A manual of entomology

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First subsection.
c. The nervous system of the digestive organs;

d. The organs of the senses.

We consequently commence our description with the vegetative organs, as being the inferior; and thence proceed to the survey of the animal organs, as the superior ones. But we do not wish by this arrangement to imply that the lowest insects have no organs of locomotion and sensation, but that in them both these organs, and also partially the vegetative ones, are not quite so perfectly developed and completely combined as in the higher orders, and from the circumstance of this difference the latter stand higher and the former lower in the system. And by these expressions, as well as by the synonymous ones, of more or less perfect, we would indicate that the structure of the former is more complex, artificial, and various than the groups characterised as standing lower and less perfect. But each group is perfect in its kind.

FIRST SUBSECTION.

VEGETATIVE ORGANS.

§ 91.

The organs of the vegetative sphere are, as it were, transmitted from the plant to the animal; it will therefore be not unimportant if we can prove that their fundamental texture displays a vegetable origin.

The plant commences its existence in the form of a cell; cell is added to cell, and the entire vegetable is but a congeries of small cells, with here and there long delicate tubes interspersed, forming, as it were, free passages between them. All the organs of vegetables consist of these two forms, consequently the nutrimental and re-productive organs must display a similar, or at least an analogous, structure, if they are to prove themselves of vegetable origin. Nothing, in fact, is more astonishing than the confirmation of this law; for cells, which in animals become small vesicles or larger bladders, and tubes, constitute the various forms of the vegetative organs. A vesicle, the egg, is the
origin of animal existence; vesicles distend themselves, and become cases; they link themselves in a series, and form vessels; and thus, by degrees, each vegetative organ is formed from the vegetable original.

We will examine this more closely in the individual organs.

§ 92.

The intestinal canal is a tube which originated from the elongation of one or the connection of several bladders. This is proved not only by its form in the lower animals, but also from its being in many, likewise in the larve of insects, a mere blind sack, consequently a bladder open only in front. In animals of a higher grade, in which it consists of several divisions separated by constrictions, it is very easily imagined as consisting of the union of several bladders.

The same holds good of the vessels: for example, the chief vessel of insects, namely, the large dorsal vessel, so evidently displays a cellular construction that we may not consistently doubt its original growth from bladders.

The very name of the air-tubes announces their form. It must, however, strike as important that the air-vessels of insects have so deceptive a resemblance to those of plants that everybody must immediately admit of their analogous structure.

The vegetable origin of the nutrimental organs is thus evidently proved.

§ 93.

It is not more difficult to show the same in the organs of reproduction. These, namely, very much more distinctly display their vesicular origin. The ovary of the female is a large bladder, containing many smaller ones, the eggs. The oviduct is an elongation of this large bladder; the uterus is another distension of it, and the vagina another elongation: other incidental appendages of the above parts display more or less distinctly a vesicular form.

It is the same in the male organs. The testes have not uncommonly the shape of a bladder (Lamellicornia), or else they are long convoluted tubes, which we know to be but modifications of bladders; the vasa deferentia are elongations of these bladders; the vesica seminalis another distension of it, and the ductus ejaculatorius another and its final constriction.

Thus the sexual organs are a still more evident repetition of the vesicular form, they being always closed at one end at least.
§ 94.

We shall show in full detail, at its proper place, that the character of the organs of the animal sphere differs wholly from the vesicular character of the vegetative organs by the integral solidity of each individual part.

FIRST CHAPTER.

OF THE ORGANS OF NUTRITION.

1. THE INTESTINAL CANAL AND ITS APPENDAGES.

§ 95.

The intestinal canal (tractus intestinorum) is the internal tube, extending from the mouth, appropriated to the reception and transformation of the nutriment. It has in general a second aperture opposed to the first, the anus, through which the indigestible unassimilating remains of the food are rejected. The instances in which such an anal aperture is deficient are very rare among insects, and occur only among larvae and maggots, but never in the imago.

This tubular structure of the intestinal canal is subject to considerable modification from distension and constriction, by means of which it is separated into several divisions, which have very justly received different names, from their functions being dissimilar. Besides these separations of the intestinal canal itself, we observe peculiar processes and appendages, which originate from it, or which, as perfectly independent parts, merely open into it. Their variety and modifications produce relations which yield multifarious differences in form and structure, and which link certain groups of insects more closely together by their complete uniformity, whereas they separate others, in which such a similarity of arrangement is not observed, more distinctly from each other, and thus more fully corroborate the dissimilitude expressed in their exterior conformation by this difference of their internal structure.
§ 96.

The entire intestinal canal consists of three skins, or layers of membrane.

The innermost membrane (Pl. XVII. f. 1), which may be considered as a continuation of the exterior epidermis, is very smooth and textureless, and only sometimes longitudinally folded, and armed above with horny lines, ridges, or teeth (Pl. XVII. f. 2. 5—7). It is particularly distinct in the pharynx, crop, and proventriculus, the horny teeth of the latter being formed by it. This internal membrane is most apparent in insects with hard cases, as the Coleoptera and Orthoptera, whereas it is not so evident in the haustellate Diptera and Lepidoptera. From the proventriculus it forms a very delicate perfectly uniform covering, and generally occupies less compass than the other intestinal membranes. We here call it the epidermis, it being its analogue, or properly, the mucous membrane, as it corresponds with the tunica mucosa of the superior animals.

The second layer, which we call with Straus the proper skin (membrana propria), is white and smooth, and usually thin, but sometimes thicker and spongy, most frequently without any texture, but occasionally figured (*Hydrophilus*, Pl. XVII. f. 2.). This membrane, which Ramdohr treats as a layer formed of transuded chyle, is peculiar to the intestinal canal, and is not found in the other internal organs; it may therefore be considered as a continuation of the second layer of the exterior integument, of which we shall treat below. Indeed, the space between the mucous membrane and this peculiar skin, which is very considerable in the stomach, and particularly in caterpillars, is often occupied by a flocky web, formed of transuded chyme, and this may have misled Ramdohr in his idea of it. According to Straus, horny prominences are sometimes observed in this intermediate skin, particularly in the vicinity of the stomach, which might be considered as absorbing pores, but which Straus, perhaps more correctly, treats as glands, and they are therefore called gastric glands (glandula gastrice). I have observed these organs only upon the inner surface of the muscular membrane, but particularly distinct in *Hydrophilus*, in which insect the long cylindrical stomach is completely and regularly covered with such glands, which consist of a transparent case inclosing a darker kernel (Pl. XVII. f. 3.).

The third layer (Pl. XVII. f. 3 and 4.) is a compact, firm, fleshy
muscular membrane (*tunica muscularis*), in which distinct longitudinal and transverse vessels can be discerned, and it lies closely upon the preceding. These vessels, which are sometimes completely reticulated, sometimes furcate separately and rejoin in the same manner *, are generally of a uniform size, but occasionally the transverse ones are stouter, the others more delicate and slender, but also more numerous and closer together, so much so that their distinct threads may be considered as the separated bundles of muscles †. This muscular membrane is not equally observable in all parts of the intestinal canal: it is very obvious in the pharynx, stomach, and colon; but it vanishes almost entirely in the crop or craw.

§ 97.

The situation of the intestinal canal is the same in all insects. It always commences as a cylindrical, and chiefly narrow tube at the somewhat wider cavity of the mouth, and proceeds in a direct line through the head and thorax. It takes the same direction in all insects which have a long and at the same time thin body (e.g. *Pimpla, Tipula, Agrion*). In these cases, however, the intestinal canal is of the same length as the body, and only in some of the broad-bellied ones, for example, the long bugs (*Gerris, Emesa, Ranatra*), it makes a small curve before its termination, so that it becomes about half as long again as the body. But if the creature be thick bodied, and the cavity of the abdomen is distended on all sides, the intestinal canal becomes longer than the body, and makes convolutions within the cavity of the abdomen; but it always passes in a direct line through the head and thorax.

These convolutions of the intestinal canal are kept in their proper situation by the multitudinous branches of the air-vessels which spread about them; indeed, this reticulation of the air-vessels is so delicate and firm that it not only makes it difficult to represent the intestinal canal with all its appendages (which besides is closely enveloped in the fatty mass) in its full extension, but makes a perfect separation of all these air-vessels absolutely impossible. We never find in insects a peritoneum, which in the higher animals retains the intestines in their place, but its purpose is supplied by these air-vessels.

* Ramdohr, Ueber die Verdunngswerkteze der Insecten Halle, 1811. Pl. XIV. f. 4, from *Pomplius Viaticus*.
† The same Pl. XVII. f. 2., from the fauces of the larva of the Ant-lion.
§ 98.

The length of the intestinal canal increases with its convolutions; or these rather are but the consequences of its extension. We very frequently find the intestinal canal twice the length of the body; indeed so often is this the case that it may be considered as the most usual structure. A nutrimental canal of this extent is called moderately long; such an intestine makes from one to three convolutions, according to their size. The long intestine (Chrysomela, Cimex) makes also two or three, but larger convolutions, and is from three to five times the length of the body. The intestine is, lastly, very long in the Lamellicornia, in which it is from seven to eight times as long as the body, and makes many folds in the cavity of the abdomen.

But these proportions refer only to the perfect insect, for the majority of larvae, namely those with a perfect metamorphosis, have a nutrimental canal of the same length, or at most of twice the length of the body. This short intestine increases in length in every distinct period of its life; but some instances occur in which this gut becomes shorter during the metamorphoses, namely, in the Diptera, the larvae of which have a very long and much convoluted intestine.

§ 99.

No general law regulating the various length of the intestinal canal has yet been discovered; in insects, in particular, it appears exposed to much irregularity. It is not however improbable, from all hitherto instituted investigations, that herbivorous insects have a longer and more distended intestine, and that those which feed upon animal matter have it shorter and narrower. We, however, find a decided exception in the vegetable devouring Orthoptera (e.g. Gryllus, Locusta), their intestine being not much longer than their body, but at the same time very broad. We perceive greater uniformity, if not in length yet in structure, in the different orders of insects, and this law we shall observe to prevail still more forcibly in the still smaller groups.

§ 100.

We will now pass from this general description of the entire intestinal canal to the examination of its different divisions. We can there-

* Ramdohr, Pl. XIX. f. 1 and 2.
fore make a primary separation of it into its several divisions and its appendages.

The divisions of the intestinal canal are, the pharynx, the oesophagus, the craw, the proventriculus, the stomach or ventriculus, the duodenum, the ilium, the oecum, and the colon.

The peculiar appendages of the intestinal canal are, the salivary, biliary, and anal vessels.

These parts are never all present together; sometimes one is wanting, and sometimes the other. For example: insects with a suctorial mouth never possess apparent pharynx, but the oesophagus originates immediately at the base of the sucking tube; they also want the proventriculus, instead of which they possess a bladdered crop, which however does not occur in mandibulated insects. The part most frequently deficient is the duodenum, which has hitherto been observed only in some of the pentamericous Coleoptera, after which the oecum is least frequently present, for it appears to be peculiar to those families only the genera of which feed upon animal matter. With respect to the appendages, the biliary vessels are seldom wanting (Chermes, Aphis), the salivary ones frequently, but the anal vessels very generally.

**THE PHARYNX.**

§ 101.

The pharynx is the distended commencement of the oesophagus, bordering upon the cavity of the mouth, and is found, as we have recently remarked, only in the mandibulata, consequently in the Coleoptera, Orthoptera, Neuroptera, and Hymenoptera. In these it is nothing else than the almost trumpet-shaped commencement of the oesophagus, and in the majority of cases is not separated from it by any evident difference of texture or construction. In some of the grasshoppers and cockroaches, in which, in consequence of their large mandibles, the cavity of their mouth is very expansive, their pharynx is very much distended, and more clearly separated from the much narrower oesophagus *. Its membrane is more dense and compact than that of the latter, excepting which it displays no other difference. The mucous and muscular membranes lie close together, and it is scarcely possible to

distinguish the proper membrane between them as a separate layer. A free space is naturally not found, as in the stomach.

THE ÖESOPHAGUS.

§ 102.

The Öesophagus (Pl. XVII. 22, a, a.) extends from the pharynx to the stomach; it is distinguished from the former by its smaller capacity, and from the latter by a variation in structure. The most remarkable form of the Öesophagus is doubtlessly its very general furcate division in the Lepidoptera, and that from each of the two spiral sucking tubes it originates by a distinct branch, which branches then unite into one channel. In general the branches of the fork are very short, but in the swallow-tail butterfly (Pieris Machaon, O.) their union into one tube commences only at the thorax*. In the other orders of insects the Öesophagus passes through the entire cavity of the thorax as a simple tube, and either terminates where the cavity of the abdomen commences, or before this, within the thorax itself; for example, in its centre in those insects the cavity of whose thorax is broad, and which consequently admits of a greater expansion of the organs which traverse it. The length of the Öesophagus therefore depends upon the length and dimensions of the thorax. Insects with a thin and narrow, and in particular with a petiolated abdomen, have a long Öesophagus, when the thorax also is long (Pimpla, Fœnus); and it is the longer in proportion to the entire intestinal canal, the shorter, narrower, and smaller we find the abdomen. The most remarkable proportions must occur in this respect in the genus Evania, but which has never yet been anatomically investigated. The longest Öesophagus yet observed consisted of more than half of the entire intestinal canal†; and among the shortest is that of the cockchafer, which occupies scarcely one-sixtieth of the entire length of that canal ‡.

We are already acquainted with the texture of the Öesophagus; its central layer however is very slight, whence the two other membranes lie closer together, which, as Ramdohr assures us, makes their separation very difficult. The inner membrane is generally here quite uniform, much more rarely thicker in parts, almost like parchment, or, as in Carabus,

† In Pimpla Enervator and Pompitus viaticus, Ramdohr, Pl. III. f. 2 and 3.
‡ Ramdohr, Pl. III. f. 1.
Meloë, Chrysomela, Blatta, and the grasshoppers (Pl. XXI. f. 2 and 3), internally covered with short stiff setae and teeth; the muscular fibres of the exterior membrane generally lie regularly above each other, but they sometimes form a loose confused net-work from open spaces remaining here and there between them.

The separation of the oesophagus from the stomach is effected sometimes by a positive constriction (Diptera, Pl. XVIII. f. 3.); it occasionally passes insensibly into it, and sometimes the crop intervenes between them, as the organ of transition; in this case the oesophagus expands by degrees into a sack-shaped crop (ingluvies, Pl. XVIII. f. 1. n, n.,) which takes the place of a first stomach, and prepares the swallowed food for digestion. In Gryllotalpa it occurs as a perfectly sack-shaped appendage of the oesophagus * (Pl. XXI. f. 7.). To facilitate this the inner surface of the crop is covered with glands (for example, in Dyticus, Blatta, &c.), the secretion of which has the function of a preparing juice. Such an expansion of the oesophagus before the proventriculus might readily be considered as analogous to the crop of the higher animals, of the birds, for example; an opinion which Ch. L. Nitzsch has already propounded †. The expansion, however, without a contemporaneous proventriculus, is of a different and peculiar kind, namely, the sucking stomach, indicated by G. R. Treviranus, and which we proceed to describe.

THE SUCKING STOMACH.

§ 103.

The Hymenoptera, Lepidoptera, and Diptera are the orders in which the proventriculus is deficient, but they possess, nevertheless, a bladder-shaped distension of the oesophagus (Pl. XVII. and XVIII. c, c.), which in the first lies directly in front of the cardia; in the second it forms a distinct bag, which opens into the oesophagus, contiguous to the cardia; and in the third it hangs appended to the oesophagus by means of a long thin duct, frequently far in front of the opening of the stomach. This organ is the before-named sucking stomach. Its function does not consist in being a receptacle for nutriment, but in promoting the suction of food, by distending, at the will of the insect, and thus, by the rarefaction of the air contained within it, facilitating the rise of

† Gattungen der Thier-Insekten, German's Magaz. iii. p. 280.
fluids in the proboscis and oesophagus. Insects which chew are naturally deficient in this apparatus, or at least in this function of it; in them it is a true crop.

In the Hymenoptera (Pl. XVII. f. 10, c,) the sucking stomach is a distension of the oesophagus in front of the cardia, and consequently perfectly resembles a true crop. Indeed, in those families of this order, which possess more a mandibulate apparatus than a suctorial, this sucking stomach must gradually become superfluous; and it is, consequently, so little distinct from the oesophagus that it was formerly always described with it, and as nodose*. It exists however as a distinctly defined organ in the families of the bees and wasps, which possess a true suctorial apparatus; and here it is a large bag, which hangs below the oesophagus, in front of the mouth of the stomach †. If it be empty it lies folded longitudinally; when filled with air it is distended as a transparent bladder, and embraces the long funnel-shaped mouth of the stomach, which is furnished at its aperture with valves.

In the Lepidoptera (Pl. XVIII. f. 5.) we find the sucking stomach still more distinctly separated from the oesophagus. In these it projects with a short neck at right angles from the end of the oesophagus, and when simple it lies as a folded bladder contiguous to and over the stomach, or upon each side of it when, as in Zygaena‡, it consists of two equal halves. This division is sometimes unequal, when a smaller bladder hangs beneath the large one§. It is always proportionate in compass to the length of the proboscis, so that it completely vanishes when the proboscis dwindles to a short cone, as in Gastrophaga pini and Cossus ligniperda ||.

Many Neuroptera, for example, the genera Hemerobius and Phryganea, have apparently similar bags, which are likewise inactively folded, but which also admit, like those of the Lepidoptera, of being distended into tight bladders. These organs may possibly be sucking stomachs, particularly as these insects, although provided with a mandibulate apparatus, take food more by suction (this is the case especially in Phryganea) than by mastication.

* For example, in the Tenthredos and Ichneumons, Ramdohr, Pl. XIII. f. 2 and 3. and Pl. XIV. f. 2.
† Ramdohr, Pl. XII. f. 6. Pl. XIII. f. 1. Pl. XIV. f. 3. Treviranus, Pl. XIV. f. 3. and Pl. XVI. f. 3.
‡ Ramdohr, Pl. XVIII. f. 1.
In the Diptera, lastly, (Pl. XVIII. f. 2 and 3, c, c,) the sucking stomach is still more distinctly divided from the oesophagus, and is a single mouthed bag, having one or several ends, and furnished with a solitary evacuating duct. When empty it is small and wrinkled, but when distended it is of large dimensions. In its natural situation it lies contiguous to and over the stomach, at the very commencement of the abdomen, whence its delicate evacuating duct, rising anteriorly, accompanies the stomach as far as the oesophagus, of the size of which it generally is, and opens into it more or less closely to the cardia *. According to Ramdohr this organ is the food bag (speisesack), as it serves for the reception of food. Meckel calls it, from the same cause, the honey vessel (honigbehälter), and he found in it a peculiar, coloured liquid. But Treviranus' representation is much too illustrative, and his investigations in insects opened alive much too conclusive to admit of the least doubt being entertained of the function of this organ.

The Hemiptera, which likewise live upon imbibed juices, have no sucking stomach, nor any analogous apparatus; this is the case also in the Pupipara and the flea, although they must necessarily be classed among the Diptera †.

THE PROVENTRICULUS.

§ 104.

The proventriculus (Pl. XVII. f. 8 & p. 21, f. 8—10) is the third division of the intestinal canal, if we may consider the crop or sucking stomach as nothing but a distension of the oesophagus. It is a small narrow and tubular cavity, much folded within, and furnished with teeth, spines, or projecting horny ridges. It lies directly in front of the mouth of the stomach, and as which it may properly be considered. It is found in all mandibulate insects which feed upon hard substances, or require the comminution of their food previous to digestion; consequently in all the carnivorous tribes (Carabodea, Hydrocantharides, Brachyptera), the wood-beetles (Cerambycina, but here somewhat altered), many Rhinophora, the Orthoptera, (with the exception of the Phasmæ and the Grylli, whose whole crop is furnished with spines which serve to triturate the food), and the Neuroptera. Exteriorly it has always a round somewhat ovate appear-

* See Ramdohr, Pl. XVIII.—XXI., and Trevir. Pl. XVII.
† See Ramdohr, Pl. XXI. f. 6., and Pl. XXIII. f. 2.
ance, and is compact, opaque, and more distinctly muscular than the rest of the intestinal canal. It consequently answers to the gizzard of the gallinaceous birds, an analogy which still more strongly confirms the general analogy of organisation existing between insects and birds.

A closer anatomical investigation of this organ displays two very distinctly-separated membranes, the exterior of which is tight and muscular, and the interior folded, smooth, and partially horny. The folds of the inner membrane are by no means accidental, but perfectly regular and differently formed in the several families. In the predaceous beetles (Cicindelacea and Carabodea, Pl. XVII. f. 8), four is the prevalent number. Four large arched folds, densely covered with short horny spines, bend inwardly in the cavity of the organ, and between these lie four smaller ones, which are sharply ridged in front. Within the large folds there are four robust bundles of muscles, which unite above and below, and thus form a closing muscle at each opening. The similarly constructed mouth of the stomach in Staphylinus has five large folds and as many small ones. In Cryptorhynchus Lapathi there are nine equal prismatic folds, from the inner ridges of which originate two rows of diverging horny processes, which meeting from fold to fold, separate a central star-shaped space from the entire cavity.* In the capricorn beetles (Cerambycina) there is no cavity at all, but at the inner margin of the cardia there are four large and four smaller horny plates (Pl. XXII. f. 1, Lamia edilis). The Orthoptera (for example, Acheta,) have six chief plates, which are covered with scale-shaped horny plates. In the Termites (Pl. XXI. f. 8—10.) I discovered a proventriculus, which consisted of a ring of twelve equal broad folds, between which again twelve finer and sharp edged ones lay. Around this ring, which formed the central girdle of the cavity of the organ, there were six strong fasciculi of muscles, which united above and below like the ribs of a gothic arch, and thus formed closing muscles. In Blatta, instead of folds we find hooked horny teeth, which spring from a broad base at the sides of the stomach, and project into its cavity. In Gryllus migratorius (Pl. XXI. f. 1—6.) I found no proventriculus, but the entire pharynx and crop were armed with rows of small but differently sized teeth, which, running longitudinally, formed in the centre transverse waved lines, but towards the cardia again stand in twos and threes upon elevated mus-

* Ramdohr, Pl. X. f. 1—4.
ular ridges. The cardia itself was armed with six Y-shaped horny teeth (Pl. XXI. f. 6. a, a). In Müller's representation of the intestinal canal of Phasma no proventriculus is visible *, I consequently surmise they would present a similar structure.

The exterior skin of this organ is tense, not folded, and it closely incloses the interior one as a similarly shaped distended bag. It agrees in structure with the muscular membrane of the intestinal canal. The space between both is occupied by fasciculi of muscles, and the spongy layer or middle membrane must necessarily be deficient here as well as in the crop, it being the produce of digestion, and therefore can only be present where this has commenced.

The larvae of all the above-named insects whose metamorphosis is complete, entirely want this organ, and in them the pharynx passes immediately into the considerably wider stomach. We do not either observe in the very voracious caterpillars of the Lepidoptera any further comminuting stomach.

§ 105.

The stomach (ventriculus, Pl. XVII.—XXII. d, d), according to most entomologists, is that portion of the intestinal canal which extends from the end of the oesophagus, or of the crop, to the opening of the evacuating ducts of the biliary vessels. Straus, Treviranus, and Joh. Müller † call it the duodenum, as digestion commences in it, in those orders which have the proventriculus, and perhaps this interpretation may be more correct than that hitherto used.

Upon examining the form of this portion of the intestine it soon becomes apparent that it is subject to many changes; it always approaches more or less to the tubular, but it at the same time distinguishes itself from the following divisions of the canal by its greater compass. The shorter the stomach is the further does it recede from the tubular form, and approaches to the ovate, conical, or bladder-shaped.

The Lepidoptera (Pl. XVIII. f. 5. d) have the smallest stomachs of all insects. In these it takes the shape of an egg, the ends of which contract into narrow tubes, and its upper surface is folded in irregular

conststrictions. Generally, upon both upper and under surface, a narrow sinewy or muscular stripe runs longitudinally, for the purpose of strengthening the there more delicate envelope. Meckel informs us* that this stomach in *Acheronta Atropos* is shaggy externally, a solitary instance of this structure in the *Lepidoptera*.

The longitudinal, more tubular, and regularly transversely folded stomach of the *Hymenoptera* (Pl. XVII. f. 10. d) approaches very closely in structure to that of the *Lepidoptera*. It commences with a funnel-shaped orifice, which is evidently analogous to the before-described proventriculus, and as such projects into the cavity of the sucking stomach, which can be closed by valves that open inwardly †. This funnel-shaped orifice facilitates the passage of the food from the oesophagus into the stomach, its aperture being thereby brought nearer to the former, indeed, during suction, rising quite up to it; the valves however preventing the return of the chyme into the sucking stomach. This structure of the stomach is found in all the *Hymenoptera*, but it varies much in compass; in some (*Sirex*) it is short, broad, and straight, the crop, on the contrary, is very long and nodose; in others (*Chrysis*) it is distended in the middle and recurvate at the extremity; in the bees and wasps it is of tolerably equal breadth, but not straight, for it bends inwardly at both ends, so that it is partially inclined towards the axis of the body.

In the larvae of these insects the whole intestinal canal (Pl. XVII. f. 9. d) consists but of this transversely folded stomach, and all the following divisions, including also the anus, are deficient: this stomach, consequently, is more compactly constructed in them than in any other insect, it being composed of five skins, whereas the others have but three. It is probable that both the mucous and muscular membranes have separated into two layers ‡.

In the *Diptera* (Pl. XVIII. f. 3. d) the stomach is a long tube, which frequently distends at the two extremities, and is narrowest in the centre (*Musca*); a callous ring is found at the cardia, which is the remains of a small bladder existing there in the larva state; the vicinity of the cardia is granulated, that is, uneven, arising from transverse and longitudinal striae. Some of the large group (perhaps all), which *Latreille* calls the *Diptera Athericerica*, have peculiar, glandular,

† Compare Treviranus, Vermischte Schriften, vol. ii. Pl. XV. f. 2.
secretory organs which evacuate themselves at the very commencement of the stomach, closely behind the cardia *. They are doubtlessly the same forms we shall more fully describe below in the Orthoptera, and which have been considered as the analogues of the pyloric cæcum of the pancreas, or liver.

The Neuroptera have a short, sometimes smooth, sometimes transversely striated cylindrical or conical stomach, in front of which, at least in Myrmecoleon and Panorpa, there is a distinct proventriculus. This is wanting in the Libellulae and Ephemeræ: their stomach is long, cylindrical, and separated from the pharynx by a slight constriction only. Lepisma, which genus, as well as the two families of Termites and the mandibulate parasites, I unite in the order Dictyoptera, has a very small stomach, and in front of it a proventriculus armed with six teeth, contiguous to which lies a broader and larger crop. The same is the case in the Termites, but their stomach is longer. The Mallophaga † have also a tolerably large crop, but the true stomach is small, and is provided beyond the cardia with two considerable points; perhaps they, as well as the genus Psocus, for both devour hard materials (the former, for example, feathers), are also furnished with a proventriculus.

The three remaining orders display stomachs of a much more complex form than the preceding.

In the Coleoptera we find a considerable variety in the structure of the stomach, we observe the most simple in those Lamellicornia which feed upon feculent substances, or upon the juices of flowers (for ex., Scarabaeus, Pl. XX. f. 2., Melolontha, Trichius). In these the short and narrow oesophagus passes, without any distinct indication of its termination, gradually into a very long, cylindrical, and equally wide stomach. The object of this great length of the stomach is evidently to prepare the food more fully for assimilation, for in the larvae of these insects it is much shorter, but in compensation it is supplied at both ends with blind, pointed appendages (organs of secretion), of which, in some cases (for example, Hister, a genus closely approximate to the Lamellicornia,) traces still remain in the perfect insect. Next to these, the tribes which feed upon fresh vegetable matter, and particularly the juices of flowers, the Chrysomelina and Cerambycina, have

* Bombbylus, Leptis, Chrysotoxum, see Ramdohr, Pl. XX. and XXI.
the most simple stomachs; in these also it is a long, tolerably broad, smooth tube, which rarely (for ex., in Chrysomela,) is beset with short flocks. These flocks are portions of the internal mucous membrane which pass through the muscular membrane, but are not covered by it. In some genera (for ex., Lema, Callichroma moschatum,) portions of this tubular stomach are broader, others again narrower, but in the majority it gradually decreases in size.

The structure is more anomalous in other families, which, although chiefly feeding upon vegetable matter, consume it in a more crude and unprepared state, viz., as fresh leaves or harder fruits. The majority of these have also a long, cylindrical stomach, but the oesophagus is divided from it by a distinct muscular ring, and it is more tense, and occasionally, as in the Hymenoptera, transversely ringed. Among these are the Rhynchophora, many of which even possess the proventriculus and the before-mentioned flocks, (for ex., Cryptorhynchus Lapathi), the Vesicifisa (as Lytta, Mylabris, Meloë), the tortoise-beetles (Cassidaria), &c.

But the Buprestidea, of all the vegetable feeders, exhibit the most remarkable structure of the stomach: in these, at its very commencement, it distends on each side into a long blind appendage, equal indeed in length to the stomach itself; and this appendage, as well as the commencement of the stomach, is furnished throughout three parts of its extent with short, blind processes, like that of the flesh feeders. The remainder of the cylindrical stomach is smooth*. The Elaterodea form a transition to this remarkable arrangement, for in them the commencement of the stomach has on the two opposite sides a short folded pocket, it then continues, as a narrow, cylindrical, transversely folded tube, and distends widely at its termination†.

The Carnivora display the most complex structure of this organ among the Coleoptera (Pl. XIX. f. 4. n, n). Here the before-described proventriculus lies in front of the stomach, from which it is separated by a distinct constriction; the stomach itself is not very long, at least considerably shorter than in the vegetable feeders, and it is covered upon the whole or major part of the upper surface with long, thin, and blind flocks. These flocks originate, as was already observed in Chrysomela, from the inner mucous membrane of the stomach, and

† Ramdohr, Pl. XI. f. 1.
pass through the exterior muscular membrane, the filaments of which it pushes on one side. They doubtlessly consist of secreting organs, whose secretion makes more soluble the heavily digestible animal matter. These flocks are found in the Cicindelacea, the Carabodea, the Hydrocantharides, the Brachyoptera, the Pellodea, the Melanoso-
mata, and the Helopodea.

The stomach of the majority of the Orthoptera is still more artifi-
cially constructed, although in many respects not dissimilar to that just described. They equally have a crop and proventriculus, the stomach itself is not very long, but tolerably broad and most frequently transversely ringed above; at its mouth there are broad, sack-shaped, blind appendages, which are not mere processes of the mucous membrane, but are also covered by the layer of muscular mem-
brane. There are two such appendages in Acheta and Gryllotalpa, and as many in Locusta, but here shorter, and more vesicular. In Gryllus migratorius I found six tubular ones (Pl. XXI. f. 6.) length-
ened above and below, each of which opened into the stomach by an oval aperture (the same \( A, \alpha, \alpha \)) and thin tubes, which lay convo-
luted in the tubular appendages passed into these openings from the internal membrane of the stomach (the same fig. 5.); consequently these apertures do not merely open into the stomach itself, but also between the innermost and central membranes of the stomach (see fig. 2. at the \(^*\)). In Blatta there are eight such appendages, four short and four long; these are also, without doubt, organs of secretion, which have been not inappropriately compared to the blind appendages in the pylorus of fishes. They would thus be analogous to a gastric salivary gland, or pancreas.

We have yet to examine the stomach of the Hemiptera, which is the most composite of all (Pl. XX. f. 3). The narrow, and generally long oesophagus suddenly distends itself upon its entrance into the abdomen into a broad, bladder-shaped, generally long, and often irregularly folded stomach (d), which is, without doubt, analogous to the crop of the other orders. The Hemiptera which imbibe raw juices, either animal or vegetable, require several successive stomachs for the gradual transformation of these substances. The first of these stomachs serves as a preparatory receptacle, wherein the materials accumulate, and where they are slightly changed, that they may be more effectively elaborated in the following divisions. This first stomach is consequently the widest of all, and thus corresponds to the crop of the Coleoptera
and Orthoptera. With respect to its precise form, it is smooth and cylindrical in Nepa, somewhat wider and transversely ringed in Lygaeus, shorter but wider, with irregular longitudinal folds, which form apparent large pockets, in Cimex. In Cimex rufipes two compact, round, transversely ringed bodies lie above, contiguous to the cardia, one upon each side of it. In Cicada the first stomach is short, but also very broad and bladder-shaped. The second stomach (p*) is in general the narrowest, but always the longest; it has the appearance of a compact muscular tube, whose function can be no other than the further preparation of the imbibed juices; it is consequently of a more solid structure, and indeed in Nepa* it is internally covered with elevated ridges, which form a reticulation of hexagonal cells. Its function and even structure therefore correspond with the proventriculus; it more triturates the food than extracts it. It is separated from the following stomach by a perfect sphincter, and sometimes is distended in front of this into a large bladder (p**, Cimex rufipes, C. baccarum), which must not be considered as a proper stomach but as a second receptacle for the triturated matter, as a second crop before the third stomach. This distension, in greater or less compass, appears peculiar to all the bugs, but is wanting in the rest of the Hemiptera. In the Cicada the second stomach is nodose, very wide in front, growing gradually narrower behind. The third and last stomach (p***), which in the bugs wider than the second, but narrower than the crop lying in front of it. In form it resembles the transversely striped stomach of the bees, its cavity being formed by four half cylindrical tubes (Cimex baccarum and C. prasinus), and these half tubes completely separate in C. rufipes, so that their third stomach properly consists of four contiguous stomachs†. In many water bugs, Hydrocorides (for ex., Nepa, Naucoris), this stomach is wanting, but in compensation the second, as well as the following portion of the intestine, are longer, as in the land bugs (Geocorides). In the Cicadaria (Pl. XVIII. f. 1. p**) it is of the same length as the second, but of less breadth, while the second (p*) is granulated upon its exterior surface. Separated from the former by a distinct sphincter, it, like it, gradually decreases and turns upwards into the first stomach, indicated as the crop (p), so that the transmission of the food describes a complete circle in the three

* Ramdohr, Pl. XXII. f. 8.
stomachs. The remainder of the intestine is continued at the opposite side of the stomach, and it is there also that the biliary vessels empty themselves.

Thus much upon the form of the stomach in the several orders of insects; with respect to its structure, almost all that can be said upon it has been mentioned above, in treating of the nutrimental canal. The three membranes described there are found also in the stomach, and here particularly distinct. They are here more loosely united than in any other portion of the intestinal canal, and their exhibition is consequently attended with no difficulty. The middle membrane is attached more closely to the innermost, and the granules are found in it which Straus (see above, § 96.) indicated as gastric glands; between this and the inner mucous membrane the chyle collects, and then transuding through the latter, it enters the abdominal cavity, undulating about all the organs.

But little also can be said of the situation of the stomach, as it is not subject to much deviation; it is always found in the abdomen, whilst the oesophagus, and very generally the crop, are seated in the thorax. As soon, therefore, as the intestinal canal enters the abdomen it becomes the stomach, and frequently, indeed, even in the thorax (Melolontha and many others). If the intestinal canal be only as long as the body, the stomach then lies directly in its axis, but if it be longer, it then makes windings, which are the larger and more numerous the longer and more extended it happens to be. These convolutions generally lie in the anterior portion of the abdomen, encompassed and retained in their place by the ramifying branches of the air vessels, the hinder portion being chiefly occupied by the sexual organs; the stomach and intestine also approaches closer to the back, the internal sexual organs filling the ventral portion, or the space beneath the nutrimental canal.

§ 106.

THE DUODENUM.

The divisions of the nutrimental canal which follow the stomach are generally more simple than the preceding, and also subject to fewer changes of form. In breadth they do not generally, with the exception of the last, or colon, equal that of the stomach; they are mostly narrower, and also more delicately constructed. This entire intestine also consists of the three membranes, which, however, often lie more closely
attached to each other, but frequently in the ilium, particularly when the muscular membrane is very delicate (*Lamia alidilis*), they leave a considerable space between them. Here and there also the muscular membrane is thicker than in the stomach, which may possibly be explained by the distribution of similar fasciculi of fibres over a narrower space, whereas in those cases in which this intestine is as distended as the stomach (for example, *Lamia alidilis*) the muscular membrane of both is uniform in its consistency.

The passage of the stomach into the duodenum is formed by a distinct constriction, which supplants a sphincter, or is possibly one; the ring thus projecting internally is called *pylorus*, immediately beyond which the mouth of the gall vessels pierce the intestinal membranes.

This intestine is also separated into different divisions by means of constrictions, which have different functions, and have consequently received different names.

The first of these divisions is called the *duodenum* according to Ramdohr, but it is scarcely analogous to the similarly named portion of the intestinal canal in the superior animals, but it more probably entirely belongs to the following ilium. In the few beetles in which it has been hitherto observed (*Silpha, Necrophorus, Melolontha, Lampyris*) it generally appears as a short, smooth tube, of equal width, or narrower (*Melolontha*) than the ilium, from which it is distinguished exteriorly by the ringed constrictions of the latter (*Necrophorus*, *Silpha*). A stronger ringed constriction separates it from the following portion of the small intestines.

§ 107.

**The Ilium.**

Wherever the duodenum is wanting the ilium (Pl. XVII.—XXII, *e, e*) follows immediately upon the stomach, from which it is separated by the above described pylorus. This portion of the intestine is likewise sometimes wanting, so that the stomach lies immediately contiguous to the colon (*Libellula*, *Reduvius*). This appears to be the general rule of structure in the bugs; and when even occasionally a small portion of the intestine is found beyond the stomach in which the biliary vessels bury themselves, it is nevertheless so inconsiderable.
that it may consistently be considered as deficient. This deficiency in
them may be accounted for by the number of their stomachs, for that
transmutation of the food which is properly the function of the ilium
takes place in their third stomach, and which consequently renders the
ilium unnecessary.

With respect to its structure, we have already indicated some of its
peculiarities in treating upon the membranes of the stomach. Those of
the ilium are generally tenser than the latter; it is invariably equally
distended, and, as it were, inflated, whereas the stomach is not un-
usually folded up. We have already mentioned that the ilium, as well
as the stomach, is frequently transversely ridged, and by this means is
distinguished from the duodenum.

The length and situation of the ilium varies considerably; it is rarely
so long or longer than the body (Necrophorus), in general shorter, and
even shorter than the stomach. The latter proportions are found espe-
cially in the Chrysomelina, and in many others which feed upon
vegetable matter it is the general rule. In many of the carnivora, for
example, the water-beetles (Hydrocantharides), the ilium on the con-
trary, is longer than the stomach, particularly in their larve, in which
it is twice as long; but this is not the case in the ground-beetles
(Cicindelacea and Carabodea), the ilium in them being not so long as
the stomach. The butterflies have the longest ilium, in proportion to the
stomach of all insects, for in them it is not merely twice as long, but
even three or four times the length of the stomach, which is the more
extraordinary as in the caterpillar it is excessively short; scarcely
extending to one-eighth of the length of that organ. In the Diptera
also it is shorter than the stomach; in the bugs alone is it sometimes
wholly deficient. It is regularly wanting in the Libellulæ and
Ephemera. There are no fixed laws which regulate the length of the
ilium, but Ramdohr has endeavoured to show its most prevalent propor-
tions to the stomach and the other parts; they are as follows:—the
most usual relation to the stomach is as 1:1, or 1:3; to the whole
intestine 1:5, or likewise 1:3. Some of the proportions are extra-
ordinary, as in Necrophorus, viz., the ilium to the intestinal canal as
2:3, to the stomach as 9:4; indeed, this beetle has the longest ilium
of any yet investigated. In Tenthredo nigra it is very short, viz., in
proportion to the entire nutrimental canal it is as 1:17. In the cater-
pillars of the butterflies it is always very short, and in general it is
short in all larvae, and it is the shorter in proportion to the extension of the stomach.

The situation of the ilium is so far determined that it is always found beneath and contiguous to, and never above the stomach, but its situation in itself varies considerably. In perfect insects it is seldom straight, but always so in those whose intestine is not longer than the body (Gryllus, Phasma, the larvae of butterflies). In the opposite cases it makes convolutions of different size and form, which are the more numerous and larger the more extended the ilium itself is.

§ 108.

In some instances the ilium appears under a different form, namely, gradually distended, and thus becoming clavate, which is however peculiar to a few beetles only. According to Ramdohr, who considers a thus distended ilium as a distinct portion of the intestine, it is called the clavate intestine. In the Chrysomelina the short ilium is thus frequently distended. In many of the capricorn beetles a somewhat distended portion of the intestine is separated by a constriction from the very narrow ilium, and this represents the clavate intestine.

In the Lamellicornia (Melolontha, for ex.) the clavate intestine appears likewise as a distended sack-shaped ilium, and is therefore called by Ramdohr the thick intestine. It is particularly distinct and large in the larvae of these beetles (Pl. XX, f. 1. f); here, namely, it appears as a broad bag here and there constricted, which, in its natural situation, turns back upon the stomach from its commencement, and extends as far as the length of the narrow ilium will admit, consequently to the end of the stomach. The bag here contracts, and the again narrow colon originates beneath it, in a bow of it, taking its course in a contrary direction towards the anus. In the perfect beetle (the same fig. 2) this bag is to be distinguished exteriorly only as a bellied distension of the ilium, which, at least in Melolontha, has five slight impressions. But if this portion be opened five elevated ridges are observed, which are divided by incisions at regular distances, so that each band appears to consist of short, contiguous, three-sided prisms*.

If the name of this portion of the intestine is to be determined according to its divisional distance from the stomach it must be considered as

* Suckow in Heusinger, vol. iii. Pl. f. 94. Straus Dureckheim, Pl. V. f. 3.
the true ilium, which is however contradicted by its function, which, like that of the caecum of the glires of the mammalia, subjects the food to a second digestion and extraction before it is rejected. We are convinced of this by the comparison of its state in the stomach, and in this portion of the canal, for we find it here much more pappy than there, but yet not so viscous as in the colon.

§ 109.

THE COLON.

The last division of the intestinal canal is called the colon (Pl. XVII.—XXII. h, h). It is divided from the preceding portion of the intestine by a valve which can completely shut its aperture. G. R. Treviranus was the first to describe and figure it*. Its internal surface, particularly near the mouth of the ilium, is thickly beset with glandular warts or flocks, which are not found in the ilium itself. We have observed glands only in the crop, and as their function there was evidently the secretion of the first menstruum of the food, they may here possibly produce a secretion to assist the rejection of the feces.

The colon generally exceeds the ilium in size, but when the conical or thick gut precedes it it is narrower; but it then is even longer than the ilium, which is not usually the case. The form of the colon varies, sometimes cylindrical, or clavate, or distended above (bees); sometimes suck-shaped (Carabodea), or longitudinally folded within (caterpillars and the larvae of Calosoma). These folds are produced by the internal intestinal membrane, and are either straight or waved, and supported by horny ridges. The muscular membrane does not assist to form these folds, but it is more compact and firmer than in the preceding portions of the intestine, yet the above described thick gut or occasional analogue (by situation) of the ilium is frequently much more fibrous. The colon is also occasionally fenestrate, that is to say, there are six ovate transparent spots in it which are surrounded by a horny margin or edge, and form either one or two rows, varying in situation, so that the spot in the lower row lies where in the upper one is found the intervening space. This structure Suckow first observed in the bees †. I found in Harpalus ruficornis a perfectly similar structure of the colon, these fenestral spots were in the internal

† In Housinger Zeitschr. f. d. Org. Ph., vol. iii. Pl. VI.
membrane, and were very bright and transparent. According to Ramdohr's observations, the width of the colon is in proportion to that of the pharynx (crop), for where the latter is broad so is also the colon, and vice versa.

The situation of the colon is always determinate, for it is always found at the apex of the abdomen, surrounded by its last segments. The evacuating opening, or anus, is found in the last segment itself; it is covered above by a peculiar valve, and beneath this the anal vessels, which we shall describe lower down, open themselves. The corresponding lower valve conceals the sexual aperture, so that both the anal and sexual apertures open into one cavity, which might be called the *cloaca*, and which are separated only by a fold if no other organ, for example, an ovipositor, be present. The anus, as well as the ilium and its correspondent the thick gut, are wanting in the larvae of the bees, wasps (Pl. XVII. f. 9.), the *FormicaLeo*, and of perhaps all the internal parasites, for example, the *Ichneumons*; their intestinal canal consisting of the pharynx and stomach, and a small bag beyond it, into which the biliary vessels open themselves; it is here that the faces collect, which are evacuated upon the perfect insect quitting the pupa state, when it is provided with an anus.

§ 110.

**THE CÆCUM.**

In many insects we find, in connection with the colon, a blind, sack-shaped appendage, or rather similarly shaped superior distension of it which we call cæcum (Pl. XIX. f. 3 and 4 φ, φ). It originates at the very commencement of the colon, contiguous to its connection with the ilium, and extends anteriorly towards the stomach, in either larger or smaller distension; it is consequently not separated from the colon by any constriction or valve, but both cavities are in immediate connection with each other. This, as well as their uniformity of structure, proves that it must only be considered as a distension of the colon. In form this cæcum is sometimes nodose (*Silpha*) and directed forwards, sometimes laterally distended (*Necrophorus*), sometimes it is a long tubular point (*Dyticus*), sometimes a shorter cylindrical process of equal width with the colon (*Nepa*), similar to this, but sometimes slightly constricted at its commencement, we find it in the butterflies. It thence appears that this portion of the intestine is more peculiar to the carnivorous tribes, as Ramdohr, somewhat justly, remarks; yet its struc-
ture in the nectar-sucking butterflies modifies this assertion. The caecum might also here, as in the Mammalia, have the function of a second stomach, and thus, therefore, be more serviceable to the carnivora, which consume coarser materials than the vegetable feeders, which are besides provided sometimes (Melolomita, &c.) with analogous organs, as the clavate and thick intestine. The caecum is represented in the Carabodea by the broad sack-shaped colon. The long caecum of the water-beetles has, according to Leon Dufour, the function of a swimming bladder, which is much to be doubted in the Coleoptera, they being provided with so many air vessels: we cannot either well imagine how air can be introduced into it, certainly not through the anus; for it is not for this purpose that water-beetles raise their anal ends to the surface of the water, but to take air beneath their elytra, as has been long well known.

§ 111.

THE BILIARY VESSELS.

The biliary vessels (\textit{vasa bilifera}, (Pl. XVII.—XXII. K, k,) occupy the first place among those organs which, although distinct, stand however in direct connection with the intestinal canal. They are narrow filiform tubes, which open at one end into the duodenum, and where this is wanting into the ilium close behind the pylorus, and at the other end are either free and closed, or pass into each other and thus apparently form one vessel, which pierces the intestinal membranes with both its ends. The biliary vessels also, at least according to Ramdohr, sometimes empty themselves into the end of the stomach, sometimes (for example, in Meloe,) upon the limits of both, that it is difficult to say whether it is the stomach or intestine. According to Ramdohr, the mouth of the biliary vessels does not pierce the internal intestinal membrane, but only the exterior muscular one, which assertion, however, is contradicted by Meckel's observation, for, by pressing these vessels, he forced their contents into the intestine. In fact, the biliary vessels always enter the cavity of the intestine, and their mouths lie at the same height, forming a circle around it; more rarely upon one side only, for example, in a vesicular distension of the ilium in \textit{Lygoeus apterus}. Other differences in the mode of their evacuating themselves are not rare. In the flies (\textit{Muscaria}) the four biliary vessels unite into two short stems, which open into the intestine at its opposite sides, or all four form but one, as in \textit{Cimex}
baccharum. Occasionally, also, the openings of the gall vessels do not lie by the side of but above each other, for example, in some of the Neuroptera, in which four of the eight biliary vessels enter upon the one side and the other four upon the other side of the intestine (Mycmeleon). If many biliary vessels exist their mouths lie contiguously, above and below each other, or although more rarely, all upon one side (Acheta), or else they unite into a tolerably long evacuating duct, (for example, Gryllotalpa).

In form these vessels are generally narrow, cylindrical, filiform, and twisted, but they are not always of the same dimensions throughout: many commence narrowly and afterwards double in size; some, by means of a spiral furrow, resemble a turned slip; others have alternately small vesicular distensions (Musca); a few have long rectangular processes, which are occasionally furcate (Melolontha vulgaris).

There are generally four in number, never fewer, unless entirely wanting (Chermes, Aphis), sometimes there are six or eight, and they are even, occasionally, innumerable. These differences in number are regulated by the order to which the insect belongs as well as by its food, whether it be vegetable or animal, as is shown in the following table:

I. No biliary vessels, Chermes, Aphis.

II. Few (4—8) biliary vessels.
   1. Four biliary vessels.
      a. Free at the end; most Diptera, as well as the families Termitina, Psocina, and Mallophaga, of the order Dictyotoptera.
      b. Anastomosing; many Coleoptera, Hemiptera, and Diptera.
   2. Six biliary vessels.
      a. Anastomosing; many Coleoptera, for example, Cerambycina and Chrysomelina.
      b. Free at the end, Lepidoptera.
   3. Eight free biliary vessels, Neuroptera.

III. Many biliary vessels, Hymenoptera, Orthoptera, and the Dictyotoptera subulicornia.

Occasionally the biliary vessels join the intestinal canal at a second place, but this union takes place only with the exterior muscular membrane, for it is attached by means of solitary fibres, but a second opening into the intestine does not occur. This union is found chiefly in those insects furnished with a clavate intestine (the analogue of the
The length of the biliary vessels is in direct proportion to their number; for when there are but few they are very long, indeed the longest of all (for example, Melolontha); but they are short, on the contrary, where they are numerous, for example, in Gryllotalpa, Libellula, &c. The long biliary vessels lie generally around the intestine; they first ascend parallel to the stomach as far as the pharynx, they then return and form a thick knot of vessels around the ilium; where there are many, some return upwards along the stomach, and the rest below along the ilium. The length also of the single biliary vessels sometimes varies, for example, in the Cerambycina, in which they form concentric circles, but the two opposite sides are always of the same length.

The biliary vessels are also always more simply constructed than the intestinal canal, for they appear to consist of but a single skin, which, besides, is very delicate and transparent, so that their contents can be distinctly recognised as a finely granulated mass. The delicacy of the smooth shining case is proved by the difficulty of removing the biliary vessels from the enveloping fatty substance, and by their being very easily torn, even when the greatest precaution is used.

In colour they generally resemble the yellowish white of the intestinal canal; in some beetles (for example, Carabus, Dyticus,) they are of a dark brown, but which becomes paler as it approaches the opening. In many caterpillars, while parallel with the stomach they are whitish, but at the intestine of a saffron yellow; Swammerdam thence applied the name of saffron vessels to them.

It may be here remarked, at the close of our observations upon the biliary vessels, that some insects in which they are numerous, for example, the bees and wasps, have in their larvæ state but few (4—6) long and thick ones, which, by degrees, whilst during the pupa state the remaining gall vessels are forming, shrink up, and become shorter until they contract to the same length as the rest*. Do they not perhaps entirely disappear, and are replaced by the shorter ones? Perhaps they are very different vessels possessing a different function, which probably disappears when the intestine and anus become formed in the insect.

* See Ramdohr, Pl. XII.
§ 112.

THE SALIVARY VESSELS.

Cuvier says, in his "Comparative Anatomy," that the secretory organs of insects always assume a tubular form, and that consequently conglomerate glands are wholly wanting in them. This assertion is strictly true with respect to the biliary vessels, which have been considered as analogous to the liver, but in the salivary vessels we find exceptions, and which are most strongly exemplified in the testes, some of which (the epididymis in Hyrodophilus) possessing many accumulated acini. Nevertheless, the form considered by Cuvier as universal is certainly the most general.

Under the name of salivary vessels we comprehend those glandular appendages of the nutrimental canal which evacuate themselves either into the mouth or into the commencement of the intestine in front of the stomach, and by their secretion promote the digestion of the food. The following are their chief differences:—

A. Salivary vessels which open into the mouth, generally beneath the tongue, and more seldom at the base of the mandibles. They take the following forms:—

1. As simple, long, undivided, twisted tubes; thus in the majority of insects, viz., all butterflies, many beetles and flies.
2. As a narrow vessel which empties itself into one or two bladders, whence the salivary duct originates (Nepa, Pl. XXII. f. 1; Cimex, Pl. XX. f. 3. A, A; Sarcophaga).
3. As a ramose vessel with blind branches, (Blaps, Pl. XXII. f. 3).
4. As two long, cylindrical pipes, which unite into one evacuating duct (Reduvius, Pl. XXI. f. 15).
5. As four small, round bladders, each pair of which have a common duct (Pulex, Pl. XXI. f. 16; Lygæus, Cimex).
6. As a multitude of such vesicles in Nepa (Pl. XXII. f. 2).
7. As capitate tubes, in the free ends of which many very fine vessels empty themselves (Tabanus, Pl. XXII. f. 4).
8. As tubes which at intervals are surrounded by twirling blind bags (Cicada, Pl. XXII. f. 5).
9. As granulated glands which on each side unite into a salivary duct, both of which join into a single evacuating duct (Gryl-
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lus, Pl. XXI. f. 12.). J. Müller observed such granulated salivary glands in Phasma; Treviranus in Apis; and I have found them in Locusta, Gryllus, and Termes.

B. The salivary vessels which do not empty themselves into the mouth, but into the commencement of the stomach. These we have already partially described, in treating of the stomach (§ 105), as short or long bags, which were either simple or furnished with processes (Buprestis); other forms, as well as those just cited, are found chiefly among the Diptera.

1. As two capitate tubes, in the free ends of which many delicate vessels open, we perceive them in Hemerobius perla (Pl. XXI. f. 4).

2. As two short processes of the same width as the stomach, in Leptis (Pl. XXII. f. 6. a, a,) and Acheta.

3. As two bags covered entirely with short blind processes in Bombylius (Pl. XXII. f. 7.) and Buprestis (§ 105).

4. As triangular processes, each edge of which is occupied by a row of vesicles in Chrysotoxum (Pl. XXII. f. 8).

5. As six narrow tubes, which surround the commencement of the stomach in Gryllus (Pl. XXI. f. 1 and 6).

6. We also consider the blind processes which clothe the stomach in the predaceous beetles among the salivary vessels.

Salivary vessels which open into the mouth are found in all the haustellate and in many mandibulate insects which feed upon hard substances. Ramdohr was the first to observe them amongst the beetles in Cryptorhynchus Lapathi. In this insect he found a long twisted vessel, which opened into the mouth, which is indeed contrary to all analogy, for the salivary vessels are elsewhere found in pairs. Leon Dufour subsequently discovered salivary vessels in many Heteromera, viz., Edemera, Mycetius, Mordella, &c. I have found them of the above form among the Orthoptera, in Locusta, and Gryllus, and among the Dictyotoptera in Termes. Among the Neuroptera, Hemerobius and Phryganoea exhibit salivary organs.

The salivary organs which empty themselves into the stomach are found among the beetles, especially in those which devour flesh and wood; and in those Orthoptera also which feed upon hard vegetable matter, and in the Diptera, among the Syrphodea, which consume the nectar of flowers, and probably also their pollen. Among the grasshoppers we occasionally find both kinds of salivary organs.
Where we meet with salivary vessels we generally find two; some insects have, on the contrary, four, each pair of which unite into one evacuating duct (Apis, Cimex, Pulex); Nepa has even six salivary vessels, three on each side, all of which open into the cavity of the mouth; two unite on each side into one stem, the third, which has been considered as a poison-secreting organ, remains separated as far as the mouth.

Many larvae, particularly the caterpillars of the Lepidoptera, have also four salivary vessels of different structure; two are slender, very long (Cossus), and filiform; two broader, sometimes bag-shaped (for example, Cossus ligniperda, O.), and considerably shorter. The first secrete a viscid liquid, from which the caterpillar spins its silk. The evacuating ducts of both unite into one, and open into the under lip, namely, into the canal of the above (§ 54) described spinneret. This pipe would therefore be more correctly called spinning vessel. Such spinning vessels are naturally found only in those larvae which prepare a web for their pupa change, such as the caterpillars of the nocturnal Lepidoptera, the larvae of the saw-flies, and of the Phryganodea. It distinguishes itself chiefly by its length and size from the true salivary vessels, which are often very small and insignificant. The true salivary vessels, according to Suckow *, open at the base of the upper mandible with a small warty protuberance (Pl. XXI. f. 13), and remain even in the perfected moth; whereas the spinning vessels totally disappear during the pupa state †.

In Myrmecoleon the spinning vessels lie at the anal end of the abdomen, and true salivary vessels have not yet been observed in it ‡.

The structure of this organ appears, according to all investigations hitherto instituted, to be very variable, for sometimes there are two membranes (the muscular and mucous) and sometimes but one. The former vary in consistency, but occasionally are uniform with those of the intestine; in the latter case they are transparent and delicate, and occasionally granulated or irregular.

The length also of the salivary vessels differs much: in some caterpillars they are two or three times as long as the intestine; in perfect insects, on the contrary, they are generally shorter, and do not usually

* Suckow's Physiol. Unternich. uber Insecten und Krustenthiere, p. 28. Pl. VII. f. 32. a.
† Ib. p. 29. Pl. II. f. 1—10. h. h.
‡ Ramadohr, Pl. XVII. f. 1—4.
extend beyond the thorax. It is thence that we detect the salivary vessels, with the exception of the very long ones of caterpillars, only in the thorax. They here lie around the pharynx, crop, or stomach, generally low down in the breast between the coxae of the legs, whilst their meandering evacuating duct, rising from beneath the nutrimental canal, ascends to the cavity of the mouth, and here, after having united with its companion, opens beneath the tongue. *Locusta* displays this aperture very distinctly. In the bees, in which the salivary organ consists of four granulated valves, the anterior one lies in the head, directly beneath the forehead, before the eyes, and was originally described by Ramdohr as the organ of smell, but subsequently recognised as the salivary gland. The evacuating duct empties itself into the tube of the proboscideal tongue, and is a spiral vessel resembling the trachea, as Treviranus has described and figured it*; in *Locusta* I found it simple, thin, and transparent, but accompanied by a delicate trachea, which followed it throughout all its ramifications and divisions.

§ 113.

THE URINARY VESSELS.

As the last distinct organ, but which is doubtlessly in strict connection with the digestive apparatus, we must take some notice of the variously formed urinary vessels, which empty themselves above the anus. These, like the salivary vessels, are sometimes mere vascular canals, at others glandular bodies which in the latter case unite into one duct, to which not rarely there is attached a vesicular distension—the urinary bladder. The duct of the latter is always separated, and never unites to those of the opposite side, and empties itself laterally contiguous to and above the anus, but strictly separated from it by the anal valve.

These vessels are found in all the *Carabodea* and the *Hydrocantharides*, in many *Heteromera* (*Blaps*), and again in *Bombylius* and *Leptis*, among the *Diptera*. Ramdohr, who first observed them, drew them to the intestine, and called them anal vessels; but *Leon Dufour* subsequently described many of their forms in detail†.

In their most simple form (in *Harpalus*) the urinary vessels appear as reniform bodies contiguous to the colon, whence a short evacuating

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† Annales des Sciences Nat., t. 8. p. 6. Pl. XIX. and XX.

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duct extends to the orifice. In Carabus auratus this body is a bunch of small round vesicles; in Car. cancellatus it is divided into two equal halves, the two short ducts of which speedily unite into one. The urinary bladder, which is wanting in Harpalus, is present in Carabus, has the shape of a fig, and stands almost at right angles with the evacuating duct. It is much the same in Cymindis humeralis; in Aptinus three equal ducts open into the bladder, each of which originates from five granulated glands with five branches. In Brachinus the glands are convolutions of shorter or longer, and sometimes furcate filaments. In Chlaenius and Sphodrus there are many solitary granules, each of which has a small duct, they all unite into one stem, which then opens into the bladder.

In the water beetles (Pl. XXI. f. 11.) the portion lying above, and over the urinary bladder, is but a simple, twisted, but tolerably long, although delicate vessel; the bladder, on the contrary, is round, but not petiolated. It is the same in Bombylus.

With respect to the structure of these organs, two membranes are distinctly discerned in the evacuating duct, the interior of which is much less than the exterior; this is constricted by parallel transverse rings. The glands also have occasionally (Chlaenius velutinus) similar transverse rings, particularly when they are somewhat larger.

§ 114.

Changes in the Intestinal Canal Occasioned by the Metamorphoses.

In the preceding description of the nutrimental canal in insects, we have restricted ourselves chiefly to their form and structure in the perfect creature. As, nevertheless, the differences which are produced in the nutrimental canal by their metamorphoses are by no means unimportant, for the intestinal canal in larvae assumes very generally a very different form, and its changes are subject to peculiar laws, partially influenced by the order to which it belongs, we must not omit taking notice of them as far as is possible in a general sketch, and must therefore make room here for a description of these transformations.

Insects with an imperfect metamorphosis, viz. the Hemiptera, Orthoptera, and Dietyoptera, have in all their stages a very uniform nutrimental canal. We find in them the same divisions in the same proportions, and even the appendages, such as the salivary and biliary vessels, agree with those of the perfect insect. The whole change,
THE ORGANS OF DIGESTION.

therefore, which the nutrimental canal undergoes in these orders consists in its lengthening in proportion to the increasing size of the insect, and at the time of moulting it covers itself internally with a new mucous membrane, the old one being rejected by the anus, or probably absorbed. This changing of the skin in the intestine is certainly remarkable, and proves, as well as the similar phenomenon in cutaneous affections in man, in which the epidermis peels off (for example, after scarlet fever), the perfect uniformity of the intestinal mucous membrane with the exterior epidermis. The larve of the *Libellulae* alone appear to make a slight exception to the rule of the intestinal canal remaining the same, their's being somewhat larger, particularly broader, than in the perfect insect, and in the latter the respiration of the colon disappearing, which was peculiar to the former.

Insects with a perfect metamorphosis, on the contrary, undergo in the intestinal canal, as well as exteriorly, important changes, which, however, refer only to the form, the structure remaining constantly the same. It is true the membranes are originally much more delicate, looser, and admit of being more readily separated, particularly in the stomach, but this difference gradually vanishes. During their larva state the intestine assumes a new skin at every moulting †; towards the end of this period, and still more during their pupa state, the intestine shrinks, particularly the stomach, and acquires thereby a more compact appearance. It is the divisions of the nutrimental canal and their relative lengths which chiefly vary, but these are regulated by very different laws in the several orders, and consequently demand of us an especial notice.

The maggots of the *Diptera* (Pl. XVIII. f. 2. maggot; f. 3. fly) have a longer intestine than the flies, but it is the stomach chiefly which occasions this greater length. The sucking stomach is present, but larger, more shortly pediculated, and, besides, there are large cylindrical salivary bags, which in the course of their change transform themselves into filiform salivary vessels. The biliary vessels remain uniform both in number and shape. During the larva state the intestinal canal remains unchanged, but it alters the more quickly in the pupa state;


† In the larve without an anus (*Myrmecoleon, Vespas, Apis*) the old skin remains in the bag behind the stomach (compare §. 105.), and is evacuated only after the pupa state through the new-formed anus.
but it is still the stomach only which shortens, until it decreases to scarcely one half of its former extent.

In the *Lepidoptera*, on the contrary (Pl. XVIII. f. 4. caterpillar; 5. imago), the intestinal canal lengthens, but so that here also the stomach becomes shorter but the ilium longer. In the caterpillar the broad, cylindrical, folded, and transversely ringed stomach occupies more than two-thirds of the entire intestinal canal, and this is succeeded by a shorter, scarcely narrower ilium; the preceding pharynx is short, and so short that it is observed only in the head. Contiguous to the stomach lie the long twisted spinnerets, and attached to it are the six united biliary vessels. In the imago the pharynx is long, and beneath it lies the sucking stomach, of which we observe no trace in the caterpillar; the stomach, on the contrary, is small, short, ovate, folded, and narrow; the ilium, again, long, filiform, twisted; the colon broader, elongated above into a short cæcum, which is likewise deficient in the caterpillar. The spinnerets disappear, but the salivary vessels, which are very small in the caterpillar, become more distinct, larger, and longer.

We have already noticed the very interesting metamorphosis of the intestinal canal in the wasp and the bee. In the order of the *Hymenoptera* also the law prevails of the stomach becoming smaller and narrower whilst the pharynx and ilium become longer. This will also apply to *Myrmecoleon*, in whose larva the colon becomes the spinneret.

But of all the orders the *Coleoptera* display the greatest changes of the intestinal canal. The larvae of the carnivora wholly want the folded horny orifice of the stomach (Pl. XIX. f. 1 and 3). Their stomach is broad, but smooth, and not beset with filamentary processes; the ilium is also broad, but short, and much shorter than after the metamorphosis. This consists in the crop distending, the proventriculus forming itself, and the stomach sending forth filamentary processes. In the *Carabodea* the ilium becomes much longer; but in the water beetles, where it is already very long, it appears to become somewhat shorter, at least in *Dyticus marginalis*, according to Dutrochet, whose investigations I have repeated, and can now confirm (see Pl. XIX. f. 3. the larva; f. 4. the beetle). In the vegetable feeders, namely, in the *Lamellicornia*, the intestinal canal in the larva is triflingly longer than the body, whereas in the perfect insect it is three or four times as long. The larvæ have a long, broad, cylindrical stomach beset with filaments.
at its commencement and end; a short, narrow ilium; a broad, sack-shaped thick-intestine; and a tolerably long but not broad colon: the beetles have a very long but narrower cylindrical stomach, an ilium resembling that of the larva, a much narrower, gradually distending, thick-intestine, and a longer cylindrical colon, which distends very widely close to the anus. In both cases, consequently, the intestinal canal is longer in the perfect state than in the larva, but in the vegetable feeders more considerably so than in the carnivora, in which it, namely in *Dyticus*, is shorter. Whereas the beetle has a much more complex intestine, and more organs to effect the change and transformation of the food than the larva, which is the more remarkable, as both, at least generally, take the same food, which is not always the case in the other orders, for example, in the *Lepidoptera* and flies.

§ 115.

II. THE FATTY MASS, OR RETE.

The fatty mass of insects is a web of generally white or yellow ragged or stringy substance interwoven in every possible way, enveloping the intestinal canal and the organs connected with it, as well as all the other internal parts, but it is never in direct immediate connection with any organ. It receives its name from its undeniable resemblance to the fat of the higher animals, and which is expressed in the above peculiarity, and even more strongly in other circumstances. It thence appears that it forms no portion of the intestinal canal, being nowhere in connection with it, but as it is the produce of digestion and as it is increased or decreased by the perfection or imperfection of the function of digestion, it must therefore, as standing in relation to the organs of nutriment, be treated of and described when treating of them. We are the more strongly impelled to this by the opinion expressed by Oken, and which *Treviranus* has recently supported by analogies, that the fatty mass of insects must be considered as their liver. Indeed in the scorpion a substance similar to the fatty mass stands in connection with the nutrimental canal by means of vessels, but they possess besides two twisted biliary vessels, which likewise here and there quit that substance. In all true insects, however, we find no such close connection of both organs, and if it cannot be denied that the fatty mass is of importance to digestion, and that much nutrimental matter is derived from it, yet this admission proves by no means its analogy to the liver. In fact, it is neither absolutely liver nor gland, but
nutrimental matter, which, during the metamorphosis, particularly during the pupa sleep, is absorbed like the fat of the lethargic mammalia during their hibernation. But the degree of reference the function of the liver has to the preparation of the fat is sufficiently well known from the example of the lethargic mammalia, therefore the above opinion, when we consider the small size of the biliary vessels supplanting the liver, or the treatment of these vessels as kidneys, a view also recently promulgated, may possibly have many supporters.

The nature of this fatty body is in so far uniform that it consists of shreds, which upon microscopic investigation are found to be constituted of small globules of animal aboriginal matter. This is the only character this fatty mass presents upon the closest investigation; exteriorly it is surrounded by delicate membranes, which consequently may be compared to the membranes of the cellular texture, but the lens does not show it very distinctly, from its transparency, delicacy, and texturelessness. Ramdohr, who considered the fatty mass as plastic lymph, obtained from experiments upon that of the Gastrophaga quercus the following result:—it melted in boiling water, effervesced with sulphuric acid, at the same time smelling like burnt horn, and in cold water was precipitated in white flocks; heated over a lamp it hardened into a white firm mass, swelled up upon the application of greater heat, and then burnt away, dispersing a stinking vapour. According to my experiments, made with the large flabby fatty mass of Cossus ligniperda, it melted in a spoon over a lamp into a perfectly clear transparent yellow liquid, which paper instantly absorbed, and was rendered transparent by it like fat; it had a peculiar smell, like that of freshly opened caterpillars; its taste was fatty and insipid. Upon increased heat it boiled up in bladders but did not become firm, or else it consumed to ashes. Laid fresh in hot water it became softer, more transparent, and particles of it floated on the top like oil.

These very contradictory results tend at least to prove that the fatty substance in different insects consists of very different constituents, which is the more striking as both experiments were made from insects of the same order, in which they even approach very near each other. Probably Ramdohr's caterpillar had been long immersed in spirits of wine, thus consequently, and by the additional influence of heat, the fat parts had separated, and only the cellular portion of the enveloping membranes remained.

The entire fatty mass forms a reticulated meshy web, which enve-
lops the interior organs and completely fills all portions of the cavity not occupied by them. In larvae the threads and laces of this net are larger and more ragged, particularly in the fat larvae of the crepuscular and night moths. The nearer it approaches the pupa state the larger are the proportions of this substance; but as soon as the insect becomes fully developed this material loses its size, and it becomes a broad, delicate, laced web. It is consequently during the pupa state that the greater portion of this substance becomes absorbed, whereby the shreds shrink up, the delicate membrane becomes narrower, and thus the preceding coarse shreds become delicate and fine laces. In this shape the fatty mass not merely represents the rete of the vertebrata, but actually becomes it, for it is the envelope of the intestines, and in conjunction with the air vessels it supports and fixes them. Thence is it that earlier (Malpighi) and more modern (Cuvier) anatomists have called it the net of insects. It is scarcely necessary, after such facts, to adduce other reasons in opposition to the above disputed opinion that this net is the liver of insects; whoever has but watched the development of a single butterfly, indeed, whoever shall but have compared an opened caterpillar with an opened moth, to him it will be evident that the fatty mass cannot be the liver.

Chemical analysis has as yet contributed nothing towards the removal of the difficulties which still involve the different views upon this subject, although a careful investigation would most certainly settle the dispute. In ants* and the cochineal insect fat has actually been found, and this consequently may certainly contribute to support the adoption of the opinion of this substance being found in all other insects.

§ 116.

III. THE BLOOD VESSELS.

We shall find the vascular system just as simple and uniform in insects as we have found their digestive apparatus complex. A vessel which passes along the back from the head to the anus constitutes the only blood vessel to be discovered in insects. That this canal is a true blood vessel, and indeed an artery, is proved by its regular contraction and expansion, which is very easily perceived exteriorly in transparent thin-skinned larvae. Malpighi, its discoverer, considered it as such,

and has described it as a great pulsating * vein. Subsequently to him, the other great entomotomists, Reaumur, Swammerdam, Bonnet, De Geer, have recognised the same organ, and concur with him in representing it as a simple and wholly closed vessel. Even the very cautious Lyonnet can consider it as nothing else; but he described the lobes of the dorsal vessel in greater detail, and has figured them more accurately than any of his predecessors. In recent times Cuvier, in his "Comparative Anatomy," has repeated the descriptions of earlier anatomists, and even after this organ had been subjected to the most painfully patient investigations by Herold and Müller, its true structure has not yet been ascertained. Carus† at last discovered the motion of a fluid not only in the dorsal vessel but also in other parts of the body, and shortly after him Straus—Durckheim recognised a structure of the dorsal vessel, which had been previously overlooked, which so entirely agrees with the insect type of organisation, that no doubt can be entertained of the correctness of his observation. My attention being drawn to it by Straus' communications, I made investigations upon the structure of the heart in several insects (for example, in the larva of Calosoma sycophanta, Lamia edulis, Termes fatalis, &c.), and I have distinctly seen the valves and apertures mentioned by him.

§ 117.

According, therefore, to these most recent observations, the dorsal vessel (Pl. XXII. f. 8 and 9.) is a thin canal composed of a delicate membrane, it is largest in the abdomen, and gradually decreases towards the head. In the abdomen it has on each side several apertures, as well as lateral muscular lobes, whereby it is attached to the back; where it enters the thorax it bends downwards (the same, f. 8. a.) that it may pass through the narrow, more deeply situated opening into its cavity, and then pursues its course above the oesophagus to the head, where it terminates with a small orifice. The number of the lateral apertures appears to vary (the same, a, a, a). Straus found eight in Melolontha, I could observe but four on each side in the larva of Calosoma. According to Müller's description of the heart there appears to

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† Entdeckung eines einfachen, vom Herzen aus bleschleunigten Kreislaufs in den Larven netzflüglicher Insecten. Leipz. 1827. 4to.
be but one aperture in *Phasma*, which also has but one pair of lateral muscles. By means of these apertures the heart is divided into so many chambers, for behind each opening there are valves which separate the preceding space from that behind the opening, so that in *Melolontha* there are eight (Pl. XXI. f. 1—8.) such consecutive chambers. The first, which lies close to the dorsal sheath of the last abdominal segment, is the smallest, and consists of one heart-shaped bag, which in front, towards the head, has an opening like a slit. The lips of this aperture consequently form the anterior side of the bag and close it, if blood, pressing forward from within, does not part them. The blood enters it through two small apertures, which likewise lie in front upon each side of the bag, but it cannot flow back through the same openings, for a half-moon-shaped valve which is affixed within the cavity of the bag beneath the aperture closes upon it, and thus, when the heart contracts, the blood must necessarily pass through the anterior opening. This first and most posterior chamber of the heart is succeeded by another in front, formed very similarly, but longer and more cylindrical, and which has also an aperture behind, viz. the anterior one of the first chamber. It is through this that the blood passes from the first chamber to the second when the heart contracts, and upon its dilatation blood pours into the chambers through the two lateral anterior openings. Thus, therefore, each chamber is always provided with blood, for the blood streams from one chamber to the other, beginning at the posterior, when that which has been received through the lateral openings from the cavity of the abdomen passes on by their successive contractions. We will explain how this contraction (systole) and dilatation (diastole) of the heart take place after we have said a few words upon its structure.

§ 118.

According to Straus, two membranes are observed in the heart, the exterior of which is smooth, dense, and longitudinally fibrous, consequently muscular. It is this which forms the above-described valves, for at the two margins of each lateral aperture it bends inwards. The posterior return forms the inner valve of that opening, and the anterior return the partition of the chamber, or both the anterior ones form the lips of the anterior opening. Both valves, as well as the entire internal lining of the heart, are covered with a transversely folded and looser
layer of muscle, which is still thicker and stronger in the middle of each chamber. Perhaps both membranes are but the different layers of one muscular membrane, and then we might, by the analogy of all blood-vessels, entertain the idea of the presence of an innermost structureless mucous membrane, which escapes observation by its delicacy.

It is from the presence of these muscular layers that it is possible for the heart to contract and dilate. By both membranes simultaneously contracting the heart becomes straitened, and this distends again as soon as the membranes become flaccid after the contraction, when the muscles of the lobes contract themselves.

§ 119.

To the posterior portion of the dorsal vessel which we find provided with apertures and valves, and which we must consider as the true heart, several triangular, flat, membranous muscles are affixed, the points of which pass on to a dorsal plate of the abdomen, and there attach themselves (Pl. XXII. f. 9). If these wings (flügel) of the heart, as they are called, are short, or consequently of the shape of an equilateral triangle, other muscles of the form of a band originate at the apex of this triangle, and pass in a diverging direction from each other, and insert themselves upon the abdominal plate, where this becomes membranous (Lamia cedilis). Generally, however, the wings are so long as not to require the muscles of attachment (Melolontha, &c.), and they then take the shape of a very acute triangle. The conjunction of these muscular wings with the heart, which they merely retain in its place, is very intimate, without its being possible to say where; whether it be by fibres passing from these wings into those of the heart, or whether the membrane of the heart sends forth lateral folds it is impossible to say. They lie in a row upon the two opposite sides of the heart, precisely where the anterior aperture of each chamber is found. They pass over these apertures, the fibres attaching themselves to a small membranous arch which crosses these orifices transversely; consequently, in front of each orifice, there is a small semicircular hole in these wings, which are thus prevented from interrupting the flow of blood.

These wings are wanting to the dorsal vessel of the Libellula, and Phasma has but one pair in the sixth abdominal segment. Besides this we find a pair of muscles passing from the posterior margin of the
heart, their apex being attached to the last abdominal segment and the colon, which has not yet been observed in other insects *.

§ 120.

The anterior portion of the dorsal vessel which passes through the thorax to the head, and which is not furnished with apertures and muscles (Pl. XXII. f. 3. c), may be called the aorta if we call the posterior portion the heart. The part which may be considered as such commences where the dorsal vessel bends near the thorax to pass into its cavity, from here the apertures and muscles are wanting. This bend is greater or smaller, according to the size of the posterior partition of the thorax, largest doubtlessly in the petiolated Hymenoptera or the Diptera, whose thoracic cavity is entirely separated from the abdominal cavity by the metaphragma. When the aorta arrives in the cavity of the thorax its course becomes then direct as far as the head, constantly keeping the central line, and accompanying the here straight oesophagus or stomach, and frequently united to it by a cellular membrane or the fatty substance. When there is a free and moveable prothorax it passes likewise into this through the common opening, or more rarely (as in Gryllotalpa †) through a small aperture in the metaphragma (Pl. XI. No. 1. f. 7. a), and here still accompanies the oesophagus as far as the head. Here, close to where the oesophagus bends down to the mouth, consequently behind the cerebrum, the aorta suddenly ceases with a somewhat distended orifice, without previously sending forth any smaller vessel; in other instances it divides in a fork, each branch of which bends laterally, and terminates after a very short course likewise with a free orifice; or, lastly, we find three short, equal, radiating branches, each open at the extremity (for example, in Gryllus hieroglyphicus, Klug. ‡).

§ 121.

We thus conclude the description of the blood-vessels of insects. The most laborious and patient endeavours of Entomotomists to discover other vessels remained unrewarded, until Joh. Müller discovered a union of the ovaries with the aorta §. We shall treat in greater detail of this

connection lower down, in the Chapter where we speak of the sexual organs; but we must defer hinting at their hypothetical use, as well as of the doctrine of a circulating system in insects, until the following division, to which we consequently refer.

§ 122.

IV. OF THE ORGANS OF RESPIRATION.

We shall find the respiratory organs of insects as complex and perfectly developed, as we have found their blood-vessels simple and imperfect. The relations between these systems appear to be in them completely reversed, for the air-vessels intersect the insect body as multitudinously as we find the blood-vessels do in the superior animals. We cannot here show whence this transposition of the usual relations proceeds, nor how an entirely different structure can produce a similar result, this belongs to Physiology; we are here required merely to explain the structure and distribution of the air-vessels, and their external orifices. Our subject thence divides itself into two portions; the first of which treats of the exterior organs attached to the respiratory organs; and in the second, we shall describe the internal air-vessels themselves.

§ 123.

A. Exterior Organs of Respiration.

The exterior organs of respiration which are found upon the surface of the body, are of a triple character, namely, spiracles, air tubes, and branchiae. The first are easily distinguished from the last, by the presence of an orifice that opens directly into the tracheae, whereas the branchiae are membranous leaves, throughout which tracheae are dispersed, without opening anywhere.

I. The spiracles (spiracula, stigmata), which are the most frequently found of all the exterior organs of respiration, appear as incisions or small round openings at the sides of the segments of the body, which are sometimes surrounded by a peculiar oval horny ring; or are encircled by merely the usual integument of the body, without any apparent distinction. Both kinds of structure are supplied with a muscular apparatus which opens and closes the aperture, so that the insect can either open it to receive air, or close it against it. We shall proceed with a description of their various forms, after this short indication of their differences.
The Organs of Respiration.

Some which are never free, but lie concealed beneath portions of the horny integument, have no exterior horny ring, but a double-lipped incision, the lips of which are formed by a thickened margin fringed with short hair. This structure is very apparent in the large spiracle which lies in the uniting membrane of the pro- and mesothorax, and particularly in Gryllotalpa (Pl. XI., No. 1, f. 2, a. a.), where, by reason of its length, it is very distinct. The horny lips are connected at their corners by a kind of joint, but in Gryllotalpa the lower corner of this incision, which lies near the anterior coxae, is broader and more prominent; and the corner of the exterior lip projects beyond the opposite interior one, forming a kind of covering, thus preventing the influx of improper substances. The entire spiracle is closed by means of a small muscle, which, originating from an inner horny projection of the lower corner of the lip, inserts itself in two horny half-rings, which surround the commencement of the tracheae. The orifice is opened or shut by the contraction or dilatation of this muscle.

Other spiracles, which besides the lips possess an oval horny margin, present a somewhat more complicated structure. The horny ridge (Pl. XXIII, f. 1—3, a.) is no distinct part, but merely the raised edge of the integument surrounding the spiracle; it thus forms an exterior ring, to which the lips of the incision are attached. These lips (the same b. b.) stand at the base of the ring, and are frequently covered upon their external surface like it upon its internal circumference, with sculptured horny scales (Oryctes nasicornis). Where they meet they again form a small projecting margin which, as in the former kind of structure, is surrounded by a fringe of fine hair. The corners of the lips lie close to the inner margin of the exterior ring, so that the true opening, upon the lips being closed, appears as the diameter of the oval ring. The closing apparatus of these spiracles is very complicated. The ends of the incisions, namely, or the corners of both lips, are prolonged inwardly into a point (the same, c. c.), to which two triangular horny plates are so attached, that one angle of the triangle with the projecting point, and the second with the opposite one of the other horny plate, form a joint, but the third remains free. From the last, as well from the sides of the triangle which are applied to each other, a flat muscle originates (the same, e.) which, when it contracts, brings the free points of both triangles together, but those which stand in connection with the inner points of the corners of the lips, it separates from each other; thus is the incision closed: but when the muscle again
relaxes, it re-opens. We must observe, at the same time, that a bag-shaped expansion of the tracheæ originates from the circumference of the spiracle, and narrows towards the latter, in a funnel shape. By means of the tracheæ arising from the point of the funnel, the whole expansion is drawn backwards, so that the axis of the funnel stands obliquely to the axis of the tracheæ; upon the inner side of this funnel, or that part next to the ventral cavity, the just described apparatus for the closing of the spiracle lies (see Pl. XXIII, f. 1—3). Such spiracles are found only upon free or slightly covered parts of the body, for example, under the elytra of many beetles.

A third form of the spiracles is distinguished from the preceding by the want of lips. In very small and round spiracles, the opening is free (for example, in the Lamellicornia), or at most covered with short hair upon their inner margin, and the entrance into the tracheæ is only rendered difficult by the obliquity of its axis to that of the spiracle. In larger oval spiracles, the margins are occupied with stronger plumose spines, or hairy tufts (Pl. XXII, f. 10), and these resist extraneous substances still more forcibly. The air is purified through these as through a sieve, and all prejudicial substances are caught there. This structure is very distinct in the large spiracle of the first abdominal segment of the male Cicada, as well as in the dorsal spiracles of the water beetles*.

The fourth and last form of the spiracles is that observed in the larvae of the Lamellicornia. In these the very minute spiracle appears at first view to take a circular shape, and upon closer inspection it is found to consist of a broad margin and a concentric middle space, which beneath breaks through the margin and connects itself with the surrounding integument. This margin, which is often ornamented with distinct sculpture (Pl. XXIII, f. 4, a, a,) Sprengel considered as a half moon-shaped opening, occasionally closed by a sieve, when the sculpture of the margin was cribiform, or by toothed processes, when the sculpture took that figure, opposite which the inner round plate lay and assisted to close it. Treviranus † opposes this view of it, and asserts that the spiracle is entirely closed, but that minute ramifications of tracheæ are spread upon its internal superficies, and imbibe the air,

as in the branchiae, through the plate of the spiracle. Both were mistaken, for these spiracles have likewise a central aperture, which leads directly into the stem of the tracheæ. This orifice, which is a small transverse incision, lies in the central round plate (Pl. XXIII. f. 4. c), and is very small in proportion to the entire spiracle, and may therefore be easily overlooked; but Kaulfuss, in his drawings to Sprengel’s Treatise, has everywhere indicated them. The exterior margin is, however, by no means perforated, but merely covered with sculpture, just like the exterior oval horny ring. I consider this margin therefore as the pre-formation of the subsequent oval horny ring, the central plate, however, as the two lips of the here still smaller incision. Internally the main stem of the trachea is observed to originate from the circumference of the aperture, a distinct proof that the incision is its orifice (Pl. XXIII. f. 4., d. d.).

§ 124.

After noticing the form of the spiracles, the next most important subject is their situation in the body, which is tolerably uniform in the several orders, but there are a few divergencies from it, which we may here briefly indicate.

In the Coleoptera each segment of the body has a spiracle, or, to speak more correctly, upon the boundaries of every two segments we find one. The first, and generally the largest spiracle, is seated in the uniting membrane of the pro- and meso-thorax, more closely approaching the exterior and lower margin of the former, where it generally remains when those two portions of the body are separated. The second spiracle lies in a very similar situation, namely, between the meso- and meta-thorax, but it is so concealed by the elytra that it can be discerned only upon very close investigation. It is then observed between the two horny plates which we called above (page 81) the anterior and posterior wings of the scapulae. In a state of repose the two plates lie closely together, and thereby completely cover this spiracle; but upon the expansion of the wings during flight, when the body filled with air distends, this spiracle also quits its concealment, that it may, like the rest, allow air to flow in and out. The concealed situation of this spiracle explains how it has been overlooked, particularly as we observe none in the similarly named segment of the larva. Straus first observed it, and has exhibited it in the cockchafer and in others. The third spiracle lies between the meta-thorax and the first
abdominal segment; it is frequently minute and indistinct, but occasionally, as, for example, in the Capricorn beetles, it is very large, indeed larger than the first. The following spiracles, six or seven in number, lie always between every two of the successive abdominal segments, so that the two last segments alone have no spiracles; we thus obtain ten spiracles upon each side, twenty together, a typical number which is never exceeded, but often also not attained.

In the Orthoptera the spiracles are not differently situated. The first which is in the connecting membrane between the pro and meso-thorax is very large, particularly so in Gryllotalpa (Pl. XI. No. 1. f. 2. a, a); the second, between the lower wing of the scapula and the dorsal piece is here quite free and uncovered (the same, fig. 8. β). The third spiracle, which properly should lie between the meta-thorax and the first segment of the abdomen, approaches more closely to the latter, and lies in Gryllus, F. (Acrhydia, Lat.) in a half moon-shaped hollow, which upon one side is partly closed by the projecting cover-shaped margin. All the succeeding ones are placed in a similar situation, namely, at the lower margin of each dorsal plate of the abdomen. In the Blattaria, on the contrary, the spiracles are always placed in the connecting membrane between two segments, and precisely where the dorsal and ventral plates meet; the same is the case in Forsicula; in these also the third spiracle lies at the anterior edge of the dorsal plate of the first segment of the abdomen, where it is very distinct although but small.

In the Hemiptera, which, by the structure of their thorax, approach closely to the Orthoptera, the first spiracle likewise lies in the connecting membrane between the pro- and meso-thorax; it is tolerably large, and narrow, and is only apparent upon the removal of the pro-thorax. A second spiracle is found between the meso- and meta-thorax, and resembles the former in being a rather long, half moon-shaped, or straight incision, and is covered by a posterior projection of the margin of the meso-sternum. This spiracle consequently cannot be seen from the exterior from the preceding projection (Pl. XIII. No. 5. fig. 2. β) lying over it, and above it is concealed by the elytra. The succeeding spiracles are in these insects, as in the Orthoptera, more approximate to the ventral segments, a spiracle being placed in each abdominal segment, whereas by analogy it should lie between every two segments. In the male Cicada the first is very large, free, and always beset with strong setæ at the margin, the following are smaller and indistinct.
Kirby and Spence describe large lateral spiracles in the bugs, lying between the meso- and meta-thorax, but I could perceive in our bugs \textit{(Pentatoma ryhipes and P. hamorrhoidalis)} depressions only at these parts; but if the acute posterior margin of the prosternum, which lies precisely in this cavity, be removed, the spiracle is observed very distinctly beneath it. In \textit{Belostoma} a very distinct spiracle is found at the posterior margin of the pleura, consequently between the meta-thorax and the abdomen, which, however, appears to belong to the first abdominal segment, because in the bugs the spiracles lie always in the ventral segments themselves, and, indeed, at the exterior margin of the ventral plates, and not, as in the beetles, beneath the wings and the elytra.

The \textit{Neuroptera} alone, of the remaining orders, have a distinctly separated pro-thorax; it is here therefore that we must notice them. \textit{Semblis} displays two distinct pairs (Pl. XIV. No. 3. f. 2. 4. a and \( \beta \)) of spiracles in the thorax, the first between the pro- and meso-thorax, and the second between the meso- and meta-thorax. Whether there be a third pair between the meta-thorax and the abdomen I could not clearly perceive either here or in \textit{Myrmecoleon}, but in the dry specimens examined by me there appeared to be incisions. The two first pairs lie, also in the ant-lion, exactly in the same place. \textit{Panorpa} displays two pairs of spiracles in the thorax and five pairs in the abdomen; the two first lie between the pro- and meso-thorax, and between the latter and the meta-thorax, and display themselves as small brown points. In the abdomen they are placed, as in all \textit{Neuroptera}, in the connecting membrane of each pair of segments, closely in front of that to which they belong.

In the \textit{Dictyoptera}, as those most closely allied to the preceding order, with the exception of the \textit{Libellulae} and \textit{Termites}, they are, from their minuteness, difficult to investigate. The \textit{Libellulae} have two pairs of spiracles in the thorax, one pair being between the pro- and meso-thorax, each of which, however, is covered by a small scale originating at the posterior margin of the pronotum; the second pair is seated between the meso- and meta-thorax, at the sides of the thorax. The former are long, somewhat bent incisions; the latter very small, ovate, two-lipped spiracles. I have observed none between the meta-thorax and the abdomen. It has also been said that they have no abdominal spiracles. But Reaumur and Sprengel admitted their existence in those
larvae which live constantly in water, but Kirby and Spence* again denied it, their attention being probably drawn to it by Roesel's† observation of their respiration through the anus. This intestinal respiration Suckow‡ has confirmed by showing branchiae in the colon, and thus proved the entire inutility of spiracles. But in the perfect insect there are seven pairs of spiracles upon the central abdominal segments, which are covered however by the margins of the dorsal plates lapping over them as they lie in the soft connecting membrane.

In the Termites the spiracles are found in analogous situations, but those of the abdomen are so small that they are seen with difficulty.

The remaining three orders very closely agree both in the structure of the thorax as well as in the situation of the spiracles. All possess our in the thorax, two of which are upon the limits of the pro-thorax, between it and the meso-thorax, and the other two lie between the meso- and meta-thorax. In the Hymenoptera, in which the thorax consists of a hard horny case, and the segments are closely united together, the posterior pair of spiracles lie upon the meta-thorax itself, whereby they distinguish themselves from all the other orders; besides which the anterior pair of spiracles are covered by a small scale-shaped projection of the posterior margin of the pronotum, which scale (tegula, comp. § 77.) lies precisely beneath the anterior wing, and is very readily recognisable in the wasps. In Pl. XII. No. I. f. 1., wherein the thorax of Cimbex is represented, the letters a and β point out the situation of the spiracles, as also in the same plate, No. II. f. 2. in the thorax of a Scuttle. The spiracles of the Lepidoptera are distinguished only by possessing a narrow, scarcely perceptible, horny ring, which lies concealed beneath the hair (Pl. XIII. No. IV. f. 2. shows at α and β, where they are placed.) In the Diptera they appear as short, somewhat compressed tubes, particularly the first, between the pro- and meso-thorax, as is shown in Pl. XIV. No. I. f. 2. in Tabanus, and No. II. f. 2. in Myopa. A similar uniformity exists in the situation of the spiracles of the abdomen, for they always lie in the connecting membrane of the segments, and are covered by the projecting margins of the dorsal plates.

The numbers of the spiracles are thus shown in their situation. If

* Introduction to Entomol., vol. iv. letter xxxviii.
† Insectenbelustigungen, 2 band. Wasserinsecten der 2 classe, Taf. II. and III.
‡ Heusing. Zeitschr. für die Org. Physiek. 2 band. 2 hft. S. 36, &c. Pl. I. and II.
we call to mind also the general law which makes the insect body to consist of thirteen segments, whereof one forms the head, three the thorax, and nine belong to the abdomen, the number of the spiracles is readily ascertained. The thirteen segments have namely twelve connecting membranes, of which the first only (between the head and pro-thorax) and the last are never supplied with spiracles, consequently there cannot be more than ten on each side at most. But as the number of the abdominal segments considerably varies, it consequently frequently happens that there are fewer spiracles. I have observed twenty in the water-beetles (*Dyticus*). According to Degeer and Latreille *, the locusts and Lepidoptera display as many: the Lamellicornia and Cerambycina possess eighteen. Many Orthoptera, the Termites, and Libellulae possess the same number. The Hymenoptera have but seven distinct abdominal segments, the last of which, according to the general rule, bears no spiracle; in general they possess sixteen: Panorpa has fourteen; many Diptera still fewer, as but five or six distinct abdominal segments are perceived in them.

§ 125.

II. The air tubes are absolutely nothing but elongated spiracles, although they are not always found, where the spiracles are placed. They are only observed in insects which live in the water, namely, in the larvae of many Diptera and some water-bugs (*Nepa, Ranatra*), and are placed either at the first or the last abdominal segment. They here appear as either long or short horny tubes, which pass directly from the general integument of the body, being open at the end, and within the orifice they are surrounded by simple or plumose setæ, or else entirely unprovided with them.

The larva of the common gnat (*Culex, Pl. III. f. 3*) is very generally known as possessing this organ, which is placed obliquely at the last abdominal segment. Simple branches of the tracheæ pass into this tube, opening where it terminates. The end of the tube is surrounded by setæ, and these support the animal upon the surface of the water when it places itself there to breathe. In the pupa state the tube at the end of the abdomen disappears, and instead of it two bent tubes project from the thorax between the pro- and meso-

The majority of the larvae of the genera most closely allied to this gnat possess no such air tube, but true branchiae or gills, yet the larvae of Chironomus* have likewise two conical air tubes upon the anal segment (Pl. III. f. 5); besides which they are easily distinguished by a more elongate vermiform shape †, as well as by their blood red colour, from the true larvae of the Culicidae. A similar structure is found in the larvae of Stratiomys; in them the entire last segment of the abdomen is elongated into a tube, and at the aperture of the tube it is provided with a wreath of plumose hairs placed in the form of a star. This coronet, which is much larger than that of the larva of Culex, likewise supports the much larger creature upon the surface of the water when it goes thither for fresh air; and it likewise takes air bubbles, which are inclosed by the setae, down with it to the bottom of the stagnant pools which it inhabits, as a provision for its next inspiration ‡. The larvae of the genus Eristalis display a considerably longer anal air tube; in these also the last joint is extended into a membranous tube, in which a second narrower and corneous one is contained, which at its open end is provided with a similar crown of hair. It is into this tube that the two branches of the tracheæ pass after having united into one. The thick, white, cylindrical larva which lives in the mud of pools, in sewers, and in excrement, directs this tube to the surface of the water, which hangs there by means of the above-mentioned setæ, while it itself lies tranquilly at the bottom, or else continues feeding. If the water should rise, for example, after rain, it lengthens this tail by pushing the inner tube as far out as is requisite. This elongation can be extended to several inches, whereby the length of the tail exceeds several times that of the body. For the expiration of the air thus received two other very short air tubes are placed upon the first segment of the body, directly behind the head; the anterior ends of the above-described main stem of the tracheæ pass into these after having previously, as well as the posterior ends, become united by means of a transverse branch.

We also observe anal air tubes in the genera Nepa and Ranatra, but which are distinguished from those above described in the first place by

* The larvae have gills (branchiae), as I have recently observed (Author, MS. Note).
† These larvae were formerly considered as a genus of annelides, and were called Brachiurus. See Oken's Zoologie, 1 band. s. 383. Taf. 9., and Viviani Phosphor. Maris, 3. 13, 14.
‡ See Swammerdam, Biblia Naturæ, Pl. XXXIX. f. 1—3.
their number, two always being present, and secondly by their form, they being simple horny tubes unprovided with setæ at their end. In Ranatra they are as long as the body, and in Nepa half its length.

It seems to be a very general law, that the situation of the spiracles should be at the posterior end of the body, not only in the Diptera, but also in all larvæ which live in water and are unprovided with branchiæ. With respect to the larvæ of the Diptera, those yet investigated have their spiracles in that situation: for example, the flies and Etridera. The larvæ of the water-beetles likewise (for example, Dyricus and Hydrophilus) have their spiracles at the anal end, contiguous to the anus, and have none at their sides, although Sprengel describes and even figures them there.

§ 126.

III. GILLS, OR BRANCHIÆ.—This third description of the organs of respiration is particularly distinguished from both the others by its want of apertures to admit the air into the tracheæ. The gills are processes of the epidermis in the form of hair or leaves, in which delicate tracheæ ramify in every direction. These vessels imbibe the air mixed up mechanically with the water, and conduct it to the main stems concealed in the body, by means of the branches of which it passes to all the internal organs. Through this arrangement insects provided with gills do not require atmospheric air, they consequently do not rise to the surface of the water, but live constantly in it concealed among water plants.

The branchiæ may be separated into two divisions, by their forms; the one being delicate and slender, resembling hair, while the other is broad, thin, and lamelliform.

The hair-shaped branchiæ seldom appear singly, but generally in approximate fasciculi, which are formed by either the ramifications of one or of several main stems (Pl. III. f. 6.), or by filaments radiating from one point (the same, f. 10). The epidermis of these processes is exceedingly delicate, as well as the small silvery tracheæ enclosed by it. This kind of branchiæ is the most usual and general; it is found particularly in the larvæ and pupæ of the gnats.

The lamellate branchiæ are found only in the Dictyotoptera and the Neuroptera, and appear as broad or pointed lanceolate leaves, and are found on each side of each abdominal segment, or only at its end.

Several, or at least two leaves, are found at each place, so that each segment of the body has never less than four branchial leaves. They are generally uniform, but an instance is known (Ephemera fusco-grisea, De Geer*), in which one of the branchiae is lamellate and the other is a fasciculus of filiform ones.

If we look to the orders in which branchiae are found, we shall speedily see that they are not rare, and, indeed, that the majority of larvae which live in water breathe by means of gills.

The following are the genera whose larvae thus respire:—

Among the Coleoptera we find hairy branchiae in the larvae of the whirlwigs (Gyrinus †), which rise from the sides of each segment, and clothe the body as simple, tolerably stiff, hairy processes. The closely allied Dyticus have no gills, but spiracles, which lie contiguous to the anus; the larva of Hydrophilus picus likewise breathes through spiracles thus placed, but the larva of Hydrophilus Caraboides, has, according to Roesel's figure ‡, ramose branchial fasciculi on each abdominal segment.

The Orthoptera never live in water either as larvae or as perfect insects, they have consequently only spiracles as the exterior organs of respiration.

Many of the Hemiptera, both in their larva and perfect state, live in water, but branchiae have never yet been observed in them. Both young and old, when they wish to breathe, come to the surface of the water, and receive air through the spiracles. Nepa and Ranatra have air tubes, which we have mentioned above.

Whereas in the orders of the Dictyoptera and Neuroptera the branchial apparatus is very general. In the first of these orders, the larvae of the Ephemerae and Libellulae live constantly in the water, and have branchiae. In the larva of the Ephemerae they lie at the sides of the body, four upon each segment, and they consist of small leaves of various forms. In Ep. fusco-grisea one branchia is a leaf, and the other a fasciculus; in Ep. vulgata § both are leaves, very narrow, and clothed at the margin with long fine hairs. The branchiae of the larvae of the Libellulae are not placed at the sides of the abdominal segments, but upon or within the last segment; and in Agrion they form three large

§ De Geer, ib. Pl. XVI. f. 3.
The organs of respiration.

Clavate leaves fringed at the margin. The larvae of Eschna and Libellula breathe through fasciculated branchiae, which lie in the colon. Thither proceed the terminal ends of the four main stems of the tracheae; they transpierce the membrane of the colon, and hang as thick fasciculi within the cavity of this organ*. As the creature imbibes water by means of it, and thus again rejects it, it helps to assist it in swimming, which, without this auxiliary aid, it would find it difficult to effect, from its deficiency of other swimming leaves. Other larvae swim by means of the branchial leaves, which move with an incessant alternating vibration.

Among the Neuroptera we are acquainted with the families of the Phryganodea and the Semblodea, whose larvae inhabit water. Both breathe during this state only through branchiae, which in the former consist of two leaves placed on each side of each abdominal segment, but varying in form according to the genera, but in the latter they appear as simple or plumose, tolerably long processes, which consist of several joints, becoming gradually acuminate, upon the under surface of which the tracheae ramify, protected by two rows of setae†.

Branchiae seem very general in the family of the gnats, among the Diptera, as they are found not only in the larvae but also in the pupae. This is the case in the genus Chironomus, whose larvae described above breathe through exterior tubes, but whose pupae are furnished with two radiating fasciculi of branchiae at the thorax (Pl. III. f. 6). These branchial fasciculi are seated close to the spot where later the first spiracle of the thorax is found, namely, between the pro- and meso-thorax.

The same is the case in the genus Simulia; the former has air tubes at the anal end as well as at the thorax, the latter two large branchial fasciculi between the pro- and meso-thorax (Pl. III. f. 9 and 10‡). The reversed relations obtain in the genus Anopheles, whose larva, described as a remarkable water animal, first by Goeze§, and afterwards by Lichtenstein||, but which G. Fischer¶ ascertained to be the larva of this gnat, bears hairy branchiae at its anal end, but whose pupa is provided

* Suckow in Hsuing., vol. ii. part i. p. 55, &c. Pl. I. and II.
† Ib., p. 27. Pl. III. f. 24.
‡ Compare Thon's Archiv. der Entomologie, vol. ii. no. ii. Pl. II.
|| Wiedemann's Archiv. für Zoologie und Zootomie, vol. i. No. i. p. 168. Pl. III.
with two curved air tubes between the pro- and meso-thorax (Pl. III. f. 7 and 8.)

Among the Lepidoptera but one caterpillar, that of Bolyx stratiotalis has been observed to possess branchiae*. In this they consist of delicate small hairs which clothe the whole body, but particularly laterally, in the vicinity of the future spiracles, they stand in fasciculi. The tracheae are observed in them as glittering silver-white threads. The caterpillar lives constantly in the water upon the leaves of Stratios aloides. I have myself observed a very similar caterpillar of a moth upon Ceratophyllum demersum, but I was not successful in breeding it. Doubtlessly others also exist among the allied genera and species, but which have hitherto escaped detection. It must strike as remarkable, that among the Lepidoptera, which apparently, from the great development of their organs of flight, are destined to dwell in the air, larvae should be found which select a place of residence of such a very opposite nature, whereas among the Hymenoptera, which appear more adapted to dwell in a variety of media, no single instance should occur of one having been observed, either in its larva or perfect state, to live in water. It is indeed true that some of their larvae live in moist places, such as the parasitic larvae of the Ichneumons, but branchiae have never yet been detected in them.

§ 127.

B. INTERNAL ORGANS OF RESPIRATION.

The internal organs of respiration are the most simple and most uniform parts found in the insect body; for they universally present themselves as ramose tubes originating from the spiracle, the exterior air tube, or from the root of a branchia, and thence spread to all the other organs. Malpighi, who by his dissection of the silk-worm was the first to obtain a correct insight into the internal structure of insects, was also the first discoverer of these internal organs; previously it was thought that insects did not breathe, an opinion which was originally propounded by Aristotle, and subsequently generally received.

As to the structure of these tubes serving for the function of respiration, and which have been called AIR TUBES OR TRACHEA, we shall find

* De Geer, vol. i. part iii. Pl. XXXVII. f. 5 and 6.
that they consist of three distinct layers, which, taking them from the exterior, appear in the following form:

The outermost membrane (Pl. XXII. f. 11.) is transparent, very smooth, without being perceptibly fibrous, but hard, and generally colourless. Coloured tracheae, which we now and then observe, for example, brown in Locusta viridissima, red in Phasma gigas, or black, as in the larva of Dyticus and Hydrophilus, derive their colour from this exterior skin, whereas both the others, especially the second, are constantly of a silvery white, and shining. A dark colour facilitates very much the detection and unravelment of the extremely delicate tracheae, particularly when they run upon the clear ground of other organs. But in those cases where the tracheae are not coloured their investigation is not very difficult when freshly killed individuals are selected for the purpose, for in them the tracheae are still filled with air: they then display themselves as silvery white, glittering threads, which here and there appear dull and transparent, from moisture having at those parts already penetrated them. In general, the last and most delicate ends are still filled with air, which, however, is forced out when the creature has been long immersed in spirits of wine, and it then becomes difficult to obtain a satisfactory view of their distribution. The exterior membrane of the tracheae consequently is structureless, nor is it in very close connexion with the second, but loosely surrounds it, leaving everywhere a free space between them, which is quickly perceived upon a microscopic investigation, and thereby readily convinces us of the presence of at least two layers.

The second layer consists of a single, tense, elastic, and very delicate filament, which twines spirally around the innermost membrane, so that its windings are everywhere, or at least very generally contiguous. This thread appears to be simple and round, but which is occasionally difficult to ascertain from its delicacy, but the microscope displays how it distributes itself about the circumference of the vessel, and that it scarcely leaves the smallest space between its successive windings, and which is filled only by membrane. In some instances, for example, in Locusta viridissima, and indeed in all insects provided with large tracheal stems, the filament becomes broader, resembling a band, and can be distinctly distinguished as such. Sprengel * detected in such larger tracheae ramose filaments, or perfectly closed rings, which were.

* Commentar. de Parl., &c Pl. II. f. 14.
separated by broader membranous spaces, these he has figured as round in Cetonia aurata *. in Lamia textor he even saw small spots between the windings, whereby the vessels of this insect appeared punctate. When an air-vessel sends off a branch the space between the two successive convolutions then widens, and the branch commences with its own spiral filament (Pl. XXII. f. 11), whereas that of the stem continues uninterruptedly; but if a trachea divides into two equal branches, each begins with its own new spiral filament, and that of the stem terminates at the point of division. These spiral filaments of the tracheae may be considered as analogous to the cartilaginous rings in the windpipe of the superior animals, although these are separated from each other, and connected only by their softer parts. But this fibrous layer of the muscular membrane in the vessels has the same function, for the contraction of the spiral filament straitens the trachea, and thus helps to promote expiration, whilst its succeeding expansion facilitates the inspiration by opening a larger space in the vessel for the admission of air. The cartilaginous rings of the wind-pipes of the superior animals fully accomplish this last purpose, and they thereby distinguish themselves from the trachea of insects.

The innermost third membrane, which Lyonnet, Marcel de Serres, and Sprengel-Durckheim admit, but Sprengel denies, is, according to the investigations of the former, a smooth, transparent, delicate, mucous membrane, and, as it were, a continuation of the exterior epidermis, with which it also stands in connexion at the orifice of the spiracles. The spiral filament lies closely adhesive to it, so that upon a rupture of the vessel its remains hang affixed to the detached spiral thread, whence Sprengel prefers considering it as a connecting membrane between the spiral fibres rather than as a distinct layer. But the fact of this innermost membrane peeling off when caterpillars moult, or pass from the larva to the pupa state, and that in place of it a new one is formed beneath, speaks distinctly in favour of its being considered as a peculiar and a separate one.

This anatomical structure of the air-vessels is found precisely the same in all the orders, and although their form is subject to many variations, yet their structure but very seldom participates in this difference. This participation of the structure in the difference of form is maintained by Straus and Marcel de Serres to be found in the air bags of the

* Commentar. de Parl. Pl. II. f. 19.
Lamellicornia, in which, according to these entomotomists, the spiral filament is deficient, whereas others, particularly Suckow and Sprengel, assert that they exist, of which we shall speak in detail below.

§ 128.

With respect to the differences of form in the tracheae, according to Marcel de Serres they may be divided into three main groups, which that writer thus distinguishes:

1. **Arterial Air-vessels.**—They originate directly from the spiracle, and ramify with the most delicate branches from this simple stem to all the internal organs.

2. **Tubular or Pulmonary Air-vessels.**—They do not receive the air directly, but stand in connexion with the spiracle by means of the former. They are larger than the arterial air-vessels, their course is more regular and straight, their diameter broader, and their branches, on the contrary, smaller.

3. **Vesicular Air-vessels.**—They are of two kinds, either large bladders, in which the air collects, and whence the branches spring, or small bladders in the branches themselves, and frequently the terminal distended ends of the branches; both forms are never found together.

Upon inspecting first the arterial air-vessels, as those most generally found, but little that is extraordinary is to be remarked in them; each main stem originates from the internal margin of each spiracle with a broader base, which narrows somewhat after a short course. Here also is the point of division of the main stem; next a branch spreads forwards and backwards, which passes to the anterior and posterior spiracles to unite with each main stem originating from them. By means of these arches all the stems of the tracheae stand in close connexion together. Between these two communicating tracheae the remaining ramose branches originate, and each spreads more particularly to those organs which lie most approximate to it. These branches frequently open into each other, and form stems running contiguously to the intestinal canal, the muscles, and the sexual organs, and whence the delicate branches for these organs originate.

The number of the branches originating from a main stem, with the exception of the two connecting tubes, is indeed very variable, but we may assume that more branches spread from the tracheae of the thorax than from those of the abdomen. This arises from the greater number of organs existing in the thorax, particularly the number of muscles,
whereas in the abdomen there are many spiracles, but proportionally fewer internal parts. The vessels of the thorax consequently belong more to the organs of motion, and those of the abdomen to the intestinal canal and the sexual organs.

Two of the many branches which the main stem of the first thoracic spiracle sends off always go to the head. One runs superficially over and contiguous to the mandibulary muscles, and also unites to its opponent upon the opposite side (Melolontha), and distributes itself with its branches to all the superior internal portions of the head. From it the ring encompassing the eye proceeds, or, where this is wanting, the branches which spread in the pigment of the eye. The inferior branch accompanies the nervous cord and the œsophagus into the head, and distributes itself to the lower lying muscles, the maxillæ, and the labium. A third branch, which descends downwards anteriorly, or as in the Mantodea, two equal branches spreading in this direction pass into each anterior leg, and each distributes itself with innumerable ramifications to its very point. The extreme posterior branch is the one connecting it with the second thoracic spiracle, the remainder originating between this and the beforementioned one, distribute themselves to the muscles, and several pass into the meso-thorax. The spiracle between the meso- and meta-thorax, generally the smallest, has also the fewest branches, namely, besides the connecting ones which unite it to the first and third spiracle, it has a main branch for the middle leg, and several ramifications for muscles. From the third spiracle between the meta-thorax and the abdomen it is generally that the greatest number of branches originate, namely, the two connecting branches, the branches for the third pair of legs, and several large ones to the muscles. The spiracles of the abdomen have each their two connecting branches, and besides which several ramifications for the internal organs. The number of these branches differs much in the genera and families, but they are about the same from the several spiracles. In the Mantodea they unite to a second, more internal, common duct, and from which the branches for the internal organs originate *.

In all caterpillars, maggots, and in the larvae of the Hymenoptera we observe only arterial vessels, the same in all the predaceous and swimming beetles, and in the Heteromera and Tetramera. In all other

insects we find them in conjunction with pulmonary and vesicular vessels, but the terminal ramifications, as well as the secondary ones, are of the arterial description.

§ 129.

Tubular air vessels are chiefly peculiar to such larvae as are provided either only at one end or at both ends of the body with spiracles; besides which the communicating tubes of the stems of the spiracles are tubular. Under the name of tubular we understand such air-vessels which proceed uninterruptedly from one end of the body to the other, and which only send forth here and there small accessory branches; or else the simple communicating vessels between two approximate spiracles, and which are without any accessory ramifications. Both have this in common, that they preeminently extend according to the longitudinal axis of the body, whereas the arterial air-vessels take their course in an opposite direction to this longitudinal course. Whence it becomes apparent that the tubular air-vessels are never insulated, but can only exist in conjunction with the arterial; the former are, as it were, the main stems and the latter their twigs.

We will now describe in greater detail some of the chief tubular air-vessels.

With respect to their first form we may assume that all larvae which live in water possess more or less developed tubular main stems. Among the Coleoptera this is the case in the larvae of Dyticus and Hydrophilus. The yellowish green larvae, figured by Roesel* of the large water-beetles (Dyticus marginalis, dimidiatus, &c.), have two large spiracles at the apex of the last abdominal segment, exteriorly contiguous to the short, plumose, anal apex. Two large, broad, black tracheae originate from them, which ascend undivided as far as the first thoracic segment, the future prothorax. There each furcates, and then both branches run to the head, one spreading over the muscle of the mandible and the other beneath it. Two small accessory branches of these two main stems spring from it at the commencement of each abdominal segment, but the inner one of these two is considerably the largest in the fourth, tenth, and eleventh segments, for these three pass to the intestinal canal, the anterior one to the stomach, the posterior ones to the ilium and thick

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gut, whereas all the rest are branches which run off to the muscles. But, on the contrary, the two exterior branches in the second segment exceed the inner ones in size, turn upwards to the back of the segment, and here anastomose, whereby is formed one transverse communicating passage between the two main stems. All the transverse accessory branches are here arterial, but the large main canal which runs longitudinally in the insect is tubular. We find a similar disposition and structure, in all the essential portions, in the tracheal system of the larva of *Hydrophilus piceus*, as is evident from Suckow's figures.

Tubular air-vessels are very general among the *Orthoptera*, where likewise, as is always the case, they are connected with arterial branches, or even with vesicular vessels. The tracheal system of *Mantis oratoria* described and figured by Marcel de Serres may serve us for an example †. Two narrow vessels originate from each of the seven abdominal segments, the shorter exterior ones of which unite in a direct tubular vessel, which runs beneath the margin of the abdomen, and passes on to the third spiracle of the thorax. The inner somewhat longer vessels unite in arches, forming a second longitudinal tube, which proceeds in an undulating line close to the superior wall of the intestinal canal, and also passes into the thorax. A third tubular vessel comes out of the thorax, running very closely to the intestinal canal: it also takes an undulating course, but beneath that organ, and sends forth branches laterally, which again unite in a fourth direct tubular vessel, and which is connected at its anterior and posterior extremities with the first named one, which runs at the edge of the abdomen. All these tubular vessels give off but few branches, and it is only from the central lower longitudinal tube that some delicate branches are given off to the intestine, and it is from the central inner small vessel, originating at the spiracle, that the air tubes come for the sexual organs.

The air-vessels of the larvae of the *Libellulae* are also tubular, and are very uniform in their distribution with those of the larvae of the beetles which live in water. Two large main stems, serpentine at the dorsal portion of the intestinal canal, which, after being bound by the

† Mém. du Musèum, tom. iv. Pl. XVI. f. 1.
colon, from which they originate in a tuft, take their course to the head, where they again furcate. On each side of the ventral portion two smaller vessels lie, which are united to the dorsal vessels by means of transverse branches. The upper one of these runs also to the head, the lower one, taking its course nearly in the centre of the body, terminates on the contrary in delicate ramifications * at the stomach. We find also in the perfect insect both the ventral and dorsal stems, the latter communicating by means of delicate canals with the seven spiracles of the abdomen.

The tubular vessels, lastly, are found very generally in the larvae of the Diptera. The larva of the common gnat (Culex) has two large dorsal stems, which originate, already divided, from the above described posterior air tube, and give off their fine branches to the internal organs †. In the larva of Eristalis tenax, Meig., which has been called the rat-tailed maggot, from its long air tube (Pl. II. f. 8.), both the two great tracheal stems unite, previously to their passing into the inner tube of the air tube, by means of a transverse branch, and remain for a small space separated, lying convoluted in front of the internal aperture of the tube, but it is only where they pass into the inner tube that they are truly united together. In the body itself they are never again united, but in the first segment in the membranous head there is another connecting tube which proceeds directly behind the cerebrum. In front of this connection they become considerably narrower, but behind it each stem proceeds out of the head as a fine tube passing into a small air tube placed at each side of the head, which were necessary for the expiration of the previously inspired air. It is probable that such anterior air tubes are found also in the larvae of other Diptera. A similar structure is found in the larva of all the flies; but they want the tail, and both the tracheal stems separately vent themselves at the posterior obtuse surface of the body (Pl. II. f. 1.).

The larvae of the Hymenoptera have also tubular main stems, but which, as they are formed of small tubes that proceed from the spiracles, are never so large and developed. Two main stems consequently proceed on each side of the body, united in each segment by means of a transverse connecting vessel, but there originate from them, at those places where the tubes of the spiracles pass into them, innumerable

* Suckow in Heusinger, f. 7. & 9.
† Swammerdam Bib. Natura, Pl. XXXVII. f. 5. h.

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ramose or arterial vessels, so that the tubular main stem is less insulated. Precisely the same structure is exhibited in the larva of the Lepidoptera, but the peculiar tubular structure is still more indistinct, for in general the transverse connecting tubes are also wanting.

§ 130.

The vesicular air vessels are properly only distended tubes, or the distended ends of accessory branches, it is thence that they are never found alone, but they are always in conjunction with arterial or tubular air vessels. They also appear under two chief forms, for they are either very large bladders, lying chiefly in the abdomen, whence arterial air vessels originate, or they are the vesicular distensions of the branches of arterial air vessels themselves.

The first form of the vesicular air vessels is found in the Hymenoptera, Diptera, Cicada, and in a somewhat altered figure in many grasshoppers.

In the Diptera, at least in the true flies (Muscidae) the Syrphodea and the Cestridae, two large air bladders have been observed at the base of the abdomen, contiguous to the intestinal canal, which are tolerably uniform in structure with the large tubular vessels, but the twistings of the thickish spiral filament are wider apart, the filament itself divides here and there, and is interrupted at other parts, whence the entire surface does not appear so regularly transversely striated as in the tubular vessels (Pl. XXII. f. 12., membrane of the air bladder of Musca vomitoria). Their form is regulated by that of the abdomen, so that they are often ovate or very generally vertically compressed, and are here and there angular, in consequence of constrictions. A large trachea originates from their under surface; it runs forward and backward to the head and anus, and gives off lateral tracheae to the spiracles of the thorax and abdomen. Other finer vessels run over the superior surface of the bladder, and ramify to the internal organs. Whether they originate from the bladder itself or from the connecting vessels lying beneath it I could not perceive distinctly in flies, but it is the case in Scolia and in Apis according to Leon Dufour. But this whole air bladder is nothing else than the tubular vessel of the larva, which during the pupa state has shortened and distended, and of which we took notice in the preceding paragraph; this air bladder must

* Compare Swammerdam Biblia Nature, Pl. XXIV. f. 1. in Apis Mellifica.
consequently be found in all flies whose larvæ breathed through the tail itself, or through spiracles seated there. The presence of this air bladder explains the cause of the glassy perfectly transparent abdomen of so many Diptera, for example, of Volucella pellucens, Meig. The Asili, which have a longer, narrower, more extended abdomen, possess, according to Marcel de Serres*, several small and successive vesicles, for example, Asilus barbarus has sixty on each side.

Many Hymenoptera display a similar structure. In some species of Bombus I have found precisely the same air bladders at the commencement of the abdomen, as has also Leon Dufour in Scolia †.

Carus ‡ has described them in the large Cicada. The air bladder originates within the circumference of the large spiracle which lies between the thorax and abdomen, it distends a little anteriorly, but spreads especially backwards, where it extends to the sixth or seventh segment; before impregnation, whilst the ovaria and testes are still filled with their contents, they are limited to a smaller space, but after copulation they occupy almost the whole abdomen, particularly in the males, in which they are generally larger in compass, doubtlessly in connection with the vocal organ, which in the females is merely indicated. Hence is explained the opinion of the ancients, who held that the males were empty.

In the grasshoppers the bladders have a somewhat different connection with the rest of the respiratory system; and they also vary considerably in form from the former, for in these they consist of bags of a somewhat longish oval shape, very pointed at both ends. In Locusta viridissima two such bags originate at each spiracle, they thence ascend close to the inner side of the general integument up to the back, where they attach themselves to a flat horny arch, which originates from each ventral plate projecting into the cavity of the abdomen, and which is affixed to the ventral plate only at its commencement. Each of these arches supports two air bladders, which, however, do not proceed from one but from two separate spiracles, so that they altogether form a zigzag line. But they are connected also above and below by a narrow longitudinal tube, and from the lower ones there are vessels connecting them with the opposite ones of the other side, and from the upper ones originate the branches which are distributed to the internal

* Mém. de Mus., as above, p. 362. † Journal de Physique, Sept. 1830.
‡ Analekten zur Naturwissenschaft und Heilkunde. Dresden, 1828. page 158. 6th. 15—17, 9.
Thus, therefore, the air bladders of the abdomen form a compact net-work, which is, as it were, spread out between the spiracles and the horny arches. If the abdomen be drawn together by muscular contraction the horny arches rise, extend the trachee longitudinally, and consequently the air contained within them is forced out; but upon its expansion the air again streams in, when every bladder, through the elasticity of its filament, is again shortened and distended. The respiratory system of *Truxalis nasutus*, of which Marcel de Serres has given a figure*, is still more complicated, for in it the bladders do not originate immediately from the spiracles, but, by means of long tubes, from the common tubular vessels which connect all the spiracles, and at the opposite end unite in a second but more delicate longitudinal tube. Also the two opposite bladders are held in connection together by undivided tolerably narrow tubes. In the abdomen there are twenty bladders, ten on each side; in the thorax six larger ones, four in the meso- and metathorax, one very large pear-shaped one above, at the dorsal portion of the pro-thorax, close to the crop, and besides many vesicular distensions of the arterial vessels; in the head there are six large bladders, two laterally, contiguous to the muscles of the mandibles, two above, at the vertex over the eyes, two in the forehead before the eyes, and between these several smaller vesicles.

The second chief form of the vesicular air vessels is found among the *Coleoptera* in the family of the *Lamellicornia*, among the *Lepidoptera* in the *Crepuscularia*, particularly in the males, and then in the dragon flies.

In the *Lamellicornia* the chief distribution of the air vessels, as throughout the *Coleoptera*, is arterial, for fascicles of air vessels originate from each spiracle; but each finer branch distends, prior to its ultimate and finest ramification, into an oval bladder, which is of a more delicate structure than the rest of the branch, whence Marcel de Serres and Straus deny the presence of the spiral fibre in these vessels, which Suckow maintains to be the case. It is true that these bladders are more transparent than the tubes, but they exhibit a peculiar punctured structure, as was even perceived and figured by Swammerdam †; and also by Sprengel ‡; and thence I would assume

* As above, Pl. XV.
† Biblia Nature, Pl. XXIX. f. 10.
‡ Commentar., Pl. I. f. 11—13.
that in these bladders, as in the larger ones of the flies, the spiral filament has torn from the distension, and only the rudiments of it are present in the darker places. These bladders accompany all the intestines, pass everywhere between the muscles, and are particularly accumulated superficially beneath the integument. A precise description is consequently impossible, from the manifold reticulation of the branches, and a single glance at the masterly representation of it in Straus will explain it better than any words unaccompanied by figures could possibly do, we therefore refer to his anatomy of *Melolontha*.

The vesicular distensions in the tracheae of the *Libellulae* are found chiefly in the thorax, and in it they lie exteriorly, contiguous to and between the muscles. They are generally pyriform, whereas those of the *Lamellicornia* and *Lepidoptera* are perfectly oval; the bags also appear to me to be connected by tracheae and to form distinct lacings.

Among the *Lepidoptera* we find the bladders chiefly in the male *Sphinges* and *Phalene*, and are sometimes small and sometimes large, as in *Acherontia Atropos*, Ochs. They are of a coarser structure than those of the beetles, so that the presence of the spiral fibre is here subject to no doubt. According to a figure in Sprengel the membrane of the bladder has sometimes a cellular appearance, and this might then be considered as an approximation to the structure in the *Lamellicornia*.

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SECOND CHAPTER.

OF THE ORGANS OF GENERATION.

§ 131.

The second chief system of the vegetative organs comprises the sexual organs destined to the propagation of the species. Under this name we understand both the vesicular and the tubular parts which lie in the abdomen generally affixed at one end, which, in a variety of forms and connections are united together in main stems, and open in one evacuating duct at the end of the abdomen beneath the anus. This last definition is subject to no exception in true insects, for what has

*Commentar., Pl. III. fig. 24.*
been considered as exterior sexual organs and sexual apertures at the base of the abdomen in the male Libellula are by no means such parts, as we shall have an opportunity of proving below; in them also that aperture is found at the end of the abdomen, in the vicinity of the anus.

These vesicular and tubular organs consist, like the intestinal canal, of several divisions, which, as the general character and function of the sexual organs consist in the secretion of fluids, may be distinguished as proper secreting organs (testes and ovaria), conducting organs for the secreted fluids (vasa deferentia and oviductus), repositories for the secreted fluids (vesica seminalis and uterus), and as evacuating organs of the secreted material (ductus ejaculatorius and vagina). These main divisions are found in function, although frequently but little distinguished in form and figure from each other, in all the internal sexual organs, as will be shown in the course of our investigation. This sketch consequently comprises the most general structure of these organs, and it will therefore be merely the individual, generic, family, and ordinal differences which will occupy us in the course of our investigation; but we will previously say something about their anatomical structure.

§ 132.

The determination of the structural relations of the membranes of the sexual organs is subject to many difficulties, in consequence of the delicacy and minuteness of these parts. It is only in those divisions which possess a greater extension that it has been possible to distinguish the presence of two layers of membrane. The exterior of these two membranes is coarser, firmer, and of a muscular consistency; the internal one, on the contrary, is more delicate, transparent, simple, and corresponds with the internal mucous tunic of the intestinal canal or the exterior epidermis. The presence of both the membranes in the large vesicles is subject to no doubt; they can there be readily and securely exhibited; even in the more delicate evacuating ducts of the secreting organs they are distinguished by the difference of their consistence, which in the internal one is considerably less than in the external one. It is more difficult to prove their presence in the secreting organs themselves, but J. Müller * has shown them, at least in the

ovaries: but it still remains doubtful whether the glandular testes consist of these two layers, which, however, may be assumed, from the similar structure of analogous parts.

§ 133.

The preceding observations apply with equal force to all sexual organs. But if we contemplate their general form we shall immediately meet with varieties which do not admit of any further generalisation, and this circumstance compels us in this place to examine more closely the differences of form which the sexual organs severally present.

Propagation is, like life in general, the result of two agents acting reciprocally upon each other. In the lowest forms of organisation, where such a separation of the animating activities shows itself less perceptibly, the propagating agents themselves cannot either appear separately, we consequently there find simple germs susceptible of development. By degrees an active and a passive agent are produced, both of which are found at first in the same individual (snails), but they soon separate into two distinct individuals, and thereby constitute the essential character of such individuals. In the former, luxuriant energy, universal momentum, and a continual impulse towards the appeasement of internal urgent desires; in the latter, patient sufferance, quiet reserve, a tarrying for excitement, and an ultimate satisfaction in the discovery, of the deficient unknown something. The former character is called the male, and the latter the female. But where shall we find the differences of these two characters more distinctly expressed than in the multiform insect world? The above cited distinction is here found so strongly marked that its high significance can no longer be subjected to doubt. We shall return to this subject in our physiological chapter, and it is there only that it will find its true place; we can merely indicate it here to enable us to arrive at the primary difference of the sexual organs. This we have now found, we have thus become acquainted with two kinds, and have distinguished them as male and female.

§ 134.

The differences of the organs of generation of both therefore lie based deeply in the conditions of life. We necessarily ask, how does it become evident to us? - Anatomically investigated, the character of the female is the formation of the germs, that of the male secretion of sperm;
all organs, therefore, which display germs (eggs) are female, and all which prepare spermatic moisture must be called male. The female sexual organs of insects consequently display bags full of eggs, ovaria; the male, sperm-secreting vessels or glands; from both originate the above characterised closer or more distant evacuating ducts, which are pretty uniform in both sexes. We may consequently distinguish in both female and male organs different divisions, which are, however, connected together, and which must necessarily constitute the different divisions of our description of the sexual organs.

§ 135.

I. OF THE FEMALE ORGANS OF GENERATION.

The female sexual organs (genitalia feminina) of insects consist of internal and external ones; the internal ones of ovaries, the ovicduct, the uterus, other peculiar appendages, and the vagina; the exterior ones of the orifice of the vagina, and its appendages, as the aculeus, the vagina tubiformis, and the vagina bivalvis.

It is not always that all the above named parts are present together, either one or several are wanting, the ovaries are deficient only in barren, undeveloped females (the neuter bees, &c.), but the evacuating ducts never; all other appendages may, on the contrary, disappear.

A. INTERNAL SEXUAL ORGANS.

§ 136.

THE OVARIES.

The ovaries are tubes or bags in which the eggs are secreted from the formative substance of the creature, and where they remain until their impregnation. We always find in insects two such organs of similar structure in the same individual; they are so placed that one lies on each side of the intestinal canal, generally filling the lateral space in the abdomen. In colour they are generally yellow, but in form they are subject to many varieties, which, however, may be classed under the following divisions:

I. The ovaries are simple bags, in which the germs of the eggs are contained. This primary form, which is the most simple of all, is subjected to no subordinate differences*.

* The ovarium saccatum described by J. Müller in Nova Acta Phys. Med., tom. xii. p. 612, does not belong here, but will be classed below, with the ovarium furcatum.
Female Organs of Generation.

Such ovaries are found in *Ephemera* and *Stratiomys*. Müller calls this form bunches of ovaries (*ovaria racemosa*), and supposes that the exterior tunic of the bag, or properly the bag itself, is wanting, the eggs being connected together by means of air-vessels; but Swammerdam's figure misled him. In a female of *Ephemera marginata*, Fab., De Geer, which I dissected, I clearly observed the exterior tunic, the ova were contained within it, egg being linked to egg by a delicate filament. In *Stratiomys* also Swammerdam has distinctly represented the bag.

II. The short ovaries, which contain but few germs, are placed longitudinally upon a large, bag-shaped, common ovarium.

There are many subordinate differences of this peculiar form, which we will briefly indicate.

1. Ovaria pectinata (Pl. XXVII. f. 2.) are short egg tubes, which contain but few germs, and are placed in a row upon the upper side of a common duct (*Mantodea*).

2. Ovaria echinata, common egg ducts, long, broad, wider anteriorly and suddenly pointed, having beneath many very small scale-shaped egg tubes, which lie over each other (dragon flies).

3. Ovaria imbricata (Pl. XXVII. f. 8.) The whole upper surface, with the exception of a narrow edge upon the lower margin, is covered with short tile-shaped egg-tubes, which lie upon each other, and embrace the intestine like a roof. Each tube contains a large developed egg and behind it the minute germs of two or three others (grasshoppers, crickets, *Phryganea*, Sialis, *Tipula*, *Sirex*, &c.).

4. Ovaria baccata. The common ovarium is a bladder or tube upon the entire upper surface of which are placed the short egg-tubes, generally containing but few eggs, (*Coleoptera vesicifera*, each tube with from one to four eggs; *Semblis*, each with six to nine eggs).

5. Ovaria dichotoma (Pl. XXVII. f. 5. *ovaria furcata*, Müller). The common ovarium is forked, and upon each prong, and particularly upon their opposite sides, there are many tubes, containing but few (3) egg germs (*Gryllotalpa*).

6. Ovaria ramosa (Pl. XXVII. f. 6.). The common egg duct does not simply furcate, but several branches are given off one after the other, each of which contains some egg germs (*Lepisma*).

III. Long tubular ovaries, which contain many egg germs, are collected together at one part of the common duct. These tubes are either entirely free, and distinctly separated from each other throughout their whole course, or else united together by a loose cellular tissue (for example, in *Harpalus ruficornis*).

1. **Ovarium spirale** (Pl. XXVII. f. 10). There is but one egg-tube to each ovarium, but which is very long, and it is twisted spirally from its apex to its base; a rare form, which has been observed only in *Sarcophaga carnaria* and some other kinds of flies.

2. **Ovaria furcata** (Pl. XXVII. f. 7. Ovaria saccata, Müll.). There are but two short ovaria, containing indistinct egg germs, and which unite with the common duct by means of a fork; at the point of union there is a bag (uterus) in which the egg germs pass through their changes until the pupa state (*Diptera pupipara*). In *Polistes* also there are but two egg-tubes, each of which however contains several eggs.

3. **Ovaria digitata** (Pl. XXVII. f. 8 and 9). A few, from three to five, such egg-tubes hang at one spot of the common duct. Many *Lepidoptera* (for example, *Liparis Mori*, with four tubes, each of which contains about sixty eggs), particularly the smaller ones (for example, *Tinca*, likewise with four tubes, each of which contains about twenty-five eggs; and *Pterophorus*, with three tubes, each containing about twelve eggs); and the *Hymenoptera*, (for example, *Chrysis*, with three tubes, each with three eggs; the same in *Xylocopa*; in *Anthidium*, also three tubes, each with about eight eggs). In *Nepa*, *Pediculus*, and *Psocus* there are five tubes, each in the latter genera containing five eggs.

4. **Ovaria verticillata** (Pl. XXVII. f. 11). Many very long tubes originate at one spot, upon the very short common egg duct. They run upwards in a long filiform point.

Such ovaria are found in the majority of female insects, namely, in most *Lepidoptera*, many *Hymenoptera*, and almost all *Coleoptera*. Müller’s ovaria conjuncta are but a trifling variety of this form, the superior filament hanging more closely together, and forming an inter-twisted cord. The fertility of the species regulates the number of the egg-tubes and their turgidity. *Oryctes nasicornis*, *Melolontha*, *Cetonia*,

*Leon Dufour in the Annales des Scienc. Nat. tom. vi. p. 299, &c. According to him the ovaria contain merely a whitish mass, but no distinct egg germs.*
FEMALE ORGANS OF GENERATION.

and Notonecta have six tubes, each with from five to six eggs; *Vespa vulgaris* and *Silpha atrata* seven tubes; *Tenebrio, Leptura, Saperda, Blatta, Ascaphus, Bombus terrestris*, from seven to ten tubes, each with from four to six eggs; *Cicindela, Carabus, Dyticus, Staphylinus, Hydrophilus, Cerambyx, Lamia tristis* from ten to fifteen tubes; *Bu- prestis mariana* twenty; *Blaps mortisia* thirty, each with four eggs; *Apis mellifica* above a hundred, each with seventeen eggs.

5. **Ovaria capitata** (Pl. XXVII. f. 12). They merely differ from the preceding in their short tubes not running upwards in a point, but which distend into a large knob, whence the point proceeds as a thin filament (*Lucanus*).

§ 137.

The situation of these very various ovaria is nearly the same in all insects, for they always lie laterally in the abdomen contiguous to the intestinal canal, and fill the whole remaining space of the abdominal cavity not occupied by that organ. They often lie free and separated from each other, but sometimes fold over from both sides towards each other, and thus form a covering over the nutrimental canal, containing it between them. The latter then forces itself into the anterior portion of the thus formed longitudinal canal, runs within it, and posteriorly it again presents itself, passing over the common duct, which the colon always covers above. Such approximate ovaria are connected by the trachea, which approach them with their large stems, and then accompany each of their individual tubes by delicate accessory branches to their very extremity. There is still another means for retaining the ovaria in their place, which is their communicating duct with the dorsal vessel, discovered and described by Joh. Müller *. Each individual egg-tube, or occasionally the common egg bag, extends in a thin, very delicate, but tolerably firm filament, which ascends anteriorly and above to the dorsal vessel to discharge itself therein. This connexion invariably takes place at that portion of the organ which we have described as the aorta, sometimes at a great distance from the ovarium, for example, in the thorax. This kind of connexion is peculiar to the ovaries of the third chief division, for the connecting filaments of each egg-tube unite in a cord, or frequently, prior to their connexion with the dorsal vessel, they meet and form a single short tube, for example,

in *Carabus*. The connecting filaments of the egg-tubes of the second class remain, at least frequently, separated, and discharge themselves singly into the aorta. It yet remains undiscovered how the connexion is formed with the vesicular ovaries, but it is probable that a single duct passes from the end of the bag to the artery.

We shall treat of the use of this connecting duct, which Müller has so admirably represented, in our physiological division, where we speak of the development of the eggs.

§. 138.

THE OVIDUCT.

The oviductus, or *tuba ovarii*, is that portion of the evacuating duct of eggs which extends from the ovarium to the connexion of the two ovaries in the common evacuating duct. It is a delicate long or short tube, sometimes thin and filiform, or broader and vesicular, and when so it has a thicker muscular structure (*Sembris*). It is rarely that each oviduct is supplied with peculiar glandular appendages which secrete a gluten to spread over the eggs, by means of which they are glued together. In *Hydrophilus*, which has four such appendages attached to each side of the oviduct, they are filamentary, gradually decreasing, blind canals, and have a granulated glandular appearance, and are doubtlessly glands, and most probably secrete the material from which the female prepares the glutinous mass enclosing the eggs; but where such appendages are wanting this takes place in the vagina, or in the duct common to both ovaries, which is then supplied with peculiar appendages for this purpose.

In general the oviduct is longer in small ovaries which contain but few egg germs, shorter, on the contrary, in larger ones rich in germs; but their dimensions are regulated by the age of the insect; long ducts are found in young individuals, and they become shorter in older ones which are ready for impregnation, or already impregnated.

§ 139.

That portion of the duct of the ovaries which extends from the union of the tubes to the orifice of the spermatheca is called the egg-canal. It is generally of greater compass than the oviduct, and distends into a belly in the middle, forming a convenient cavity for the reception of the eggs. But no other object attends this reception

† Ib. Pl. L. f. 2.
than their mere passage, for the impregnation of the egg, as we shall see below (§ 208), does not take place here, but probably at the end of the egg-tube, at least its development commences there. In those instances only in which this portion of the female organs is provided with appendages which secrete a gluten do the eggs remain somewhat longer in this common duct to be covered by the secretion of those glands, that they may be thereby fixed as with a gum to the leaves of plants and other objects. Consequently this portion of the sexual organ is nothing more than a canal, and we must ascribe as well to insects as to many other inferior animals a uterus bicornis; indeed in the majority of cases, particularly those which possess ovaries having many egg-tubes, a uterus multicornis, for at the end of the egg-tube the development of the egg commences, and here consequently also its impregnation by the semen ensues.

§ 140.

APPENDAGES TO THE EGG-CANAL.

The egg-duct is most rarely a simple organ unprovided with vesicular or vascular auxiliary cavities, as, for example, in Donacia, Eristalis tenax, Musca, Tipula, Ephemera (Pl. XXVII. f. 13); in the majority of insects, on the contrary, it exhibits various appendages which take a variety of forms, and exercise different functions.

These appendages vary in number from one to five. If one only be present it is always a vesicular or purse-shaped distension of the duct, which appears destined to the reception of the male semen during copulation, and is thence called the spermatheca. This organ is always situated at the superior parietes of the duct, and opens into it with a small orifice surrounded by a callous margin. This margin is properly the sphincter of the neck of the bag, which prevents the escape of the semen. When it opens the semen flows immediately into the duct from the mere situation of the bag. According to Audouin, the male organ during copulation passes into the orifice of this bag, and thus pours the semen directly into this receptacle. We find this kind of simple vesicular appendage in Acheta, Blatta, Anthidium (Pl. XXVII. f. 14.), Ascalaphus, Sialis, Semblis, Psocus, and Nepa; the same in Hydrophilus, Tenebrio, Lytta, and Chrysis, but in the latter it has a superior or lateral vascular apex (Pl. XXVII. f. 15.), which is evidently the organ we shall presently describe as the gluten gland. In general, namely, this vessel discharges itself into the duct contiguously
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to the spermatheca, yet in the instances named above not, but into the spermatheca itself. It is somewhat similar in \textit{Psocus}, for here the gluten vessel does not merely discharge itself into the spermatheca, but lies entirely in it. For thus I interpret the purse-shaped appendage found by Nitzsch \footnote{Compare Gram's Magaz. vol. iv. p. 281. Pl. II. f. 3. c. f. fig. 4 and 5.} in \textit{Ps. pulsatorius}, in which from one to four pediculated knobs are enclosed which unite into one duct, which runs into the excretory duct of the spermatheca.

If two appendages are found at the duct it must be carefully observed whether they are symmetrical in situation and form or not. Two dissimilar appendages are found in most insects, (namely, the genera \textit{Carabus}, \textit{Harpa}lus, \textit{Melolontha}, \textit{Lucanus}, \textit{Meloë}, \textit{Spondyla}, \textit{Sirca}, \textit{Apis}, \textit{Xylocopa}, \textit{Tinea}, \textit{Pterophorus}, and \textit{Cercopis}). The one is larger and broader than the other, purse-shaped, and corresponds both in situation and function with the just described spermatheca. In \textit{Melolontha} (Pl. XXVII. f. 16. a), \textit{Lucanus}, \textit{Spondyla}, and \textit{Cercopis} it is a short-necked pear-shaped bladder; in \textit{Pterophorus} the same, but a short blind bag springs from it laterally; in \textit{Xylocopa} (Pl. XXVII. f. 17. a), \textit{Apis}, and \textit{Tinea} it has a longer very narrow neck; in \textit{Trichius} a superior vascular appendage; in \textit{Sirca} (Pl. XXVII. f. 18. a), in which it is very large, at the part where the bladder contracts into a neck, two tolerably long, pointed appendages are found; in \textit{Meloë} it is constricted near the middle, and the lower smaller half has a round auxiliary bladder, which discharges itself into it by a narrow caudal.

The second appendage (Pl. XXVII. f. 16—18. b.) is in general much longer, but also thinner and vascular. This form itself, which is common to all the secreting organs of insects, bespeaks its glandular function. Observation has also taught us that a white glutinous liquid is secreted in this organ, which, after the eggs are laid, disappears. This gluten likewise covers the impregnated eggs, and it is very probably what fastens them together, as well as to other objects; consequently all appendages which are not spermathecae are called gluten glands or vessels. With respect to their form, besides the simple, tubular, and vascular form which are found in \textit{Trichius}, \textit{Tinea}, and \textit{Cercopis}, there is a clavate one found in \textit{Melolontha}, and a vesicular one furnished with a short neck in \textit{Meloë}. In \textit{Xylocopa} it is a long gradually decreasing bag, which discharges itself by a very
narrow tubular pedicle into the uterus; in Harpalus and Spondyla, on the contrary, it is a round bladder, which has a very long, twisted, fine duct, and which in Spondyla contains a hard horny interior; in Pterophorus the vessel distends before its orifice into an ovate bladder; and in Lucanus (Pl. XXVIII. f. 1. b, b) there are two such bladders, which unite by means of two short ducts into a common one, and originate from very fine, short, twisted vessels, by their distension. The form of these organs, lastly, is very peculiar in Elater murinus, in which, according to Leon Dufour, they are vessels successively furcate, which at the base of each fork distend into a triangular bag. The symmetrical appendages in Hippobosca resemble these, but the bag-shaped distensions are wanting.

Where the duct has two symmetrical appendages, as in Lepisma (Pl. XXVIII. f. 3.), Musca, and Pediculus they are always gluten depositories; in Lepisma they are large and bag-shaped, and upon the upper surface here and there constricted; in Musca longer and clavate; but in Pediculus, on the contrary, they are two short blind bags, provided with accessory points.

We find three appendages in Gryllotalpa, Calosoma, and Stratiomys. In the first instances two of them are equal, namely, clavate or vesicular gluten vessels, which empty themselves into the duct by means of narrow canals; the third, on the contrary, is the bag-shaped spermatheca, which in Gryllotalpa has another superior, long, vascular appendage. In Stratiomys Swammerdamm * found three long, vascular, gluten ducts, which originated from round glandular bodies.

Four appendages are seen in some Lepidoptera, for example, Pontia Brassica. The most anterior one is a simple, tolerably long, twisted vessel, which in others (Gastrophaga Pini, see further below) consists of two furcate branches; the second is the spermatheca; the following are again long twisted vessels, which unite in a short duct after they have previously distended in two oval bladders. In Cicada, Latr. (Tettigonia, Fab.), in which there are also four appendages, two symmetrical vessels are found in front of the spermatheca, but the vessel behind it is simple but much longer than the two first.

Five appendages, lastly, are found in several, particularly the Noctua. A bladder-shaped, one-sided, sometimes long and clavate, or distended
and egg or pear-shaped one, which discharges itself into the duct by a narrow canal, is the spermatheca; the other four are vascular gluten glands. In *Vanessa Urticae* they are short, the anterior one broader than the posterior, both discharge themselves into the duct at one part but at opposite sides, before the spermatheca; in *Gastrophaga Pini* (Pl. XXVIII. f. 4.) they are very long, and the anterior as well as the posterior unite into a simple but very short canal. The anterior one, which discharges itself close in front of the spermatheca, is distended in the middle into a bladder; in the posterior ones, which discharge themselves into the vagina, this vesicular distension takes place at the end of each single tube before they unite into a common duct.

The poison vessels of the *Hymenoptera aculeata* are appendages of a peculiar description. In them a round, perfectly ovate bladder (Pl. XXVIII. f. 5, 6. b, b), with a narrow duct, discharges itself into the sting, which we shall describe below (§ 145). This bladder lies quite at the end of the abdomen close to the orifice of the sexual organs. It contains a bright clear fluid which is secreted by two either long very fine, much twisted vessels, or of shorter ones, originating from a fasciculus of furcate vessels (*Pompillus* *†*), which opposite the orifice sink into the bladder, and either separated as far as their orifice, as in *Vespa crebro* (Pl. XXVIII. f. 6. a, a), or as in *Apis mellifica* (f. 5. a, a), are united into one vessel, a little distance before the connexion with the bladder. May not the posterior vessels of the *Lepidoptera*, which we have just described, be analogous to these, and both be properly considered as organs secreting urine?

§ 141.

THE VAGINA.

The last portion of the common evacuating duct lying behind the egg-evacuating duct is called the vagina. It is a short direct tube, narrower than the egg canal but wider than the oviduct. Its function being to receive the penis of the male and to assist in depositing the eggs, it is, like all the other organs of insects which require constant distension, held in this state by horny leaves and ridges. There are generally three such horny plates, one above, one lateral, and one beneath. In *Harpalus* the superior plate is a thin bone, which towards the exterior distends in the shape of a shovel, and is there armed with

*Ramdohr,* Verdauungsorgane, Pl. XIV. f. 5.
strong thorns; in the capricorn beetles (*Cerambycina*) it is elongated into a horny, many-jointed ovipositor. In *Hydrophilus* it runs out on each side into a horny point, which Suckow* considers as the analogue of the clitoris. In *Melolontha* the vagina has on each side a small pocket, into which the lateral wings of the penis pass during co-pulation, which explains the cause of the protracted union of this insect.

In all insects provided with an aculeus or an ovipositor, the vagina opens at its base, so that its canal passes directly into that of the ovipositor. The valves and spines of this apparatus are consequently nothing more than the horny bone which lies within the vagina, and which is then prolonged beyond it.

**B. External Sexual Organs.**

§ 142.

The external sexual organs of insects do not always project beyond the apex of the abdomen, but usually lie in the cavity into which the orifice of the anus and of the vagina open. This cavity, common to both, is formed of two valves, the one larger, lying upon the dorsal side, and the other smaller, upon the ventral side, and beyond which the former projects all round. These two valves, which are not visible exteriorly, but are enclosed by the dorsal and ventral plates of the last abdominal segment, are evidently nothing but the last segment itself, those called the last being the last but one. It is only thus that we can explain the disappearance of the segments of the larva in the perfect insect, in which we shall also generally discover nine segments if we include the last concealed one. But where there are nine visible segments the last is not then concealed, but free. It is within this last abdominal segment, whether it be concealed or free, that the orifice of the vagina is found, and indeed, beneath the anus, divided from it only by a projecting plate. The entrance itself is opened, mostly by horny substances, which have partly been described in the preceding paragraph in the description of the vagina. The lateral horny ridges, namely, become more elongate, so that they project as far as the limits of the valves, gradually separating, and thus forming a spacious entrance. The length of the vagina depends upon that of these horny ridges; they are short in the *Carabodea*, and often armed at their apex with a strong hook (*Har-

palus ruficornis), which doubtlessly retains the penis during copulation. In the capricorn beetles unprovided with an ovipositor (the Prionodea) they are long, superiorly broader, pointed towards the apex, and gently bending from each other. There are other forms in other insects. In the orders possessing an ovipositor they appear as its valves, or as its wings in those which possess only a vagina bivalvis, this leads us to the investigation of the free sexual organs which project beyond the apex of the abdomen.

§ 143.

The free, exteriorly visible, sexual organs of female insects are of a threefold description, at least three chief forms entomologists have distinguished by peculiar names, namely, the laying tube (vagina tubiformis), the laying sheath (vagina bivalvis), and the aculeus, called also the terebra, but which is one and the same organ with the preceding.

The laying tube (vagina tubiformis, Pl. XXIV. f. 14.) is a mere continuation of the abdomen, and consists, like it, of rings which gradually decrease in compass, so that the largest and first, exactly as is the case in the telescope, receives within it all the rest, when this organ is withdrawn within the abdomen, wherein it lies concealed. These rings are nothing else than segments of the abdomen itself, which have adopted this altered shape and function in the course of the progressive alteration of the relations of organisation. The proof that this opinion is correct is shown in their number, for in the majority of cases (for example, in the flies,) there are nine abdominal segments, when these rings of the vagina are added to the visible ones of the abdomen. The anal aperture also lies in this tube, which could not be the case if it were merely an ovipositor. Thence, therefore, the last of these tubes only can interest us here, from its containing the female organs. In Cerambyx it is a leathery canal, of which that side nearest the venter is supported by two horny ridges; at the end of each bone there is a short two-jointed process, the first joint of which is large, thick, bulbous, and armed on the exterior with short spines; the second, however, is small and round, and has two stiff setae at its extremity. In the flies, which all possess a tubiform vagina, its last joint has above a horn plate, to which also two short single-jointed, hook-shaped, crooked processes hang attached. The tubiform vagina of the ruby tails (Chrysis) appears, as far as I have been able to ascertain from
FEMALE ORGANS OF GENERATION.

The vagina bivalvis is most closely related to the vagina tubiformis. It is found in the Orthoptera, some Neuroptera (Raphidia), and the Tipularia. In its most complete development it is a sabre-shaped tube, which curves upwards, into which the vagina opens, and it is formed of two valves (Locusta, Pl. XXIV. f. 10—14.) I consider these two valves as the two lateral horny leaves mentioned above in the description of the orifice of the vagina, and which here are prolonged and now take the form of valves to that organ. The internal valves corresponding with the last abdominal segment become also visible, and here appear as the cover both above and below (f. 10. A, B,) at the base of the vagina bivalvis itself. All Orthoptera, consequently, have nine distinctly visible abdominal segments. In Locusta this vagina is long, sometimes indeed (Locus. viridissima) even longer than the body, each valve is gently sloped, and has a channel upon its exterior surface which projects internally as an elevated ridge. At the base it is covered beneath by the last deeply emarginate ventral segment, above it lies the anus, and contiguous to it two short, simple, spinous processes. Between the two larger valves there are two smaller ones (f. 12 and 14. b, b,) which are connected by a delicate membrane with the internal elevated ridge, and sometimes lose themselves in this or remain separated from it. Frequently the apex of the exterior vagina is split at the channel, when the exterior sheath appears, at least at its end, to consist of four pieces *. In Gryllus, instead of this projecting vagina we observe four short thick processes, the lower ones of which are moveable, and form one articulation with the superior ones that are closely attached to the abdominal cover. From the superior, stronger, thicker ones thus intimately connected two processes are continued within the abdomen, and to which are attached the muscles moving the lower ones; the orifice of the vagina lies between the lower ones, and the anus above the superior ones. We may make the following

* Kirby and Spence, Introd. to Ent., vol. iv. p. 152., mention six pieces, but I have never observed in our indigenous Locusts any but the structure described above, and never six divided pieces.
ANATOMY.

comparison between this organ and that of Locusta, the lower moveable processes are analogous to the two valves of the vagina bivalvis; the superior ones however to the spinous processes contiguous to the anus, but with this difference, that in Locusta these processes are articulated to the horny piece which bears them, and which lies between the orifice of the vagina and the anus; in Gryllus, on the contrary, the superior processes form an integral portion of that horny piece. Acheta agrees in structure with Locusta, but its vagina is more delicately constructed; the anal processes are longer, and at their apex apparently jointed.

The female Tipula have likewise a bivalve vagina which very much agrees in structure with that of Gryllus. In Ctenophora atrata, two pointed, long, and sabre-shaped processes originate above from the last dorsal plate, and bend from the sides towards each other, forming a bivalved vagina. They correspond to the superior immoveable processes of Gryllus or the moveable processes of Locusta. Beneath this last dorsal plate, and consequently between the valves, the anus is placed. A triangular fleshy process encompassed by a delicate horny margin separates it from the orifice of the vagina lying beneath it. It also has on each side two processes of the last ventral plate, which are above shorter, broader, inwardly arcuate, and gently bowed externally. These two valves form the true vagina, and therefore correspond to the inferior processes in Gryllus and the long vaginal valves in Locusta. In a state of repose they lie concealed between the superior or anal processes, and all four appear to form a bodkin-shaped process.

§ 145.

The terebra, or aculeus, is found in all the Hymenoptera and in the Cicadaria.

With respect to the aculeus of the Hymenoptera, although it has been occasionally tolerably well explained by the earliest entomologists, it has not always been recognised by modern ones, and therefore frequently imperfectly described. This fact is the more striking as it has actually nearly the same structure in its essential parts in all the families, and is merely subject to slight differences of form. For the present we will pass these over, and proceed to examine its essential parts.

The chief character in which the terebra is distinguished from the vagina bivalvis is the presence of a second pointed boring organ lying between the valves. This fuller development of it is not found in the
vagina bivalvis, but it is indicated in the shorter internal valves, which
in Locusta viridissima are united to the larger ones by membrane, but
in other instances they are found free and separate. The terebra
of the Tenthredos is an intermediate form; it, consequently, does
not pierce firm substances, but merely guides the eggs into already
existing cavities; but the aculeus forms the cavity itself for the egg;
pierces into bodies not firmer than itself, and as a defensive instrument
it wounds very severely. We may therefore distinguish the exterior
sheath (vagina aculei) and the inner sting (aculeus, seu terebra) as
the chief parts of this kind of ovipositor; we will first turn our atten-
tion to the sheath.

We have but little to say of the exterior sheath, for its differences
are unimportant. It always consists of two valves (Pl. XXIII. f. 6.
a, a), which are united by articulation with the dorsal plate of the last
abdominal segment, by which it is partially covered above; the ventral
plate then covers it from below. They are as long as the sting itself,
and lying together form a tube, in which the latter is completely con-
cealed. If the sting project beyond the apex of the abdomen they
accompany it. A thus projecting sting (aculeus exsertus) Latreille
calls a terebra. But when the sting lies concealed within the abdomen
(as for example, in the bees,) the valves are there also, and they embrace
the concealed sting (aculeus absconditus) precisely in the same way
as the exserted one. The exterior upper surface of the sheath is
generally rough and uneven, particularly in the projecting aculeus,
and entirely covered with short hair; the edges are simple, smooth,
and fit closely together.

The internal sting is differently formed according to the peculiarity
of its function.

In the Tenthredonodea it diverges most in form. In these it should
not properly be called a sting, but a saw, and indeed earlier entomologists
have compared it with this tool. It consists (Pl. XXIV. f. 8.), like
the sheath, of two valves (a, a, and b, b), between which at their base
there lies a short triangular process (c). Each internal valve has the
same form as the sheath enclosing it, but it is smaller, so that it can be
entirely embraced by it. The inferior edge of the inner valve is finely
toothed (Pl. XXIV. f. 9. a), very sharp and narrow, inwardly separ-
ated by a projecting line from the remaining very smooth surface of
the valve. The exterior has likewise a corresponding projecting ridge
(the same, b, b), which, like the ridge, is finely and sharply toothed;
raised lines run over the whole of this surface from tooth to tooth, and from the elevated ridge to the superior edge, which makes the whole exterior surface even, and gives it the appearance of a fine file. With this saw-like apparatus the Tentredo cuts the substance of leaves, letting an egg drop in, which is there developed that it may subsequently feed upon it. The short triangular process forms merely a key-stone to the margins, gaping at the base, and is of no importance to the function of the organ; but it is necessary to mention it, as it is of great consequence in the structure of the sting in the rest of the Hymenoptera.

If we examine the projecting sting of the Ichneumons, for example, Pimpla (Pl. XXIII. f. 12—14.), we first observe the two exterior valves, (f. 14. a, a,) and between them, a fine horny sting which is a little dilated at its extremity (f. 12.). This sting was long considered simple, and even Gravenhorst, in his monograph of the European Ichneumons, describes it so *. But it also is double; the upper part (f. 13. a, and 12. a,) is channelled beneath, completely smooth, and only at its broader point beset with small teeth; the lower (the same, b,) much finer portion is a hair-shaped very pointed bristle, which lies within the channel of the superior one; this also is broader in front and lancet-shaped, and fits into a cavity of the upper part of its own shape. There is thus a truly a passage in the aculeus, but so narrow an one that no egg can pass down it, and in this cavity how should it move along? The egg merely slides down the superior channel, and is secured and pushed on by the inferior bristle pressing against the channel from the base towards the apex, pushing the egg above it. But, to refer this structure back to that described in the saw-flies, we must conceive the two internal valves as united in the superior simple half tube, and the bristle as the elongation of the central process at the base of the valves.

Its structure is still more artificial in Sirex and the Bees. In Sirex (Pl. XXIII. fig. 5—11), in which the sting projects, we find likewise the exterior valves (a, a) and the central aculeus (b). This again consists of the superior channel (c, c,) and the bristle lying within it, which is here double. (d, d,) All three are dilated at their end (f. 7), the channel is split, and that portion as well as the bristle upon its entire

* Ichneumonologia Europaea, tom. i. p. 89. "Haec seta terebra est, et canali centrali longitudinali instructa esse dicitur, per quem ova poneruntur."
margin beset with short serrated teeth (f. 9 and 10). That the bee's sting is similarly formed, although it lies in the abdomen, is shown in Swammerdamm's figure*. Latreille cites the true aculeus in Sirex as double†, but personal investigation will readily convince of his error and the correctness of our representation. The spirally twisted aculeus of Cynips (Pl. XXIII. f. 15—18), according to the opinion of early entomologists, viz. of Roesel, differs in structure from that of the bee's only in that its apex, which is covered by valves beset with hair, projects above the abdomen. Its supposed spiral twisting consists in its base being somewhat bent; the point however somewhat sinks, so that it represents the figure of an S. (f. 16. a section; a, a, the valves; b, b, the two exterior setae lying in it; c, the central one).

The description of the aculeus of the Cicada still remains. Its form in C. Fraxini is as follows: the large triangular dorsal plate of the last abdominal segment (Pl. XXIV. f. 1. a.), which at its apex is bent down, covers from above the two double-jointed sheaths (the same, b. and c.). Both joints are connected together by a soft membrane; the basal joint (f. 2. b. b) is broader, shorter, and hollowed out; the last joint (the same, c. c.) is longer, narrower, towards its apex somewhat broader, triangular, within hollowed in a channel. This last joint is free, but the first is connected by a joint to the ventral plate. Between these lie the aculeus (the same, d.), a horny, round organ, a little dilated at its base, and near its apex compressed, where at the edge it is toothed; and this again consists of three horny ridges connected by soft membrane. A still larger one (f. 3, a, a, seen from beneath, f. 5 from above), broader in front, and there likewise toothed at the margin, lies above and forms the channel; two finer narrower ones, pointed at the apex (f. 3, b, b, from beneath, and f. 4 from above) lie in the preceding, and project beyond it at the end, forming its apex (the same, f. 2 n.). They all form combined a tube capable of distension, in which doubtless the eggs are pushed down by the valves themselves after the aculeus has pierced the vegetable substance, for which purpose evidently it is armed at its apex with the strong teeth.

This, therefore, is the structure of the ovipositor in the different groups of insects: in its investigation we have concluded our examination of the female sexual organs, and pass now on to the male organs.

* Biblia Natura, Pl. XVIII. f. 3.
We have already indicated that the male sexual organs consist essentially of the same parts as those of the female. They also are divided into interior and exterior; the former of which comprise the testes, vasa deferentia, vesica seminalis, and ductus ejaculatorius seminis; and the latter, the penis and the prehensile organ connected with it, and placed at the sexual orifice. We will therefore now proceed to the consideration of the internal male organs of generation.

A. Internal Organs of Generation.

§ 147.

The testes are glandular white bodies generally present in pairs, and which secrete the spermatic fluid. They regulate themselves in form and structure according to the differences presented by the glandular organs in insects in general, so that the majority are long convoluted vessels; some take the form of fasciculi of blind filaments, and a few lastingly appear as round glandular bags. Their structure is regulated by their exterior appearance. Vascular testes have, like all the glands of insects, two tunics; the internal loose mucous one displaying a parenchymatous appearance, the exterior one smooth, but coarser in structure, and corresponding with the exterior muscular membrane of all internal organs. Round testes have likewise a smooth coating, which enclose a multitude of small vesicular bags in the cavities of which the sperm is secreted.

As the testes are analogous to the female ovaries, we should conceive that they as well as the latter should stand in connection with the dorsal vessel; but this has not yet been detected, although many forms of testes extend in delicate filaments upwards which may apparently be the indication of such a communicating thread, as is the case in the ovaries. The analogous importance of both organs, which is most strongly proved by the progressive metamorphoses of insects, to which we shall subsequently return, is evinced also by the situation of the testes in the
abdomen, as they occupy precisely the same place possessed by the ovaries of the female, namely, the lateral spaces in the abdominal cavity contiguous to the intestinal canal, yet inclining more towards the venter. Those only which are united into one testis lie directly in the middle of the body immediately beneath the nutrimental canal.

With respect to their precise shape, having thus indicated their most general differences, and distinguished them as tubular or vesicular, they may be arranged under several chief forms with various subordinate differences, which the following classification endeavours to display.

I. Simple testes. The long testes which, in the early stages, are divided, approach more closely together in the progress of development, and, lastly, in the pupa state, unite into one single globular testis, (Pl. XXIX. f. 1.) the earlier separation of which is indicated by a ring upon its surface. Each of the hemispheres divided by this ring has its own peculiar duct, which unite afterwards together.

This structure of the testes is peculiar to all the diurnal, crepuscular, and nocturnal Lepidoptera, as well as the Pterophori; other moths (the Tinea) have them always separated. This testis consists, upon closer inspection, of a thick cellular mass, which is pierced everywhere by delicate ramifications of the tracheae.

II. Separated testes. The testes remain during the whole course of the insect’s life separated from each other, and lie on each side of the intestinal canal.

A. Simple vascular testes. Each testis is a simple filiform or wider vessel, which lies either extended at full length, or makes convolutions, but it sometimes is entangled in a hank.

1. Testiculi lineares (Pl. XXIX. f. 2.). They lie stretched out, and are wider than the ductus ejaculatorius into which they pass by means of a sudden constriction, and run upwards in a conical point. (Libellula.)

2. Testiculi clavati. (Pl. XXIX. f. 3.). Each testis is an obtuse club, which gradually contracts itself into the ductus ejaculatorius, and thus imperceptibly passes into it. (Cercopis, Tinea.)

3. Testiculi filiformes. (Pl. XXIX. f. 4.). The testis is a twisted filament, which lies wound up in the abdomen, and, before it passes into the duct, distends into a longitudinal sperm bladder. (b. Tipula.)

4. Testiculi spirales. (Pl. XXIX. f. 5.). They distinguish themselves from the preceding merely by each filiform testis being twisted
spirally, and originating in a superior free and very fine filament. (Rana tra.)

5. Testiculi furcati. (Pl. XXIX. f. 6.). The testis here is also a twisted canal, which furcates at its extremity and extends into two short capitate ends*. (Apis mellifica.)

6. Testiculi convoluti. (Pl. XXIX. f. 7.). The filiform testis is very long, much longer than the abdomen, and convoluted into sometimes a round (Dyticus), sometimes ovate (Calosoma) ball. (Carabodea Hydrocantharides.)

B. Compound vascular testes. Each testis is a bundle of shorter or longer filiform or filamentary blind vessels, or bags, which all unite into one common duct.

1. Testiculi scopacei. (Pl. XXIX. f. 8.). The short blind processes which the testes form, are of equal length, and sit close together upon the upper side of a common duct. (Hydrophilus.)

2. Testiculi fasciculati. (Pl. XXIX. f. 9.). The somewhat longer blind processes are tolerably equal in size, and are seated contiguously at one spot, namely, at the end of the funnel-shaped distended sperm duct. (Buprestis Trichodeax, Clerus, Epidydimis in Locusta, Pl. XXVIII. f. 5, a.)

3. Testiculi stellati. (Pl. XXIX. f. 14.). From the end of the simple sperm duct, short fine, star-shaped or radiating filaments originate. (Apatel.)

4. Testiculi flosculosii. (Pl. XXIX. f. 15.). The filaments at the end of the sperm duct are here short, distended bags, which are placed around the distension of the sperm duct, like the petals of a flower of the class Syngenesia. (Asida, Tenebrio, Edemera.)

5. Testiculi imbricati. (Pl. XXIX. f. 10.). Short purse-shaped, smooth pockets, which pass over each other like tiles, clothe a broad compressed bag, which runs out into a short, at first serpentine sperm duct. (Locusta viridissima.)

C. Compound vesicular testes. Each testis consists of oval or round and large or small vesicles, which unite either by degrees together, or at one end of the there distended sperm duct.

1. Testiculi racemosi. (Pl. XXIX. f. 11.). The bladders are


According to Swammerdamm, Biblia Natura, the testes are kidney-shaped bodies.
tolerably large, pear-shaped, and open by degrees, sometimes several together, into the common sperm duct. The lower bladders are larger and longer stalked. (Staphylinus.)

2. Testiculi granulati. (Pl. XXIX. f. 12 and 16.) The end of the sperm duct is dilated into a bladder, which is entirely covered with round, button-shaped blisters. (Blaps, Pimelia, Musca.)

3. Testiculi vesiculosi. (Pl. XXIX. f. 13.) The long testis consists of several rows of little bladders, which are placed around the extremity of the sperm duct. In Semblis there are three rows of such bladders present.

4. Testiculi vesiculoso-cirrati. (Pl. XXIX. f. 7 b.) The reflected end of the sperm duct bears several petiolated, larger, capitate bladders, and between these there are fasciculi of smaller, ramose vessels, the extreme ends of which originate from four delicate glandular bodies. (Silpha obscura, according to Leon Dufour.)

D. Capitate testes. The testis consists of several sometimes round or long kidney-shaped glands, which lie at the end of the common sperm duct, or each duct bears but one such glandular body.

1. Testiculi capitato-simplices. (Pl. XXIX. f. 17.) Each testis consists of a single, differently formed glandular body. In Lyttua and Meloe, this body is globose or uneven and granulated (f. 17); in Sialis, Phryganca, and Apis (according to Swammerdamm), it is kidney-shaped, and the duct opens at the spot where the kidney is emarginate.

2. Testiculi capitato-gemini. (Pl. XXIX. f. 18.) The sperm duct is furcate, and each branch bears a similar round glandular testis. Donacia and Callichroma have equal branches: in Lamia ædilis, the superior one is longer (f. 18).

3. Testiculi digitati. (Pl. XXX. f. 1.) At the end of the sperm duct there are five conical glandular bodies, which extend in long serpentine fine vessels. (Nepa.) This form is as it were intermediate between the capitate and vascular testes.

4. Testiculi capitato-compositi. (Pl. XXIX. f. 19 and 20.) The sperm duct gradually divides into several branches, each of which sends off one (Cetonia Prionus) or several capitate testes. (Lepisma Cicada.)

5. Testiculi capitato-verticillati. (Pl. XXX. f. 2.) Each testis consists of several globose frequently-compressed glandular bodies,
ANATOMY.

The epidydimis is likewise a glandular organ frequently formed upon the type of the true testes, and opens with a peculiar either narrower or wider duct into the common duct of the sexual organs. We find this organ in a few beetles only: its function also is not distinctly known; the few hitherto observed forms are the following.

We observe the epidydimis most distinctly in *Hydrophilus piceus* (Pl. XXX. f. 3). They are here two long oval pointed bodies, turned back about their centre, which contain within an exterior fine tense skin a second glandular one, forming many rather long and regularly successive little bags. Upon a first inspection, this body appears, from its narrow, contiguous and parallel bags, as a convoluted vessel, and as such Suckow erroneously explains it *. From this organ there originates a long broad bag, with at first a narrow but suddenly distending orifice, which appears to be formed like the trachea of a spiral filament, but, upon closer investigation, displays a structure similar to the epidydimis. It also consists of two membranes, of which the inner parenchymous mucous membrane likewise forms narrow, parallel bags, which I almost consider as the actual secreting cavities. In them we find a yellowish finely granulated liquid, the secretion of this epidydimis. Both these bags (Pl. XXX. f. 10. aa.aa.) open at the end of the common duct in front of the sperm bladder. (The same, a*.*a*.) They are somewhat longer, or certainly quite as long as the testes with the sperm duct, and extended they are of about the length of the abdomen, but they are usually rolled spirally. Similar appendages are found in *Lytta* and *Melolö*, but the epidydimis here is a serpentine, lace-shaped vessel, which, upon the ventral side, empties itself into the vesicular distended vessel, which, upon the ventral side, empties itself into the vesicular distended point of union of both the conical...
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In Trichodes, the epididymis is also a simple, very much convoluted vessel, without distension or appendages.

In Locusta and Gryllotalpa, the epididymis forms a convolution of vessels. In Gryllotalpa, each of the four thick testicular bodies appears to consist of one convoluted vessel. The superior one or epididymis is smaller, conical, and provided at the end with a long free filament; the lower true testis is larger and kidney-shaped. Both display upon their surface evident windings of vessels, which are surrounded by a darker mass. Their ducts unite beneath the large testis into a small sperm bladder, into which also the thick convoluted gluten vessel empties itself.

In Locusta, each epididymis consists of two divisions: the upper one (a.) is a fasciculus of long, snow-white convoluted vessels, which all unite by degrees into a tolerably large duct; the lower one (b.), on the contrary, is an oval bag, the superior surface of which sends off short round, tolerably narrow, filamentary processes. The sperm duct empties itself into the neck of the bag, but the duct of both bags, as well as the short one of the upper fasciculated epididymis, form likewise two short tubes, which speedily unite with the broad, almost bag-shaped ductus ejaculatorius. At this point of union, we find on each side a small round little bladder, which is the vesica seminalis.

These are the different forms of the hitherto observed epididymes; other vascular appendages of the male sexual organs we shall shortly investigate, and discern in them gluten organs.

§ 149.

THE VASA DEFERENTIA AND VESICA SEMINALIS.

The ducts which connect the testes with the common ductus ejaculatorius, are called vasa deferentia, or sperm ducts. They are fine tubes, originally of very small circumference, which either retain a uniform size, or distend in front of their orifice, and widen into an oval, long bladder. This distension is called the vesica seminalis or sperm bladder.

We can speak only of the number and length of the sperm ducts. With respect to their number, we observe where several testicular bodies are found. There are also at first several sperm ducts, all of which, either

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* See Brandt and Ratzeburg Arzeneithiere, vol. ii. Pl. XIX. f. 12 and 13, e. e.
† Suckow, as above, Pl. X. f. 5—7.
‡ Ibid. Pl. XII. f. 20.
by degrees or at one spot, unite into one common duct. The first case is found only in the compound capitate testes (T. cap. compositi), but universally here. Thus the twelve ducts of the twelve glandular bodies of Cetonia aurata unite by degrees to a common sperm duct; indeed some of them previously unite together before they empty themselves into the common duct. In *Prionus* (Pl. XXIX. f. 19.) the single ducts empty themselves alternately into the end of the common sperm duct; the same in Cicada, Latr., in which each branch bears several glands. The second connection of the sperm duct is peculiar to the verticillate testes: here all the single sperm ducts unite at the end of the common duct, consequently at one spot. It is similar in the double testes (T. cap. gemini), where consequently the sperm duct furcates at its extremity; the same in *Blaps*, where two equal branches are found, each bearing a testis, and then a third, longer originating from the fork, which, however, bears no testis. The length of the sperm ducts is subject to no less variety. They are short in all those instances where they do not exceed the length of the abdomen, and, consequently, make no convolutions, as for example, in Lucanus, Hydrophilus, Locusta, Callichroma, Libellula, Nepa, and, in general, where there are large testes; moderately long, that is, from twice to three times the length of the abdomen, they are found in those instances in which the different appendages we are about to describe are wanting, for example, in Semblis, Sialis, Phryganea, and Cercopis; long or very long in those testes which are smaller and composed of several bodies, or in general of a convoluted canal, for example, in *Dytcus*, in which they are about five times as long as the body, and, like the testes, convolute themselves into a small knot (Pl. XXIX. f. 7. b.); then in Necrophorus and *Blaps* eight or ten times as long; in Cicada, Lat. fourteen times as long; and in Cetonia aurata, nearly thirty times as long. A short but very broad and indeed gradually distending sperm duct is found in Meloë and Lyttia (Pl. XXIX. f. 17. b.), whilst in other cases it maintains a uniform compass.

The sperm bladder has generally a more muscular structure than the sperm duct. The size is proportionate to that of the testes, and is wholly wanting to the less compact sexual organs, where the narrow sperm duct passes into the common ductus ejaculatorius without any distension. It is wanting, for example, in the Carabodea and Hydrocantharides, in Lucanus, the Capricorn beetles, all *Lepidoptera*, Libellula, Cercopis, and several others; as a slight distension at the
end of the sperm duct, it appears in the Lamellicornia, in Semblis, Tipula; as a large ovate distension, at the end of the sperm duct in Hydrophilus (Pl. XXX. f. 10.) and Apis; as a peculiar appendage to the sperm duct, in Phryganea (Pl. XXX. f. 6. b.b.). In Lytta, Meloë, and many others, we find but one sperm bladder, which has originated from the union of both the sperm ducts; into this the lace-shaped epididymis then empties itself.

§ 150.

PECULIAR APPENDAGES.

We perceive appendages to the male organs similar to those glandular ones we noticed above in the female sexual organs. With respect to their peculiar purpose, we know certainly as little as of the true function of the vessels accessory to the female organs; but it is just as probable that here as there they are gluten secreting organs, and, consequently, glandular. That such appendages are not absolutely necessary, is proved by the circumstance, that, as in the female, so also in the male sexual organs, they are frequently entirely wanting, and that sometimes they correspond in both sexes, as in Musca, Donacia, Semblis; in other cases are found only in the female, as in Tipula, Ephemeræ, and Nepa; and in others again are found in the male alone, as in Pterophorus and Cercopis. This deficiency of them in one sex, when present in the other, speaks against the opinion of Suckow*, according to whom they secrete urine; for this would necessarily be peculiar to both sexes, but which does not invalidate their being gluten secreting vessels of the sexual organs, which in general in male individuals are much more numerous, and are of a different form and situation to those found in the female. These appendages are also found where urinary organs show themselves, as in the Carabodea and Hydrocantharides. Comp. § 114.

If we more closely investigate the number and the form of these appendages, their first and most important character is their almost symmetrical situation and equal number. Tipula and Blatta only, as far as our knowledge extends, make an exception to this rule; as in Tipula (Pl. XXX. f. 14.), according to Suckow, an uneven clavate process is found at the point of union of both sperm ducts, which, according to all analogy, can be explained only as a gluten organ,

particularly as in many other insects the same part appears in a similar form. In *Blatta*, according to Gaede*, there is a large bladder at this precise spot.

The symmetrical gluten organs are, in the first place, double, and, indeed, short clavate processes, which, at the point of connection of the sperm duct, empty themselves into the ductus ejaculatorius. We thus find them in *Sialis, Ephemera, Lepisma, Nepa, Apis* (Pl. XXX. f. 8.), and *Piophila casei*, Meig., in which, however, the clavate bag has a lateral pocket. In the *Carabodea* and *Hydrocantharides*, it appears longer, indeed as long as the abdomen, proportionately narrower, and already making some windings. In the former, at least in *Calosoma sycophanta*, each bag is flat, somewhat depressed from its apex, spirally convoluted, and into it, shortly before its termination, the sperm duct empties itself (Pl. XXX. f. 13.); in *Dyticus*, on the contrary, it is round, irregular, twisted, and with its opponent, as well as with the sperm duct, it is bound together. Still longer, and, consequently, more twisted, but otherwise uniform, they appear in *Gryllotalpa*, where they are at least twice the length of the short testes; in *Stratiomys*, it is once and a half as long as the testes and the sperm duct; in *Tinea*, equally long, but narrow and filiform. In all these cases, they unite with the sperm duct at one spot, to form a common ductus ejaculatorius. Longer than the testes, but likewise thin, narrow, and filiform, we find them in the *Lepidoptera*: here, consequently, they make several turnings, and then empty themselves in the sperm duct itself, a short space before its union with the ductus ejaculatorius. (Pl. XXX. f. 12.) The *Lamellicornia* possess the longest. They here appear as two long narrow, much convoluted filiform vessels (Pl. XXX. f. 9. b.), which, towards their base, distend into a long oval occasionally broad bladder (*Melolontha*), which, together with the sperm duct, passes into the common duct at one spot. The length of this vessel is sometimes considerable; for example, in *Oryctes nasicornis*, about twenty times as long as the body, but in *Cicada*, Lat., where we observe similar vessels only five times as long.

The ramose is the last form of the single-paired gluten organs. We have already observed such in the female appendages in *Elater* and *Hippobosca*; among those of the males, we find them in the Capricorn beetles. In *Callichroma moschatum*, I found a thick tangle...

* Beiträge zur Anatomie der Insekten, p. 20.
of very fine vessels, which, upon opening the insect, was covered by the
dorsal portion of the posterior end of the intestinal canal. Upon closer
inspection I found that all these vessels were merely the branches of a
main stem that was furcated, which was the case also with each branch,
and I thus found eight successive furcations. The terminal ends I could
not distinctly perceive, but they are probably loose. In Lamia oedilis,
at least, where only one furcated vessel is found on each side, the
branches are free, but unequal, the exterior one being shorter, and the
interior longer, the stem emptying itself into the sperm duct (Pl. XXX,
f. 11.); and it is the same in Callichroma moschatum.

Where there are two pairs of appendages, they display the same
forms. In Aesclaphus Italicus they are, according to Hegetschweiler,
four unequal, pear-shaped bladders, which empty themselves into the
sperm duct: the smaller ones have besides a superior vascular
appendage. According to Posselt*, two pairs of vascular appendages
are found in Geotrupes stercorarius; to Hegetschweiler, in Clerus
alvearius; to Gade, in Tenbrico molitor; and also in Blaps mortisaga,
Meloë and Lytta, in which they are short, but of unequal length, and
one pair empties itself upon the upper surface, and the other pair upon
the under surface, into the sperm bladder†. In Hydrophilus, there
are also two pairs of unequal appendages; the inner ones are shorter
but broader, the exterior ones longer, and they furcate into two equal
branches: both empty themselves between the sperm ducts, the testes,
and the epididimis, into the end of the common ductus ejaculatorius.
(Pl. XXX. f. 10. b. 5. and bb. bb.).

In Notonecta glauca there are even four pairs of equal vascular
appendages; and in Buprestis mariana, according to Gade‡, there
are two pairs of vesicular ones and two pairs of vascular ones together.
One pair of the first is very small, the other longer, clavate, and bent:
also one pair of the vessels is bag-shaped, and the other filiform and
tolerably long. All unite at one spot in the ductus ejaculatorius, into
which also the sperm ducts, but at some little distance further back-
wards, empty themselves.

* Beiträge zur Anatomie der Insekten, Pt. 1. f. 16.
ANATOMY.

§ 151.

DUCTUS EJACULATORIUS.

The ductus ejaculatorius seminis is that tube which extends from the point of union of both sperm ducts or sperm bladders to the commencement of the penis. It displays in its structure coarser muscular fibres, and is of a more compact nature than the sperm duct. It is analogous to the egg canal of the female organs, and appears sometimes, like this, vesicular (Hydrometis), and sometimes contracted by degrees, consequently clavate (Lucanus, Lytta), sometimes simple and of equal width. In length it varies much, sometimes short, scarcely visible, yet broad (Locusta, Gryllotalpa), sometimes longer, but yet, in proportion to the other internal sexual organs, still short (Calosoma, Melolontha, Trichius); moderately long when it attains about the same length as the sperm ducts (Hydrophilus, Lytta, Meloë, Papilio); long, lastly, when it is longer, indeed considerably than the sperm ducts (Lucanus, Lamia). The most remarkable form of the ductus ejaculatorius I observed in Lamia cedils. In this it is about eight times as long as each sperm duct, and geniculated. But to display this remarkable structure most justly, I must extend my description to that of the entire sexual apparatus.

If a male Lamia cedils be opened from its back, we first observe in the centre the convoluted intestine, and contiguous to it, on each side, about the centre of the lateral space, two white testes. Both unite into a narrow sperm canal, which runs towards the anus, and there unites itself with the opposite one of the other side, after each has received a furcated gluten gland. After a short course in a direct line, the ductus ejaculatorius bends forward, runs in a serpentine direction up the central line as far as the abdominal nervous cord, but beneath the intestinal canal, as far as the thorax, and here again bends a second time, turning upon itself like a knot, it then runs back again in a gentle curve to the anus, there to pass into the penis. From its first bend, this duct is no longer free, but it is enclosed in a wider membranous tube, into which also pass eight delicate tracheae, the fine ramifications of which spread upon the duct, and accompany it as far as the second bend, after they having one after the other previously dispersed themselves in fine branches. But from its second bend, the ductus ejaculatorius is accompanied by a strong horny ridge, which lies in the superior portion of the enclosing tube, retaining it tensely distended, and which terminates only where it passes
into the penis. In the other capricorn beetles (for example, *Callichromia moschatum,* the ductus ejaculatorius is indeed much shorter, but likewise twice geniculated. That portion from the point of connection to the first knee is wider, more vesicular, and transversely ridged, taking the place of the sperm bladder, which is wanting, to the equally wide sperm ducts; the other, double as long but much narrower portion, bends forwards as far as the commencement of the sperm bladder, re-bends back to the anus, and then passes into the penis, having reached the spot of its first geniculation. The penis, or rather its exterior case, is united to this first knee by means of a muscle.

We are as yet unacquainted with other remarkable or peculiar forms.

B. EXTERNAL ORGANS OF GENERATION.

§ 152.

THE PENIS.

Having already perceived a great variety of form in the female external organs of generation, we might expect to find this still more extensively the case in the male organs, had their parts been as widely investigated and described. But that which does not invite close inspection by its exterior or the problematical nature of its form, but much rather withdraws itself from the eye of the inquirer, and is concealed upon a first superficial examination, does not so easily excite curiosity and stimulate the desire for instruction, because it is not supposed to exist. This is the reason why the structure of the penis has been made less frequently the subject of description than the female ovipositor, although possibly there is no other so variously formed an organ, nor one subjected to such characteristic and generic differences.

The penis of beetles consists essentially of two parts, namely, of the exterior horny case analogous to the bone in the penis of the dog, and the internal delicate membranous penis itself, which admits of being considered the free ductus ejaculatorius. The exterior sheath alone is visible upon a first examination, as it entirely covers the internal tube and allows it only at its apex, where it is divided a little, to project. This sheath is clothed, either entirely or partially, by a delicate membrane (the preputium), which may be considered as a continuation of the inner membrane forming the cloaca. This membrane has also sometimes horny ridges to support it. Thus much upon the penis in general; more will
be derived from the following particular description of it in individual insects.

In *Carabus* (*C. glabrat us*, Fabr., Pl. XXV. f. 1—4.), in which the withdrawn penis extends to the commencement of the thorax, the preputium extends only to the end of the fourth segment (the last connate one counted as two); it is wide, bag-shaped, truncated at its extremity, and is supported by two fine bones, which have the same shape as the bag. At the base both bones lie closely together, but they with their shanks so separate that the two shanks of the upper one pass to the upper valve of the cloaca, and those of the lower one to its lower valve. The basal portion of the penis projects beyond the upper portion of the bag, driving this before it, so that it is covered by a continuation of it. Besides, the sides of the bones stand in close connection with the exterior integument by means of muscles, which hold the prepuce back when the penis is pushed forward. Three horny pieces are also found in the case of the bag, one heart-shaped one beneath, exactly between the shanks of the bone, and the two others at the apex of the upper portion which clothes the free part of the penis. There are likewise bony processes which support the case of the produced part of the bag, and stand in flexible connection with the horny sheath of the penis. The apex of the produced portion of the bag is divided where the upper end of the penis lies, and through this aperture the ductus ejaculatorius seminis passes into the latter.

The penis itself is a gently bent, horny cylinder, above round, distended towards its end, and flattened with obliquely truncated extremities; upon its lower or ventral side it has a longitudinal aperture, which is surrounded by a callous margin, which indicates the outlet of the ductus ejaculatorius.

*Dyticus* (Pl. XXV. f. 5—10.) displays already important differences. The two valves which form the cloaca are much larger, the upper one is soft and ovoate, the lower one harder, larger, and longitudinally divided into two lobes. Both lobes are placed upon a transverse horny piece, one wing of which encompasses the exterior margin of each lobe, and is bound to it as well as to the ventral plate by strong muscles. The prepuce of the penis lies between these two valves, which, as in *Carabus*, is a membranous bag, but the horny bones of which are differently formed, and display stronger muscular connections. The prepuce itself is held distended by two horny pieces. A broad horny arch, shaped to the bag, surrounds its whole circumference, but lies
lower down, so that the withdrawn penis projects beyond it; the upper margin of this horny arch is somewhat reflected, and forms two processes, to which muscles are attached that assist to push the penis forward (Pl. XXV. f. 7. a, a). The second flat longitudinal horny piece lies in the lower part of the bag between the shanks of the arch (Pl. XXV. f. 6. b). If the prepuce be opened we first meet with the horny sheath of the penis, a bilobate organ gently bent from right to left, between the valves of which lies a similarly bent and pointed horny spine. Both valves are closely connected by membranes and muscles, and are themselves enclosed in a membranous sheath (Pl. XXV. f. 9. a.), which is withdrawn by means of a fine horny bone flattened at its end; it so lies between the prepuce and the penis that it retains the skin when the muscles push the penis forward. The valves of the penis are thickly beset, upon the bowed inner margin, with long setae, which are placed in a close row, as is also the inner spine. This spine has, similarly to the above-described female ovipositor, an excavated channel, in which lies a fine lancet-shaped bristle; both are connected together by means of flexible skin and muscles, and between the bristle and the channel is the outlet of the ductus ejaculatorius. This spine therefore is the true penis, and the two valves are its case.

The penis of *Hydrophilus* (Pl. XXV. f. 11—14.) approaches very closely in many particulars to that of *Dyticus*. The prepuce here also is a truncated bag, from the upper surface of which the penis projects. In the lower part of the bag lies a broad, shovel-shaped, horny plate, from the margins of which on each side a bone originates, which form the lateral limits of the bag; upon the upper side, at the end, lies a triangular perforated valve, which forms also the superior valve of the anal aperture, and sends off two free lateral processes to the bone of the lower portion (c, c). The cloaca penetrates beneath this valve, and is separated from the penis merely by a fold of the prepuce. The penis itself consists of the bivalved sheath and the unequal spines lying between them. Upon the inferior side the valve borders upon a heart-shaped horny plate (o), which appears to form the support of the entire organ; its lateral margins turn upwards, and a coarse skin is attached to it, which closes the canal of the penis from above. The valves (e, e) of the penis itself are pointed downwards, they are bent, concave, horny bones, which are internally filled by membrane and muscles, which unite to them the central spine of the penis. The most central spine (l. f.) is not bivalved, as in *Dyticus*, but a perfectly closed tube, at the
under surface of which runs a narrow spatel-shaped horny bone, and there is a hair-shaped one at its superior surface; the aperture (x) is enclosed by two small horny arches.

In Melolontha the penis is only half covered by the prepuce; its case is posteriorly, particularly upon the upper surface, entirely horny, and distended like a bladder; two processes originate from it, which are nearly conical, somewhat sloping, and furnished anteriorly with a knob; these are contiguous beneath, and above they are united by a strong membrane: between them lies the membranous canal of the penis, which consists of several folds of the ductus ejaculatorius *.

In Callickroma moschatum the prepuce is a thin cylindrical bag, which in front is obliquely truncated, and it terminates above with a triangular horny plate. At each of its lateral angles a bone originates, which inclining forwards proceeds beneath to unite itself there with the corresponding one of the other side, forming a perfectly horse-shoe-shaped arch. The case of the penis, which is similarly shaped, lies entirely enclosed within this prepuce; it is likewise more membranous, but terminates in front with two horny valves, the broader and lower one of which entirely embraces the narrower superior one upon the lateral margin, and sends forward two flat processes into the skin of the case. The membranous canal of the penis lies within this case, as a continuation of the ductus ejaculatorius (Pl. XXVI. f. 1 and 2.).

Among the Orthoptera we find in Blatta the penis perfectly unsymmetrical. The sexual organs are only visible upon the removal of the dorsal plate, for they lie concealed between the two last ventral plates, and are protected on each side by the short, jointed processes; we then observe a triangular irregular valve (Pl. XXVI. f. 17, 18. a), which covers the passage to the sexual aperture from above, and contiguously, two other, likewise unequal, bags (the same, b and c), which protect the sides, and lastly, beneath, a hook bent upwards obliquely over these parts (the same, d, d). Upon closer examination the superior valve displays itself as a triangular membranous lobe supported by several horny pieces, at the anterior apex of which there is placed a stiff horny hook, which is curved backwards (Pl. XXVI. f. 5). The inferior valve, standing opposite to this superior one, is a flat horny plate (f. 6. a), with which laterally the right dorsal valve which bends upwards (f. 6. b) is united by means of a flexible membrane. The yet remain-

* See Straus, as above, Pl. III. f. 5., Pl. V. f. 1—3., and Pl. VI. f. 1.
ing portion of the visible sexual organs is the penis (f. 7), consisting of a superior sheath formed by two horny pieces, which are united by a membrane (f. 7. a,) and the central unequal upwardly bent spine, which is furnished at its extremity with a barb (f. 7. b.).

The comparison of this organ with that described in the Coleoptera has therefore now no further difficulty; the superior and inferior valves are the case of the penis, here indeed entirely transformed, which is united by the withdrawn prepuce to the surrounding parts; the penis itself lies formed in it, at least in situation, just as we have described it in Dyticus and Hydrophilus.

In the Hymenoptera I shall first describe the penis of the saw-flies. When in a Cimex the last ventral and dorsal plates are removed, upon the dorsal side we immediately meet with the flexible anal valve, beneath which the anus lies, and then with a fold of the prepuce, which separates the anus from the sexual organs. These are entirely enveloped in the membranous prepuce, and consist of two large hooked horny bodies, which are united at their base by a flexible membrane; between these likewise lie the bivalved flexible penis, in which, precisely as in the female saw-flies, the central bone is wanting. The particular form of each single joint is shown in the figures 8—10. of Plate XXVI. The exterior valve consists of two joints (f. 8 and 10. a, b), the upper one of which is small, triangular, somewhat arched, and membranous; the lower one is larger, and consists of strong horn. Between these lie the broad lobate valves surrounded by a horny ring (f. 8 and 10. c, c), from which the canal of the penis (f. 10. d.) is continued.

In Vespa, where we find almost the same parts, we immediately detect an important difference, which is, that the central unequal spine of the penis, or here rather the true penis itself, is present. Figures 11—13. of Pl. XXVI. show the male organs of Vespa Germanica. Two large round valves, to which above there is attached a small spinous process, form, as in Cimex, the exterior case of the penis (f. 11. a, a). Between these exterior ones the inner ones lie (the same, b, b); these are smaller and more delicate organs, which embrace the penis, they are of the consistence of parchment, and distended at their end into a shovel shape. The penis itself is a delicate bent shovel, which, previous to its dilatation, is provided with two barbs (f. 13. a, a), and has upon its superior side a deep almost tubular channel, through which the semen is ejected.
The male organs of the Lepidoptera (for example, of Deilephila Euphorbia, Pl. XXVI. f. 14—17.) display two exterior horny valves densely covered with scales; these valves are attached to a projecting horny ridge upon the circumference of the sexual organs (f. 14 a, a). Beneath these exterior valves there are two interior finer, pergamentaceous, and delicately haired ones, which, as well as the exterior ones, correspond together at their internal margin, and on their external margin they stand free. Each runs upwards in a sharp fine hook, and has beneath also, contiguously to it, a membranous process, which partially covers the penis (fig. 15. displays this inner valve from the inside). The penis lies between these inner valves; it is a pergamentaceous somewhat bent tube, which is open and emarginate in front (f. 15 and 17.). Upon the upper side, opposite the valves, there is a strong, bent, conical hook, which has anteriorly two points, an exterior one which bends inwards, and an interior one which bends outwards, and between the points a conical membranous process projects, which is also perforated (f. 14. c), and forms the anal tube. Both organs, the former internal valves supplied with a hook, and these hooks standing opposed to it, serve, without doubt, to retain the female organs during copulation.

The male sexual organs of the Diptera have, in the majority of cases, been noticed and figured by Meigen in his monograph of this order*; we can therefore give a more comprehensive description of them than of the preceding ones.

We everywhere find exterior, and even often interior valves, and between these the penis. The chief difference of this order is, that the male sexual organs in most instances project beyond the apex of the abdomen, and lie there exposed, which was not observed in the former ones. We thence find the prepuce, or rather that membranous bag which contains the withdrawn organs to be wanting in the Diptera. The differences of the exterior valves is very great. In the family of the Tipularia I formerly described a new insect (Nematocera nubeculosa), which was distinguished by large projecting sexual organs†. Two thick, large, black, shining processes, each of which bears a small bright brown reflected appendage, form the exterior valves, and be-

* J. W. Meigen's Systematische Beschreibung der bekannten Europäischen, zweiflüglichen Insekten, 6. B. mit Kupfern, 1818—32.
tween them lies the short tubular penis. A very similar structure is observed in the predacious flies, particularly *Laphria* and *Asilus*, yet the large cylinder is bound by membranes to the ventral side, in which shape it forms an actual bivalved sheath, and the exterior superior smaller appendage is wanting. The sexual organs are most striking in the *Empidodea* and *Dolichopodea*. In the former we observe at the last abdominal segment of the male two large orbicular sloping valves, which are fringed at their margin; between their lower edges there is a long, fine, upward bending bristle, which frequently lies completely concealed between the valves. This bristle, in which we detect above a fine channel, I consider as the penis, and the valves as its case. In the *Dolichopodea* the last segment of the abdomen, turned downwards towards the venter, forms the case, which is exteriorly convex but interiorly concave. The upper free space of this cavity is occupied by a horny bristle, which is so united by membrane to the case that it can open and shut its aperture. In the thus formed cavity of the capsule the penis lies. In front, attached to the capsule, there are two bent, thickly fringed lamellae, completely resembling those of *Nematocera*. I am almost induced to consider them as the projecting inner valves, but they evidently serve as retaining organs. The anal aperture appears to lie at the base of these valves.

In the true flies (*Musca*, for example,) the sexual organs are placed at the ventral portion of the last abdominal segment, the ring of which is hook-shaped, and by this curve covers the organs in repose; contiguous to the apex of the hook there are two moveable, differently formed valves, the analogues of the exterior valves in *Dolichopus*, and in front lies the anal aperture; further towards the venter, about the middle of the hook, we find the sexual organs, likewise two either longer or shorter bent lobes, between which a simple, thicker, sometimes clavate process (the penis) is displayed. Occasionally we find, contiguously to the larger ones, two small triangular valves, which may be considered as the inner valves of the penis.

Among the *Hemiptera*, we discover in *Cercopis sanguinolenta*, both in the male and in the female, two valves at the apex of the abdomen, of which those of the male are considerably the smallest; when opened, we find at the base, between the exterior valves (Pl. XXVI. f. 18.), two smaller internal ones (f. 19. a, a), which are attached by articulation to two horny bones. Between these the penis rises, and is, like the ovipositor, a long, thin, setiform organ, which is not however, as in
the female, bent from below upwards, but from above downwards, so
that its apex is turned towards the venter. This point is broader than
the upper part, and apparently armed with barbs; consequently, during
copulation this spine of the penis must penetrate the ovipositor of the
female if impregnation is to follow. This insertion, however, is only
made possible by the hook-shaped bend of the penis, and much facili-
tated when the male sits upon the female. The _Cicada_ actually thus
copulate, but as their connection lasts long, and the constant weight of
the male would be oppressive to the female, the male descends by her side, when she reposes. In some genera of the _Cicada_, the
pronotum of which is decorated with processes and excrescences, which
project beyond the abdomen (_Combophora, Centrotus_), the first act of
copulation can only take place in this position of both sexes by the side
of each other, they have probably therefore a laterally bent penis for
this purpose, thus adapted like the downward bent one of the pre-
ceeding.

We must lastly notice the male sexual organs of the _Libellulae_, as
the erroneous opinion has long been held that they were not placed at
the end of the abdomen, but at its base. This very naturally ori-
ginated from the observation that the male flew about with the female,
retaining her anal extremity by means of clasps affixed to the base of
the abdomen, and at the same time held her in the neck by the valves
of its tail, apparently occupied in copulation. But if we closely exa-
mine the economy of these insects we shall speedily observe that males
fly at sitting females and rapidly copulate with them, like the flies.
The preceding is merely an expression of mutual inclination which
announces itself by the male suddenly seizing the female by the neck
in the air, and thus flying off with her, whilst she, if willing to respond
to this attention, bends up her anal end to the male, and allows herself
to be there seized by the hooks lying at the base of the abdomen; but
if not pleased with his caresses she does not bend her body up to him,
but hangs it freely and unparticipant downwards, and remains like a
prisoner attached to his chain.

The following is an accurate description of the male sexual organs,
as well as of the prehensile organ at the base of the abdomen.

We observe in the ventral plate of the ninth abdominal segment an
aperture closed by two valves (Pl. XI. No. 3. f. 9. d). If these valves
are removed we detect a small, delicate, horny ring, which surrounds
the aperture of a short membranous cylinder; this cylinder is the penis,
and the anterior aperture the extremity of the ductus ejaculatorius. Hence the structure of the external sexual organ is as simple as that of the internal ones (comp. § 147. II. a. 1).

The prehensile organ which lies in the ventral plates of the second and third abdominal segments has, on the contrary, the following very complicated structure. In the first place it consists of three divisions (the same, 4 and 5. A, B, C), the two first of which are placed upon the second abdominal segment, which apparently, at least laterally, consists of two rings; the third forms the ventral plate of the third abdominal segment. The foremost division (the same, f. 8.) consists of six horned pieces, two anterior triangular smaller ones (a, a'), to which two broad, thin, sithe-shaped hooks, which are bent backwards, are attached (c, c'), and the two posterior ones (b, b'), which are harder and more horned, and distend about the middle of the upper edge into two dentate knobs. At d the anterior and posterior parts are jointed together (f. 5. represents them extended, f. 8. as bent), and in the centre, between the two pieces of the two sides, there remains a deep unoccupied cavity (f. 4). The second division (f. 4 and 5. n. and f. 7.) consists of two pieces. The larger basal piece, or the ventral plate of the second division of the second abdominal segment, is quadrate, provided at each angle with a small process, which unites it with the preceding and succeeding pieces. Its central surface is deeply excavated, but it rises on each side to a strong obtuse point directed forwards (f. 7. a), the posterior edge of which is thickly beset with bristles. Between the two points, consequently in the concave central groove, the second piece lies, which is a geniculated, strong, horned hook (f. 7. b); it is united to the first by a joint, and can, by means of muscles, be directed upwards or withdrawn within the groove. The third division (f. 4 and 5. c. f. 6.) is larger than the preceding, and appears as a bellied, anteriorly concave, horned knob (f. 6. a), which is entirely filled with muscles. These muscles serve to move the anterior hook-shaped appendage, which again consists of two parts, the large, bellied, double-pointed hook (f. 6. b'), and the thin, cylindrical, double-jointed pedicle (f. 6. c, c'); this hook, in repose, lies in the anterior excavation of the horned bladder (f. 6. d'), but when raised it stands free upon the two-jointed pedicle. A long, thick, pointed, horned bone proceeds backwards from the horned bladder, and it is this which forms the ventral plate of the third abdominal segment (f. 4 and 5. c, e, c).

But this entire prehensile organ is only seen when the reflected
margins of the dorsal plate are bent backwards; it is therefore entirely covered in dry specimens by these margins. Males may be detected in dry specimens by their above thick and clavate abdomen and the larger anal fangs.

III. Development of the Sexual Organs during the Metamorphosis.

§ 153.

It is evident, from Herold's* admirable investigation, that even in the larva the germ of the future sexual organ exists, and indeed with the distinctions of male and female. The larvae are born with these extremely small and almost invisible germs, which develope themselves in the course of its life, but most rapidly in its pupa state, until they attain their perfect development upon the full growth of the insect.

If a caterpillar be opened from the back we observe, after the removal of the fatty substance, upon the intestinal canal, at the posterior extremity of the large stomach, two small roundish or ovate bodies, from which posteriorly two filaments originate, which unite into one canal close to the anus, beneath the rectum. But these filaments are so fine, or become so in their progress, that they almost entirely disappear, and could not be followed to their termination by even the exact Lyonnet. If several larvae, of different sizes and of different ages, be opened, we soon detect differences in these bodies, for some (in *Pontia brassicae*) are more cylindrical, and are divided by constrictions into four successive vesicles; the others are flatter, subsequently ovate, and by constrictions from the apex to the base divided into four equal lobes. In the first instance they were small testes, and in the last the preformed egg-bags or ovaries. This form remains unchanged until the pupa state, merely increasing considerably in size.

In the pupa state the convoluted sperm ducts, and in the female the gluten glands and ovaries, gradually develope themselves. In *Pontia Brassicae*, upon which insect Herold made his observations, the testes gradually approach each other until they lie contiguously. From this common situation a closer connection is formed, the sides press each other flat, and by degrees intimately join together. Thus, from the earlier separate four-chambered testes a simple globose testis is formed,

* Entwickelungsgeschichte der Schmetterlinge. Kapel and Marburg, 1815, 4to. with plates.
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which, however, probably still consists of two divisions. From the two hemispheres two delicate canals originate, which, after many convolutions, unite into a thicker but frequently twisted duct; closely in front of this point of union there hangs attached to the sperm duct a simple, long, twisted vessel, the gluten gland. The development of the female organs displays itself most conspicuously in the enlargement of the ovaries. They increase at the expense of the egg canal, which by degrees disappears, whereas the egg bags become continually longer, and twist themselves up spirally from the apex. The point of union of the very short oviducts distends, and sends off on one side a pointed bag, the spermatheca; opposite this a smaller vesicle is formed with a longer, vascular, much twisted appendage: farther below, near the vagina, there hang also vascular, long, and much convoluted gluten glands. Both distend prior to their emptying themselves, and perforate the vagina at one spot close to each other.

This is an abbreviation of the description of all the changes made during the pupa state. In the caterpillar there were simple bodies with simple delicate canals, these pass over unchanged in form into the pupa, and undergo by degrees changes the results of which are the lastly completed structure which we have here briefly indicated.

It is to be regretted that similar observations have not been made in several insects, and although they would probably present the same results, many attractive details worthy of observation might be produced. This refers particularly to insects with an imperfect metamorphosis. We may ask does the transformation of the sexual organs take the same course, and the bodies present at the birth of the larva merely enlarge, and only when the pupa displays the rudiments of wings undergo a general change of form? If we refer to the development of the intestinal canal, which has, from the commencement, its perfect form, we might feel inclined to adopt the same view of the sexual organs: we must confess that this view appears the most natural, because in insects with an imperfect metamorphosis the pupa state appears to be of infinitely less importance, and that consequently the changes in structure cannot be so great as there where the pupa sleep steps in so abruptly between the preceding and succeeding active periods. And may not possibly the lesser degree of importance which the pupa state possesses in insects with an imperfect metamorphosis be the consequence of their smaller change in the form and structure of their organs? Could not, therefore, as the change of the internal organs
is significantly less, and is indeed limited almost to the mere enlargement of the parts with their retained relative proportions, the change also of the exterior form almost entirely disappear, and the whole metamorphosis be restricted to a mere increase of size? Truly both phenomena are dependent upon the same law, neither eventually conditionates the other, but must proceed from the similar results of one cause, which evidently lies deeply concealed in the mode of development of the Articulata in general, so that where the one displays itself the other must also be present and both synchronous, neither the latter before the former nor the former before the latter.

IV. Conformity of the Female and Male Sexual Organs.

§ 154.

At their origin both kinds of sexual organs, as we have seen above, appear under the same form. This same conformity, displayed at the origin of the internal parts, is also subsequently verified in their fully developed state. This law we laid down at first (§ 131), for both systems have the same object, viz. the elaboration of the productive fluid. In the female it is the ovaries where this fluid is prepared, and in the male we call the same organ the testes. Very similar ducts originate from these organs, and afterwards unite and conduct by a single narrower canal their contents outwards. This conformity of importance in the internal parts is still more strongly proved by their forms frequently agreeing. Long cylindrical testes correspond with long ovaries filled with the germs of eggs (Libellula); ramose bunched testes with similarly formed fasciculated ovaries (Locusta, Gryllotalpa); compound, radiating, and united testes with similar radiating or twirling ovaries (Lamellicornia); indeed, sometimes the number of the single bodies in the testes agrees with the number of the egg tubes (Melolontha, Trichius). It is very natural that the appendages should be differently formed, for their function is different; for example, the spermatheca of the female organs must necessarily be wanting in the male, for they receive no sperm, but only impart it: consequently the reciprocal conformity of the internal organs is so evident, that it is difficult to doubt it; but this is not the case with the exterior organs. In these no endeavour has yet been made to trace the parts of the one in the other sex. But if the descriptions be compared which we have given of the male and
female external organs, it will escape no one that this analogy is not to be overlooked even here. The female vagina in every case consists as well as the male penis of horny bones and ridges, which are united together by a flexible membrane. If these horny bones project beyond the abdomen they form the aculeus, or ovipositor, which has in its entire structure the most striking resemblance to the penis. Exterior valves enclose in both organs an internal compound instrument, which is, as in the grasshoppers, where we observe the ovipositor, either con¬nate with the exterior valve, or it remains separated, as in the bees, wasps, and other *Hymenoptera*. If the structure of such a sting be compared, for example, with the penis of *Dyticus*, we observe, even to their smallest parts, the greatest conformity; indeed, even the male sexual organs of the wasp agree both in number and situation of the individual parts wholly with the sting of the female. Henceforward, therefore, it may not appear hazardous to assert that the ovipositor, by its conformity in structure with the penis, is analogous to the clitoris of the superior animals. This view, which as far as I know is here propounded for the first time, may be liable to many objections, particularly by those who do not pass beyond forms, nor elevate themselves to general simplifying and retrogressive ideas; but they who study natural bodies in conjunction with others furnished merely as orismo¬logical auxiliaries, and who are not merely acquainted with ten thou¬sand species, but endeavour also to discover the general results of their various vital phenomena, will here discover a not wholly unimportant contribution to the solution of this great problem.

We have above shown that the jointed ovipositor is no peculiar organ belonging only to the sexual ones, but rather the mere apex of the abdomen; its divaricating in form therefore cannot be cited as a proof against the opinion that the ovipositor is a transformed clitoris.