygos oviduct, *od'*. The hypodermis, *h*, and very delicate pupal cuticle, *cu.*, are shown.
- 55 *d*. The eleventh section of the series. *r.s.*, the base of the receptaculum just separated off from the azygos oviduct, *od'*. Between it and the oviduct the obliquely cut ends of some cells of the vesicle. The azygos oviduct opens below by a small pore into which the cuticle, *cu.*, is prolonged. The pore is the bursal aperture.
- 55 *e*. The thirteenth section of the series. *r.s.*, the receptaculum cut across. *od'*, the posterior region of the azygos oviduct completely closed in below by union of the edges of the furrow seen in fig. 54 *f*. It is still in continuity with the hypodermis, *h*, of the body-wall. *cu.*, the pupal cuticle.
- 55 *f*. The sixteenth section of the series, just at the commencement of the sebaceous apparatus, *gl.* The azygos oviduct, *od'*, opens to the exterior by a second pore, the posterior or oviducal

aperture, into which the pupal cuticle, *cu.*, is prolonged. A small portion of the cuticle lies detached in the lumen of the oviduct.

- 55 *g.* The eighteenth section of the series. The sebaceous region, *gl.*, is more clearly marked. The azygos oviduct, *od.*', is closed below, but continuous with the hypodermis, *h.* *cu.*, the pupal cuticle.
- 55 *h.* The twentieth section of the series. The vesicle region of the sebaceous glands, *v.gl.*, is shown dorsally; below it are the cut ends of the two sebaceous glands, *gl.*, which are turned ventrally. *h.* and *cu.*, as before.
- 55 *i.* The twenty-second section of the series. The sebaceous glands, *gl.*, are so much curved upon themselves that they are cut through twice over. The next section passes through the apex of the curve. Compare fig. 38, Pl. XVII., which shows what the external appearance corresponding to the sections must be alike. *h.* and *cu.*, as before.

PLATE XIX.

With the exception of figs. 59 and 64, all the figures on this Plate are drawn to the same scale as the figures on the preceding Plate, viz. under obj. B, oc. 2, Zeiss, draw-tube in.

Fig. 56. Transverse section through the anterior end of the azygos oviduct. Three sections behind fig. 58. *od.*', the azygos oviduct. It is solid and composed of cells cut obliquely, with a small amount of transparent intercellular substance closely resembling fig. 47, Pl. XVII., which is, however, more highly magnified. It is seen to be continuous with the hypodermis, *h.* and probably represents a solid invagination of that layer of cells. *cu.*, the delicate pupal cuticle. *cu.*', the larval cuticle.

Figs. 57 *a* to 57 *d.* Transverse sections of the azygos oviduct from a pupa one day old.

57 *a.* Section just behind the spot where the solid azygos oviduct, *od.*', is joined by the paired oviducts. Note the extreme thinness of the hypodermis, *h.* beneath it, a feature seen also in the next section, and showing probably that the hypodermis cells have undergone transverse fission.

57 *b.* The next succeeding section, still solid.

57 *c.* The next section with a lumen; its ventral wall is thin.

57 *d.* The next section. The lumen is larger; the hypodermis, *h.* is cut obliquely and therefore looks abnormally thick. *cu.*, the pupal cuticle. It is naturally V-shaped, as the portion cut through is the commencement of the median furrow in the eighth segment, shown fig. 7, Pl. XV.

Fig. 58. Surface view of the junction between the paired oviducts, *od.*, and the azygos oviduct, *od.*' The plane of the section is nearly parallel to the surface. The hypodermis cells are cut transversely. The section is taken from a quiescent caterpillar, the same specimen from which fig. 56 is taken.

Fig. 59. Transverse section of the right paired oviduct taken from the same specimen as fig. 55 in the preceding Plate. It is solid and there is a single row of superficially placed nuclei. Obj. D, oc. 2, Zeiss, draw-tube in.

Fig. 60. Longitudinal section of the right paired oviduct from a pupa *two* days old. The drawing is taken close to the ventral end, just where the lumen ends. The union with the azygos oviduct in this specimen is solid.

Fig. 61. A similar section from a *three* days old pupa.

Fig. 62. A transverse section from a pupa of the same age as the last, showing the junction between the lumina of one of the paired oviducts, *od.*, and the azygos oviduct, *od.*'

- Fig. 63. A transverse section through one, the right, of the paired oviducts from a pupa between seven and eight days old.
- Fig. 64. A small portion from the wall of the azygos oviduct, the same section that is drawn fig. 55 c, Pl. XVIII. It is the left-hand portion just above the dotted line leading from the letters *od.* The cells of the wall, *w*, of the oviduct with their nuclei are plainly seen, together with an aggregated mass of mesoblast cells, *m*, on the outer surface of the oviduct. Obj. D, oc. 2, Zeiss, draw-tube in.
- Fig. 65. Transverse section from a *one* day old pupa of the tube connecting the sebaceous apparatus to the hinder end of the azygos oviduct, the external opening of which was cut through *five* sections in front of the one here figured. *d.v.gl.*, the tube which becomes subsequently the common duct of the sebaceous vesicles. *m*, mesoblast cells. Compare fig. 38, Pl. XVII.
- Fig. 66. The next section posterior to the preceding, showing the central cavity, *d.v.gl.*, continuous with the duct, and the two lateral cavities, *v.gl.*, which become subsequently the vesicles of the sebaceous gland.
- Fig. 67. Transverse section from a *two* days old pupa showing, *v.gl.*, the sebaceous vesicles; *d.v.gl.*, their common duct, nearly vertical in position; *od.*, the lumen of the azygos oviduct opening by the oviducal or posterior aperture to the exterior. *m*, mesoblast cells; *h*, hypodermis of the body-walls; *cu.*, the pupal cuticle, V-shaped and indicating the median ventral furrow of the pupa seen in fig. 7, Pl. XV.
- Fig. 68. The following section. The common duct, *d.v.gl.*, of the sebaceous vesicles is seen opening medianly between the vesicles, *v.gl.* *od.*, the posterior end of the lumen of the azygos oviduct. *m*, mesoblast cells intruding between *d.v.gl.* and *od.* *h*, the hypodermis of the body-wall.
- Fig. 69. A combined drawing of two consecutive sections from a pupa between *six* and *seven* days old, showing the lumen of the azygos oviduct, *od.*, communicating by a short seminal canal, *s.c.*, with the duct, *d.b.c.*, of the bursa copulatrix. *m*, mesoblast cells. There are traces of a delicate cuticle in the oviduct and seminal canal.
- Fig. 70. A combined drawing of two consecutive sections from a pupa between *five* and *six* days old, showing the minute and transitory pyriform vesicle, the homologue, probably, of the pyriform capsula seminis as it is usually seen in Lepidoptera, appended to the receptaculum seminis. *r.s.*, the receptaculum seminis.
- Fig. 71. Transverse section through the hypodermis, just anterior to the bursal aperture of a pupa between *five* and *six* days old, to show the ridge of elongated cells which subsequently form the transparent elliptical body, *e.b.*, fig. 20, Pl. XV., covering the bursal aperture of the imago.
- Fig. 72. A similar section close to the bursal aperture of a pupa *seven* to *eight* days old. The elongated cells are cut obliquely. *d.b.c.*, the wall of the bursal duct cut parallel to the duct. *cu.l.*, irregular lamella and filaments of the cuticular liquid (?) formed about this period.
- Fig. 73. View from the internal aspect, showing the rectum, *r.*, cut through; *o.ap.*, the terminal portion of the azygos oviduct; *od.gl.*, the two odoriferous glands meeting in a common vestibule; and *f,f*, the folds of hypodermis which constitute the terminal papilla of the abdomen. From a dissection of a pupa between *nine* and *ten* days old.
- Fig. 74. Transverse section to show the origin of the odoriferous glands in a pupa between *five* and *six* days old. *od.*, the azygos oviduct, showing the commencement of the common duct of the sebaceous vesicles. *m*, mesoblast cells. *od.gl.*, odoriferous gland of the right side, a simple tubular invagination of the hypodermis, *h*.
- Fig. 75. A similar section from a pupa *six* to *seven* days old. *od.*, the azygos oviduct, two sections in front of the one in which the common duct of the sebaceous vesicles appears. *m*, mesoblast cells. *od.gl.*, the left odoriferous gland. The aperture of the right gland is shown. The apertures of the two glands are now nearer to one another, and the vestibule, *v*, is forming. *x*, indication of the lateral fold to form the terminal abdominal papilla.

- Fig. 76. A transverse section through the ventral apertures of the two odoriferous glands, *od.gl.*, showing the greater depth of the vestibule, *v*, in a pupa between *seven* and *eight* days old. The section passes through the apices of the cells forming the anterior wall of the vestibule; the contour of the latter is indicated by dotted lines.
- Fig. 77. A transverse section through the oviducal or posterior aperture of the azygos oviduct, *od.l'*, with the right lateral fold, $\times$, of the hypodermis, which is now much deeper as compared with fig. 75. *cu.l'*, filaments and bands of the cuticular liquid (?). From a pupa between *six* and *seven* days old.
- Fig. 78. Transverse section through the anus, *an.*, and the right lateral fold, $\times$, of the hypodermis, from a pupa between *seven* and *eight* days old. The terminal papilla is now, as may be concluded from this figure, of considerable size.