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Second section.
SECOND SECTION.

ANATOMY.

§ 86.

The examination of the exterior form of the body is succeeded by the investigation of its internal construction. This branch of natural science is distinguished by the name of Anatomy (derived from ἀνατείμνειν, to cut up); but the portion of it which treats of the interior structure of insects might be appropriately called Entomotomy (derived from ἐντο-μος, insect, and τίμνειν, to cut).

As it was not our object in the preceding chapter to explain the mode whereby the different parts of the body stand mutually connected, but which combination and connection is of importance to the formation of the complex organism we have already examined externally, it is therefore incumbent upon us, in this section, to display the fundamental parts, or, as it were, the keys of this entire organism, and what the different materials are which must necessarily unite to constitute the organic body we have just treated of. The information which will be conveyed in this section will consequently be richer in its results towards a knowledge of the life of insects in general, as it will materially tend to show how far the differences of form are influenced by differences of structure, and what their mutual relations are. We shall nevertheless restrict ourselves, even in this section, to a mere description of forms, but principally of the internal parts, and consequently of their structure, reserving the reply to all questions upon the importance of each individual organ, its function, and sphere of action, to the next ensuing section.

But, before we pass on to the contemplation of these new objects, a few general remarks will not be inapposite to determine the natural succession of the investigations we are about to institute.
Experience has instructed us that every organism is not only transitory in its duration, but that it also requires the assimilation of fresh matter, if it is to be preserved from perishing immediately after its appearance. To meet this necessity nature has furnished every organic body with two different sets of organs, which are called systems, the one of which provides for the preservation of the individual by means of nutriment, and is thence called the Nutrimental System, and the other for the continuance of its resemblance, or kind, and which is called the reproductive System. Both systems, therefore, are the essential peculiarity of every organic body, and without them no organism can be imagined.

§ 88.

Indeed, the very lowest organic bodies, plants, display no other organs than such as belong to these two systems; but the animal destined to a higher grade of organisation adds to the phenomena of vegetable life two new proofs of its vitality, and which must be treated as the results of a greater freedom of nature. This liberty displays itself at once in its independence of its original place of abode, by the power it possesses of constantly changing it; in fact, the power of locomotion is the first and principal peculiarity of the animal, and this power also qualifies the second phenomenon peculiar to animal life. If, namely, the animal is to make an advantageous use of the freedom it derives from its power of locomotion, and if it be to be secured against all the disadvantages consequent upon this power, it must necessarily possess faculties which apprise it of the nature of its situation, and these it has received in the organs of sensation. Both, consequently, the organs of locomotion and sensation, are peculiar to the animal, and wholly wanting to the plant, whilst the organs of nutriment and re-production are common to both.

§ 89.

And as the organs of nutriment and re-production are first observed in the plant, and as the whole vegetable kingdom displays no higher development of life, they are distinguished as vegetative organs, and their circle of action the vegetative sphere. Whereas the organs of locomotion and sensation, as the exclusive peculiarities of the animal,
have received the name of ANIMAL ORGANS, and their compass of action the ANIMAL SPHERE.

§ 90.

The greater development or separation into several distinct organs, and the more complex structure of each, are the phenomena gradually displayed in the progressive ennoblement of the animal kingdom, commencing at the most simple conditions of animal existence. Insects maintain in every respect a central situation in this series; their organs, therefore, will not display to us a very artificial structure, nor will their combination be very complex. But we shall find the above indicated four chief differences, which are dependent upon the vital phenomena of the organism, sufficiently distinctly exhibited in them. Now, as the several organs of each individual system not only aim at one object in their functions, but also display considerable conformity in their structure, it will be suitable to regulate the arrangement of our present investigation by their differences, whence we derive the following themes:—

I. Investigation of the vegetative system and its organs. These are,

A. The organs of nutriment, consisting of—
   a. The **intestinal canal** with its appendages, as digestive organs;
   b. The **heart and blood vessels**, as organs of circulation;
   c. The **air vessels**, as respiratory organs.

B. The organs of re-production; consisting of—
   a. The **female organs of re-production**, and
   b. The **male organs**.

II. Investigation of the animal system and its organs.

A. Organs of locomotion:—
   a. Passive organs of motion; here the **exterior integument** as analogous to the osseous system.
   b. Active organs, the **muscles**.

B. Organs of sensation:—
   a. The **brain**;
   b. The **nervous system** in general;
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 flocks of, 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 gastral glands (glandula gastricae). 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 Verdaunungswerkzeuge der Insecten Halle, 1811. Pl. XIV. f. 4, from *Pomipulius 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 cæcum, the proventriculus, the stomach or ventriculus, the duodenum, the ilium, the cæcum, 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 pentamerous Coleoptera, after which the cæcum 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 grass-hoppers and cockroaches, in which, in consequence of their large mandibles, the cavity of their mouth is very expansible, 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

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*Ramdohr, ib. Pl. 1. f. 9.*
distinguish the proper membrane between them as a separate layer. A free space is naturally not found, as in the stomach.

THE ŒSOPHAGUS.

§ 102.

The Œsophagus (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 Œsophagus is doubtless its very general furcated 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 Œsophagus 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 these 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 Œsophagus 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 Œsophagus, 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 Œsophagus 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 Œsophagus; 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.
Meloe, 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 (inguivas, Pl. XVIII. f. 1. b, b,) 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 prepar ing 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-Inseckten, Germain's Magaz. iii. p. 200.
flavours 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 suckorial, 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 suckorial 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 Tenthrados 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.
§ Treviranus, Pl. IX. v, v.
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 *Rhinchophora*, the *Orthoptera*, (with the exception of the *Phasmea* 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 scaleshaped 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.
cular 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.

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

constreictions. 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 Acherontia 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. b) 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 esophagus 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. n) 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. n) 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 Athericeræ, have peculiar, glandular,
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 caecum 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 Ephemerae: 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 larva 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

* Bombylius, 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, Callrichroma 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 Rhynchoptera, many of which even possess the proventriculus and the before-mentioned flocks, (for ex., Cryptorrhynchos Lapathii), the Vesicifosa (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 internal mucous membrane of the stomach, and

† Rumohr, Pl. XI. f. 1.
pass through the exterior muscular membrane, the filaments of which it pushes on one side. They doubtlessly consist of secrerning organs, whose secretion makes more soluble the heavily digestible animal matter. These flocks are found in the Cicindelacea, the Carabodea, the Hydrocantharides, the Brachyptera, the Peltodea, the Melanosoma, and the Helopodea.

The stomach of the majority of the Orthoptera is still more artificially 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 membrane. 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.) lengthened above and below, each of which opened into the stomach by an oval aperture (the same A, A, A,) and thin tubes, which lay convoluted 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 (p), 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 (d *) 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 (d **, 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 (d *** ) is 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, Nau- coris), 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. d **) it is of the same length as the second, but of less breadth, while the second (d *) 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 (d), so that the transmission of the food describes a complete circle in the three

* Ramdohr, Pl. XXII. f. 8.
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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 gastral 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 edulis)*, 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 edulis,) 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 iliun (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

* Ramdohr, Pl. IX. f. 6.
† Ib., Pl. V. f. 1.
‡ Ib., Pl. IV. f. 2.
§ Ib., Pl. XV. f. 4.
|| Ib., Pl. XXV. f. 5.
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 Chrysmelina, 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 larvæ, 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 Libellulae and
Ephemeræ. There are no fixed laws which regulate the length of the
ilium, but Ramdohr has endeavoured to show its most prevalent pro-
portions 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 larvæ, 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 larvæ 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 Ramdolir, 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 larvæ of these beetles (Pl. XX. f. 1. e); 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 externally 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

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the true ilium, which is however contradicted by its function, which, like that of the cecum 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 sack-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 horn}'y 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 horn}'y 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

* Vermischte Schriften, vol. ii. p. 105. PI. XII. f. 3.
† In Houselier Zeitschr. f. d. Org. Ph., vol. iii. PI. 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 o, q). 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 cæcum 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 (Melolomia, &c.) with analogous organs, as the clavate and thick intestine. The cæcum is represented in the Carabodea by the broad sack-shaped colon. The long cæcum 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 (vasa biliferâ, (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 Meloë,) 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 Lygaeus apterus. Other differences in the mode of their evacuating themselves are not rare. In the flies (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 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 (Myrmecoleon). 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 organs of nutrition.

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 larva 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 epidiymis in Hyrdophilus) 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. XXII. 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 Cryptorrhynchus 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, Mycetmus, Mordella, &c. I have found them of the above form among the Orthoptera, in Locusta, and Gryllus, and among the Dictyoptera in Termes. Among the Neuroptera, Hemerobius and Phryganca 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 viscous 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

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* Suckow's Physiol. Unternich. uber Insecten und Krustenthiere, p. 28. Pl. VII. f. 32. a.
† Ib. p. 29. Pl. II. f. 1—10. b. h.
‡ Ramohr, 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 proboscidial 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

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

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 METAMORPHOSIS.

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 Dictyoptera, 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,
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 larvæ 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 *Cara¬bodea* 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 Dutochet, 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 *Lamellico¬rnia*, 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
THE ORGANS OF DIGESTION.

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
nutritamental 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—Dürckheim 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. n.) 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

† Entdeckung eines einfachen, vom Herzen aus blechsenfigen Kreislaufes 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. p. 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 odilis). 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.
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 cribriform, 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 divergences 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 exerts 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 larvae. 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. I. 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. (Acrydium, 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 setae 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 rufipes} and \textit{P. hamorrhoidalis}) depressions only at these parts; but if the acute posterior margin of the prothorax, 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 Scolia. 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

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* Introduction to Entomol., vol. iv. letter xxxviii.
† Insectenbelustigungen, 2 band. Wasserinsecten der 2 classe, Taf. II. and III.
‡ Heusing, Zeitschr. für die Org. Physick. 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 (*Dytcus*). 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 setae, 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-

thorax (Pl. III. f. 4). 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 Culicidæ. A similar structure is found in the larvae of Stratiomus; 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 setæ, 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 annelids, and were called Branchiurus. See Oken's Zoologie, I band, s. 233. Taf. 9., and Viviani Phosphor. Maris, 3. 13, 14.
‡ See Swammerdamm, Bibliä Nature, 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 larvae which live in water and are unprovided with branchiae. With respect to the larvae of the Diptera, those yet investigated have their spiracles in that situation: for example, the flies and Estridae. The larvae of the water-beetles likewise (for example, Dyticus 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 BRANCHIA.—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 trachea. 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 branchia 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 branchiae 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 branchia is the most usual and general; it is found particularly in the larvae and pupæ of the gnats.

The lamellate branchiae 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 larvae 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

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§ De Geer, ib. Pl. XVI. f. 3.
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 tracheæ; they transpire the membrane of the colon, and hang as thick fasciculi within the cavity of this organ *. As the creature imbibles 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 *Phryganoidea* and the *Sembloida*, 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 tracheæ ramify, protected by two rows of setæ †.

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 pupæ 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 Haeus. 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 Botys stratios-talis 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 tracheæ are observed in them as glittering silver-white threads. The caterpillar lives constantly in the water upon the leaves of Stratios-tetes 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 TRACHEÆ, 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 larve 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 tracheae of insects.

The innermost third membrane, which Lyonnct, Marcel de Serres, and Straus-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

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*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 tracheæ, 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 tracheæ stand in close connexion together. Between these two communicating tracheæ 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 tracheæ 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 mandibular 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 oesophagus into the head, and distributes itself to the lower lying muscles, the maxillae, 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

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 *Hydraphilus 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 *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

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† Mém. du Muséum, 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 larvae 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, 6.
ramose or arterial vessels, so that the tubular main stem is less insulated. Precisely the same structure is exhibited in the larvae 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 Oestridae, 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 trachee 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 larvae, 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

organs. 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 tracheæ 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 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.
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 Sphinxes and Phalæae, 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.

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
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 oviduct, 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. 185

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 vesticipa*, 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 Pterorrhous, with three tubes, each containing about twelve eggs); and the Hymenoptera, (for example, Chrysis, with three tubes, each with three eggs; the same in Xylo-copa; 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,

and Notonecta have six tubes, each with from five to six eggs; *Vespa vulgaris* and *Silpha atrata* seven tubes; *Tenebrio, Leptura, Saperdula, Blatta, Ascalaphus, 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; *Blaps mariana* twenty; *Blaps moritisaga* 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 (*Semblis*). 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 filamental, 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 germ, shorter, on the contrary, in larger ones rich in germ; 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. Lf. 2.
FEMALE ORGANS OF GENERATION.

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 the same 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
to the spermatheca, yet in the instances named above not, but into the spermatheca itself. It is somewhat similar in *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* in *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 *Carabus*, *Harpatlus*, *Melolontha*, *Lucanus*, *Meloe*, *Spondyla*, *Sirex*, *Apis*, *Xylocopa*, *Tinea*, *Pterophorus*, and *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 *Melolontha* (Pl. XXVII. f. 16. a), *Lucanus*, *Spondyla*, and *Cercopis* it is a short-necked pear-shaped bladder; in *Pterophorus* the same, but a short blind bag springs from it laterally; in *Xylocopa* (Pl. XXVII. f. 17. a), *Apis*, and *Tinea* it has a longer very narrow neck; in *Trichius* a superior vascular appendage; in *Sirex* (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 *Meloe* 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 *Trichius*, *Tinea*, and *Cercopis*, there is a clavate one found in *Melolontha*, and a vesicular one furnished with a short neck in *Meloe*. In *Xylocopa* it is a long gradually decreasing bag, which discharges itself by a very

* Compare German's Magaz., vol. iv. p. 281. Pl. II. f. 3. c. f. fig. 4 and 5.
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 furcating, 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 (*Gastrophuga 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 *Noctuæ*. A bladder-shaped, one-sided, sometimes long and clavate, or distended

* Bib. Naturæ, Pl. XLIII. f. 8,
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 Urtnce 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 (Pompilus*), 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-

pulous ruscoronis), 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 horny 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
dry specimens, to have precisely the same structure, only that in these, as well as in the flies, each ring has its horny covering, which are connected together by membranous parts.

§ 144.

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 Locusta any but the structure described above, and never six divided pieces.
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 immovable 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 (*e*). 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 sepa-
rated 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 *Tenthredo* 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 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

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*Ichnemonologia Europaea*, tom. i. p. 89. "Haec seta teretia 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 Swammerdam'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 setæ 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 doubtlessly 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.

II. OF THE MALE ORGANS OF GENERATION.

§ 146.

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.

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. (*Ranatra.*)

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 Trichodes, 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. (*Apate.*)

4. Testiculi flosculosi. (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, Ædemera.*)

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

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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 Lyttus and Meloe, this body is globose or uneven and granulated (f. 17.); in Sialis, Phryganea, 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,
concave in the centre, each of which has its peculiar duct. All the ducts are of equal length, and unite at one and the same spot to a common sperm duct. The number of glandular bodies varies: we find six in Melolontha vulgaris and Oryctes nasicornis, nine in Trichius fasciatus, and twelve in Tr. nobilis, on each side. This form appears to be the most complete of all, whence it is peculiar to the beetles only.

§ 148.

**THE EPIDYDIMIS.**

The epidyd simis 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 epidyd simis 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 epidyd simis. 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 epidyd simis. 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 epidyd simis 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

sperm ducts. 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 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 Arzeneitherie, vol. ii. Pl. XIX. f. 12 and 13. e. e.
† Stuckow, 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 Dyticus, 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 Lytta (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 Phryganæa (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 epidydèmis 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 Carabidea 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

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* 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 furcate, 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 ocellata, at least, where only one furcate 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 Ascalaphus 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 albivarius; to Gade, in Tenebrio molitor; and also in Blaps mortisaga, Meloe 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 epidydims, into the end of the common ductus ejaculatorius (Pl. XXX, f. 10. b. b. 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 backwards, empty themselves.

* Beiträge zur Anatomie der Insekten, Pt. 1. f. 16.
§ 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 (Hydrophilus), 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 so than the sperm ducts (Lucanus, Lamia). The most remarkable form of the ductus ejaculatorius I observed in Lamia edulis. 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 edulis 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 tracheæ, 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, *Callichroma 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 prepuce 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 ovate, 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 (f, 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 Callichroma 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.
ANATOMY.

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, peregmentaceous, 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 peregmentaceous 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 Europaischen, zweiffälig- ligen 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 lamellæ, 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 facilitated 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 and sits 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 preceding.

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 originated 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 examine 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 unpaticipant 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 horny 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 horny, 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, horny 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, horny 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 horny bladder (f. 6. d), but when raised it stands free upon the two-jointed pedicle. A long, thick, pointed, horny bone proceeds backwards from the horny bladder, and it is this which forms the ventral plate of the third abdominal segment (f. 4 and 5. c. e, 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 larvæ 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 larvæ, 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.
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 synchronical, 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 (*Libellulae*); 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. External 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 oris¬mological 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.
SECOND SUBSECTION.

THE ANIMAL ORGANS.

§ 155.

The animal organs forming the systems of sensation and of motion no longer display a vegetable, but strictly a peculiar, purely animal character. We have before seen (§ 91.) that the intestinal canal, the vessels, and the sexual organs are mere repetitions of vegetable structure, in as far as they consist, like plants, of cells, tubes, and thin membranes. But we will now show that these aboriginal forms of structure are not found in the animal organs.

§ 156.

The characteristic of the animal organs is rigidity and solidity. The entire organ is throughout of one structure, and consists of one substance, which, indeed, still frequently is encircled and enveloped by vegetable forms, as for example, the nerves by thin membranes, but these constitute no essential component of the peculiar mass, but serve only as its exterior case or covering.

If we examine the muscular system with this view we detect solid fibres, which lie closely contiguous to each other, forming by degrees larger bundles, that unite into an entire muscle. Even the nicest microscopical investigation detects no cavity in the individual fibres, but a solid uniform mass throughout. Each solitary fibre therefore is entire in itself, which, indeed, upon close examination, appears divided by transverse partitions, and thus seems composed of cells, but in fact it is not so. But we therein see the difference between the vegetable and animal organs, the former growing into an individual organ from the aggregation of consecutive vesicles or cells, and the latter from the union of solid globules. The animal organs, therefore, originate in the following manner; it is not cells added to cells, but globules, animal atoms, as some naturalists express themselves, to globules; a row of such globules form a solid fibre, several fibres the bundle, and several of these a muscle or nervous cord.
§ 157.

The nerves consist of filaments formed of consecutive globules, which are enclosed by delicate membranes, the nervous sheath (neurilema). These globules are originally very loosely connected, and the nervous filament then appears as a delicate tube, which encloses a finely granulated papy mass. The first commencement of the nerves is found thus formed, as well in the embryo of the superior animals, as also in all the inferior ones; and whilst the latter constantly retain this original grade of organisation, the nervous cord in the former works itself on in the progress of development to a firm filament. Several of such little filaments form the thicker nervous thread, and several of these the nervous cord. Where such threads or cords anastomose, meet, or cross each other, the nervous mass distends and forms knots or ganglions. That which we call the brain (cerebrum), which lies in the head, is the largest and most perfect of these ganglia, and indeed composed of various other smaller ones, and in its most perfect state of organisation it is even furnished with internal cavities. It is there first found where a head is first distinctly separated from the body. In all animals without a head there is no brain, but their nerves originate from a nervous ring encompassing the pharynx, which here represents the central organ of the nervous system, whilst the brain, where it is developed, gradually draws this ring to it.

THIRD CHAPTER.

OF THE ORGANS OF MOTION.

§ 158.

The organs of motion fall into two different sub-systems, namely, the active or muscles, and the passive. The passive organs of motion are, according to the different groups, subject to great changes, and only in the higher grades of animal development do they become a
distinct system, namely, as bones, whereas beneath the grade of the *Vertebrata*, they by degrees disappear, and only here and there, for example, in the *Sepia*, the *Echinus*, and some of the *Mollusca*, viz. the *Terebratula*, we observe more or less important precursory formations. In general, in the *Invertebrata*, the exterior integument supplies the place of the passive organs of motion, and this is especially the case in the *Articulata*. In the *Crustacea* and *Insecta*, by their solidity in the latter, and their quantity of calcareous matter in the former, they imitate the structure of the true bones, and send off processes into the cavities they form, which serve for the insertion of muscles, and in every respect appear as a skeleton removed to the exterior. As such we shall also consider and describe them. But it must nevertheless not be overlooked, that the integument, as a continuation of the intestinal canal, and, as it were, a re-fold of it, belongs properly to the vegetative organs, and will in its structure present us with many accordances with it.

I. Of the Horny Skeleton.

§ 159.

The exterior of insects displays itself to us as a horny case, which is sometimes firm and brittle, and sometimes soft and flexible, and in this last consistence it takes the appearance of a leathery skin. This case acquires its greatest consistency and strength in the beetles, especially in their elytra, which wholly consist of it: we find it very soft and thoroughly membranous in many of the *Diptera*, in most of the parasitic insects, and in almost all larvae, particularly in the orders with an imperfect metamorphosis. Also at first, when the developed head quits the pupa case, the horny integument is in all equally soft, flexible, thicker and more fleshy, and even colourless; but after a few hours it attains firmness, and gradually hardens in the course of a few days to a rigid coat of mail, in which the insect is clothed. This change of the integument takes place chiefly under the influence of the solar light; the colours particularly are brought out by its impulse. For as plants which grow in the dark take a pale or light yellow colour, insects also retain this their original colour as long as they are withheld from the effects of the light of the sun. Thence also is it that the majority of larvae which live in the earth, or in dark shady places to which the light of day cannot approach, are generally pale or colourless, and it is
thence also that even perfect insects remain paler if they cannot, immediately after quitting the pupa case, get into the light. From the same cause the many pale yellow and particularly red-legged varieties proceeds which we find in vast numbers of truly black or dark brown insects. We must not, however, wholly attribute the darker colouring solely to the effect of light; the increase of the pigment during the development contributes much to it; indeed in some, namely, such insects whose legs remain of a bright red whilst the remainder of their body is entirely coloured, it may be caused by the original deficiency of the pigment. The effect, nevertheless, of the solar light is incontestable, particularly in the colouring of larvae, for they are always variegated, when from the very commencement of their life they have been exposed to the influence of light, as is the case, for example, in the caterpillars of the Lepidoptera. Also, from variegated or coloured larvae, beautiful insects appear to proceed, whereas, from dull-coloured ones, or pale or brown, and more or less uniform coloured ones, brown or black insects. But the influence of climate is great upon colour, and, as is the case in birds, we find the most beautiful and gayest colours in tropical climates, whereas, the farther they recede from the equator, the darker or blacker they become.

§ 160.

In structure, the horny case displays considerable conformity with the skin in general, as it, like the latter, consists of three layers.

The exterior and finest layer, the epidermis, is smooth, shining, and without any traces of texture. It admits of being pretty easily separated from the coloured mucous rete lying beneath it, particularly in recently developed insects which have been preserved in spirits of wine, and is, in the majority of cases, colourless, sometimes, too, even brown, and but rarely black, if the mucous layer be black. Uncoloured, as it is in general, it is transparent and perforated all over with small holes, through which hairs rise when the surface is hirsute.

Beneath this delicate epidermis we find the soft rete mucosum. According to Straus it consists of two layers, of which the superior smooth one is closely attached to the epidermis, and this alone appears coloured. It is here we find the cause of the glittering, brilliant colours with which many insects are so beautifully decorated. In the butterflies and many others, namely, those with membranous wings,
it is brown or black, as also in all black insects. The variegated colours of these do not therefore proceed from the rete mucosum, but from the hairs clothing the surface. In spirits of wine it readily dissolves, and thereby distinguishes itself from the second layer, which is not affected by this fluid, and is uniformly black or brown *. This second layer is always covered by the first, and participates no otherwise in the colouring than by its darkness or depth adding to the intensity of the colour above it. In bright yellow, red, or white-coloured spots, it passes over naturally into this lighter colour.

The third and thickest layer of the general integument, the true leathery tunic (corium), betrays itself by its want of colour and peculiar structure. It consists, namely, of several layers of crossing fibres, which form a light web, which, upon a careful investigation, again admit of separating into several stratifications. Straus sometimes distinguished three, at others five, such strata. In the elytra of beetles (for example, *Dyticus, Hydrophilus*), there are delicate canals between these layers, in which the formative juice seems to flow, when the still small and short elytra of a just-developed beetle distend themselves; it is also in this leathery skin that the bulbs lie which surround the roots of the hair. It is from this skin that the roots of the hair derive their nutriment. A perforated point, many of which are displayed upon the surface of a multitude of insects, is a partial deficiency of this leathery skin. The epidermis and mucous rete consequently sink down, and thus a hollow is formed upon the surface. At the same time, the sinking of the harder epidermis forms a point to which the layers of the corium are attached; thence is it that the points stand generally in rows between two fibres of the corium, for example, the three rows of punctures in the large water beetles. (*Dyticus marginalis, &c.*)

§ 161.

We must consider the spines, hairs, and scales which cover the surface of many insects, as portions of the integument, and, as it were, partially separated parts. All three are like the horny substances of the higher animals, for example, the claws and nails, not processes of

* According to Straus, p. 16. But if the brightly-coloured layer dissolves in spirits of wine, how is it that so many insects, namely, the blue metallic or aequous ones, retain their colour in this fluid, and only some red or yellow ones lose it?
all three layers of the integument, but merely of the epidermis: they are thickenings, and also often folds of this cuticle, between which a coloured mucous has inserted itself. The corium is wholly wanting in these excrescences. They are divided according to their form, and the mode of their connection with the integument, into three different groups.

1. **Spines** differ from the following kinds by their wanting a true root. They are therefore nothing else than pointed, spinous, conical or hair-shaped processes, which rise from the surface, and correspond with it in colour and clothing. As a clear proof that they are mere processes of the epidermis, or, when they appear more bossed (as in the great horns of the Lamellicornia), that they are true elevations of the entire integument, is evinced by the circumstance that they produce a hole in the horny substance exactly of their own dimensions when broken off. These spines are not always simple, they are frequently ramose, furcated, &c., as is observed in many of the caterpillars of the butterflies.

2. **Hairs** are distinguished from spines in the first place by their greater fineness and lesser compass, in combination with their proportionately greater length, and again by the root by which they are attached to the true skin. The hairs themselves are fine horny cylinders, which frequently split and divide themselves like feathers, and send off branches, thus acquiring a resemblance to the feathers of birds. In general, they are largest in compass at their centre, and become narrower towards both ends: the lower one is somewhat puffed out, and has a small knob which sticks in the corium like a bulb in the earth, and this is surrounded by a thin shell, exactly as is the case in the large beard bristles of the mammalia.

3. The **scales** are properly flattened hairs: this is shown not only by their gradual transition from linear to lanceolate and spatulate forms, but also their exactly similar connection with the integument. Each scale, namely, has a small pedicle, at the end of which the knobby root is placed, and this with its sheath is inserted in the skin. The scale itself is either round, pointed, forked, toothed like a saw in front, and provided with longitudinal furrows upon its superficies. Even this delicate and sometimes extremely fine membranous excrescence consists of two layers of the epidermis, between which the pigment has inserted itself. In the iridescent butterflies (Apatura Iris, A. Ilia, Papilio Adonis, Menelaus, &c.), the scales of the wings
play into a multitude of shades of colour, which proceeds, according to Roesel *, from their peculiar structure. For whilst the surface of the scales in the majority is flat, there are in these sharp parallel ridges just as if small prisms were affixed to their surface. These prisms are all upon one side of a metallic blue, and on the other side brown, and thus according to the position of the butterfly or of the observer, either the brown or blue side is seen †.

§ 162.

With respect to the chemical composition of the common integument, it agrees in general with that of horn, but nevertheless distinguishes itself by some peculiarities of proportion, which may probably arise from its being formed, by not merely the epidermis alone, but by the entire cutis.

All true horny substances consist essentially of azote (10. 2—12. 3), carbon (43. 0—53. 7), hydrogen (7. 3—2. 8), and oxygen (29. 3—31. 2). In nitric acid it is dissolved, as also in a heated solution of potass or natron; muriatic acid, on the contrary, is coloured only by degrees. Boiling water somewhat distends horn, but a continued boiling in closed vessels (Papin's digester) will nearly entirely dissolve it. Dry distillation develops ammonia in combination with carbonic acid, as well as other hydrocarbonates, and a peculiar stinking oil, besides which other burnt matter remains which is no further changeable.

The horny case of insects has as externally, a uniform consistency, so also internally, the same constituents; but it nevertheless distinguishes itself by the admixture of a peculiar substance, viz. chitine or entomeilin, as well as by small portions of phosphate of lime and magnesia. The peculiar character of chitine is its insolubility in caustic potass. Exhibited separately, which is very easy by means of treating horny parts in a solution of potass, it appears as an almost colourless transparent substance, which becomes brown in nitric acid, and in the dry distillation produces no carbonate of ammonia, and therefore appears to contain no azote, and it burns in fire

† This supposition of Roesel's is erroneous; the change of colour arises from the reflection of the light, the same as in the buds of the Iris. The scales are merely longitudinally striated.—Author's MS. Note.
without previously melting, but it is soluble in boiling or heated sulphuric acid.

Besides the above, small portions of albumen, a peculiar brown colouring matter which dissolves in caustic potass, but not in boiling alcohol, as well as traces of phosphate of iron, have been found in the horny integument of insects, upon different analyses. The albumen belongs doubtless to the third tunic, as does the brown colouring matter to the mucous rete: to this also we attribute the chitine, whereby the true horny skin, namely, the epidermis, will be found to agree entirely with the horns of the higher animals.*

§ 163.

After this general inspection of the horny skeleton, we arrive at the different parts of which it is composed. As we have already, in the first section, in stating the orismological definitions of the insect body, sufficiently exhibited its structure and explained its composition of different pieces, we may here proceed more briefly, and merely add the description of those parts which escape the observer upon an exterior orismological examination. It will suffice then to repeat that the entire body of the insect consists of HEAD, THORAX, ABDOMEN, and the limbs, namely, SIX FEET and TWO OR FOUR WINGS.

The head exhibits itself as a single horny bladder with an anterior and posterior aperture. The anterior one is closed by the cibarial organs, and by the posterior one it stands in connection with that of the thorax.

The thorax consists of three divisions. The first or PROTHORAX has two or four horny plates; the DORSAL PLATE (pronotum); the BREAST PLATE (prosternum), and the SHOULDERS PLATES (omia).

The second or MESOTHORAX exhibits four, six, or seven plates. The simple DORSAL PLATE (mesonotum); the sometimes simple, sometimes divided BREAST PLATE (mesosternum), and the two, also sometimes simple, or likewise divided SHOULDER PLATES (scapulae). In many orders (Diptera, Hymenoptera), the three or six last are connate, and form ONE RING.

The third or METATHORAX has, like the middle one, either two,  

four, six, or seven different plates. Above, in the centre, is the third dorsal plate (metanotum); opposite to it on the breast, the simple or divided third breast plate (metasternum); between the two, the side plates (pleura), and auxiliary side plates (parapleura), sometimes separated, or either united together, or with the pectoral plates.

This is the result of the investigations there instituted upon the thorax: it now remains for us to inspect the cavities formed by these plates, from the interior; perhaps, also, from this point of view we may discover some peculiarities.

§ 164.

INTERNAL SKELETON OF THE HEAD.

In the Hemiptera and Diptera, the head is a mere horny bladder without any internal processes or bones for the insertion of muscles. The same is the case in the head of the Lepidoptera, but the occipital aperture is divided by a transverse bar into two holes, the under one of which is the smallest, and admits only the nervous cord through it; through the upper one pass the pharynx, vessels, tracheae, and muscles. These parts are not found in the Hymenoptera, but, on the contrary, a broad ridge springing upwards from the lower margin of the occipital aperture, which is prolonged towards the frons in two points, and divides the upper portion of the head from the under. The Libellulæ among the Neuroptera exhibit the former division of the occipital aperture into an upper and under one; they have also several ledges in the head, which spring from the anterior margins of the eyes, and divide the large eyes from the brain, and this again from the frons. In the Orthoptera, we again find the separation of the aperture into an upper and under one. On each side, contiguous to that cavity, there springs a process; both unite in an arch, forming a narrow cover, which is attached in front to the frons by means of two other processes. I call this cover the tentorium, because, as in the higher animals, for example, Felis, beneath it lies the cerebellum of insects, or the second ganglion of the nervous system, from which the mandibular and labial nerves originate. Over it runs the pharynx, and above it lies the first ganglion or the cerebrum. In the cavity of the head of beetles we do not find the tentorium in the shape just described, but as two high ledges originating from the throat and the
lower margin of the occipital aperture, between which lies the cerebellum, and it is covered only by the pharynx. Sometimes (Dyticus) the pharynx rests upon a bar, connecting both ledges, and then the cerebellum lies beneath it, and further forward, but the nervous cord runs between the ledges. Contiguous to the occipital aperture two small hooks spring from the ledge, which encompass the nervous cord, and other longer fine branches of them project forwards towards the front, which they do not reach, but bend upwards, and serve for the insertion of small muscles, which retain the pharynx, running between these branches. This frame-work is larger or smaller according to the development of the cibarial apparatus, consequently most distinct in the predaceous beetles with large oral organs.

§ 165.

INTERNAL SKELETON OF THE THORAX.

In the structure of the thorax, the Hemiptera, Orthoptera, Neuroptera, and Coleoptera accord better together, from their prothorax being more distinctly separated than in the other orders, in which the entire thorax forms but one whole. This last structure is certainly the most simple, and we will therefore commence with its inspection.

Upon paying some attention in the examination of the thorax of a fly, bee, or butterfly, the important preponderance of the mesothorax cannot escape immediate observation. The central dorsal plate occupies the entire dorsal surface, whereas the anterior one forms but a ring (collar), and the posterior one also is not much more developed, and, indeed, in flies and butterflies is entirely covered by the scutellum, (compare Pl. XIV. No. 1. f. 2. and No. 2. f. 2.).

The internal skeleton of this simple thorax is very unimportant in the Diptera. Where we observe furrows on the exterior there are internal ridges which correspond, and which surround the muscles at their insertion, and separate them from each other. Audouin calls those projecting ridges, which are also generally found where two separate parts join together, Apodemes, Apodemata, and those to which muscles are attached Apodemata insertionis. The largest of all these ridges is Kirby and Spence's Metaphragma, a thin, pterous partition, which, descending from the superior margin of the metathorax, arches itself convexly outwards towards the abdomen, and thus separates the entire cavity of the thorax from that of the
abdomen. Beneath this partition, namely, at the pectoral side, a lunate space remains free, through which the internal organs pass from the thorax into the abdomen. Besides this most important position of the internal skeleton of flies, we find, in the neighbourhood of where the wings are attached, other horny arches, which serve for the insertion of the alary muscles. In front also of the larger partition the scutellum sends into the cavity of the thorax a small ridge, which is however as unimportant as the other is important. The dorsal muscles ascend obliquely through the thorax from the great partition to the mesonotum, and thus hold the whole structure together.

In the Lepidoptera, which in the structure of their thorax have most resemblance to the Diptera, the conformation is already somewhat more complicated. In this both agree that everywhere where there are exterior furrows we find corresponding interior ridges which separate the points of insertion of the muscles, and thus increase their firm adhesion. Such a ridge rises from the centre of the mesonotum, which passes to the scutellum, and there unites with the ridge that separates the scutellum from the mesonotum. From the posterior margin of the scutellum a broad partition (the mesophragma of Kirby and Spence) descends, it bends first backwards and then forwards, and thus forms a hook, to which the large dorsal muscles are attached. This partition is analogous to the ridge of the scutellum in the Diptera.

The third very narrow thoracic segment leans against it, forming also a posterior partition, which, however, is much more delicate and fine than the first; consequently the relations of both the partitions, in comparison with those described in the Diptera, are changed, here the first is the largest, and there the second. The pectoral side of the thorax exhibits a central projecting ridge as the line of separation between the coxae and other smaller ones corresponding with the exterior furrows.

The Hymenoptera make the direct passage from the forms already described to those in which the prothorax is separated. The exterior furrows of their thorax are true sutures, in which their parts are joined. This has been already sufficiently explained above (§ 74—78.), and it is there shown that the collare is the true prothorax of the Hymenoptera; we will therefore here proceed with the internal processes. In the prothorax there are two strong pointed processes (Pl. XII. No. I. f. 4. a, a), each of which has a double root; one exterior one comes from the margin of the prosternum, and an interior one from the
central ridge of the same part; between these roots the muscles of the coxae pass, and between the processes themselves run the pharynx and the nervous cord, and it is to these processes that the connecting muscles of the pronotum and prosternum are attached. In the mesothorax we first find the prothorax (the same, 3. a), a small, not very high, horned partition, which descends from the anterior margin of the mesonotum, and we next find a delicate ridge which encompasses the whole distinctly separated mesonotum. The mesosternum and scapulae are closely joined in a half ring, and from the central carina of this ring springs a broad strong ledge, which at its upper margin is furnished on each side with a strong process (the same, 6. a, a); they form with the ledge a rectangular cross, and serve as points of insertion for the muscles of the coxae of the middle legs, lying on each side contiguously to the central ridge. In Cimbex the cross is very distinct, in Scolia it is merely a ridge, somewhat distended above. The metathorax of the Hymenoptera is more complicated than in the Diptera and Lepidoptera, because in them the abdomen is attached by only one small spot, namely, by the circumference of the aperture beneath the metathorax, consequently there the metathorax encloses more powerful muscles than in the preceding orders. The metathorax is therefore exposed, and appears, for example, in Scolia, as an equilateral triangle above the articulation with the abdomen, upon the very smooth apex of which the abdomen turns (Pl. XII. No. 2. f. 1). The apex itself is perforated, and admits a strong band through it, which retains the abdomen (Pl. XII. No. 2. f. 3*). In front of this triangle is placed the very narrow metanotum (the same, f. 1 and 2. f, f), and at its posterior margin a triangular process runs inwards (the same, f. 4* and 5*), to which the muscles retaining the abdomen are affixed. Between the metanotum and metathorax the two large side pieces and their auxiliaries lie, separated from each other by furrows, from which internally strong ridges spring, and to which the muscles of the posterior legs are attached. In the saw-flies, which do not possess a petiolated abdomen, the pleura, join together behind the metanotum (the same, No. 1. f. 1 and 2. h, h), and the metathorax lies internally as a narrow margin of the metanotum, but the band is a semicircular tense membrane, which is distended by the pleura, and is very distinct in Cimbex.

Among the orders with a free prothorax the Hemiptera occupy the lowest place. The entire prothorax is a single, above very broad, beneath narrower ring, from the centre of the pectoral plate of which
two horny arches spring, which pass over the cavities of the coxae, and attach themselves to the sides of the pronotum. These arches serve for the insertion of the muscles of the coxae. Two other spinous processes originate from the upper half of the ring yet more laterally, and bend down to the beforementioned arch, proceeding gradually further from the exterior case. In the very large mesothorax, anteriorly there is no prophragma, whereas posteriorly, beneath the scutellum, a very large mesophragma, which is longitudinally divided, the lower points of which unite with the arch, which, as in the prothorax, span themselves over the cavity of the intermediate coxae. Other lateral ridges correspond with exterior furrows. The metathorax is again very narrow; it has no metaphragma, and no arch spanning the cavities of the coxae, the muscles of which are attached to the mesophragma. This description is sketched from Cicada fraxini, Latr. In the bugs, which possess a much smaller, at least flatter, thorax, I found (namely, in Pentatoma hæmorhoidalis,) traces of the horny arch, and a distinct mesophragma, which likewise, like the mesophragma of the Cicada, is divided, but at its centre diverges much more considerably, and is in intimate connection with the pleurae.

The skeleton is much more perfect in the Orthoptera. Among them the grasshoppers occupy the lowest place. In the prothorax, the saddle-shaped pronotum of which encloses the entire part, we observe two bent, flat, but high processes, which originate from the exterior margin of the prosternum and rise to the pronotum. Two other processes spring from the middle between the cavities of the coxae, and form in removing from each other two arches, which span those cavities. On the interior of each bow there is also frequently a smaller process, which bends to its opponent, and thus covers the nervous cord (Pl. XI. No. 2. f. 2. a, a). Both processes serve for the attachment of muscles, and the larger bow for those of the coxae; from the smaller ones two narrow muscles spring, which ascend to the back and affix themselves to the margin of the dorsal piece. The same processes are found also in the second and third thoracic segments, which likewise form small arches, beneath which the nervous cord runs. Instead of the first named exterior ones from each pleura a strong hook-shaped carina runs, which separates the muscles of the legs and wings (the same, 6. b, b). The superior partitions, the meso- and metaphragma are small, and do not lie vertically but obliquely, whence the cavity of the thorax acquires much compass and wide avenues. The most perfect skeleton amongst
the Orthoptera is found in the mole cricket (Gryllotalpa vulgaris). In
the prothorax (Pl. XI. No. 1. f. 1—3), which is formed of a very
large, hard, bellied pronotum (a) and a very narrow, small, keel-shaped
prosternum (b), we observe a large horny partition (c), which de-
scends from the central line of the pronotum and spreads forward in
two furcating processes (e, e); to these processes two others attach
themselves, which originate from the upper margin of the aperture of
the neck, distend themselves in an arch downwards, and posteriorly,
and thus encounter the fork of the central ridge. And thence where
these processes join the furcate process the prosternum, which ante-
riorly is formed like a T, unites itself to them with its two branches,
and thus closes the anterior aperture of the prothorax. Posteriorly
two other processes originate from the central line (f, f), which de-
scend downwards, bend there towards each other, and join the posterior
extremity of the prosternum (*); at the same time each gives off a
hook which is directed upwards and backwards, and between these a
single horny bone lies (h), which stands in connection with them by
means of muscles (* *), and upon which the large pharynx rests.
Beneath this bone runs the nervous cord, encompassed by the posterior
shanks of the central ridge. The skeleton of the meso- and meta-
 thorax is much smaller. Two processes descend from the scapulae
(Pl. XI. No. 1. f. 4 and 3. d, d.) and unite together beneath, at the
central line of the mesosternum (the same, e). From the point of
union there arises a short dagger-shaped process (the same, 5), which
is barbed on each side at its base, and proceeds nearly to the end of the
metasternum. This point is, as it were, the true breast-bone, to which
the muscles are attached, and upon it the intestinal canal rests. From
the anterior margin of the metanotum the small mesophragma ori-
ginates, and which is perforated by a hole (the same, 7. a), through
which the aorta passes, and besides there comes from the suture of the
metasternum and the pleur a clavate ridge, prolonged internally at its
anterior end into a pointed spine.

Some of the Neuroptera are very similar in structure to the grass-
hoppers, at least I found in the Termites just such horny arches upon
each of the three thoracic segments as covers for the nervous cord, and
horny ridges which separate the muscles from each other on the inner
surface of the pleur a.

The most perfect internal skeleton of all however is found in the
Coleoptera, although some portions of the thorax, namely, the prothorax, do not form so complex a frame as in Gryllotalpa.

The prothorax consists in the majority of beetles of two separated pieces, which, only in some capricorns (Callichroma, Saperda,) and all the Rhynchophora, are connate*.

In Carabus, Dyticus, Buprestis there lies between both two other free pieces, which I have called omia, and which must be considered as the free lateral walls of the dorsal plate. The moveable spines in Acrocinus longimanus (Kirby and Spence's Umbones) are probably these same pieces, at least we can give no other explanation of these otherwise perplexing organs. The internal skeleton of the prothorax consists in a process originating from the prosternum between the cavities of the coxae, which divides itself into two when those cavities are distant from each other (Oryctes). Above, this process has a tooth on each side, which bends towards the side of the prothorax, and sometimes unites with it (in Hydrophilus, Pl. X. No. 3. f. 6 and 7. a, a). It has frequently more or less the appearance of a fork, or the letter Y, and Kirby and Spence thence call it antefurca, a name which, notwithstanding its bad construction, does not suit, because this process does not always furcate, and is indeed wanting in many beetles, namely, in those with a simple prothorax. In such cases a partition between the cavities of the coxae occupies its place. I call it, when present and of importance, the processus internus prosterni. The nervous cord passes between its branches.

In the mesothorax the partition or prophragma descends from the anterior margin of the mesonotum, and is directed somewhat forward. It is in general but very short, and rather a small ridge, to which the connecting muscles of the meso- and metathorax are attached. We again find the internal process upon the mesosternum, but here it originates with more widely divided shanks, each of which shanks forms an arch, which, as in Cicada, spans the aperture of the cavities of the coxae, and ascends as high as the suture of the scapulae, to unite itself with the surrounding margin of that part. In the Lamellicornia this arch does not reach the suture, but projects freely into the cavity, serving as a point of attachment for the muscles. In this shape the entire

* Meckel erroneously says this of all. See his Vergleich. Anatomie, vol. ii. Part i. p. 76.
process is called by Kirby and Spence the medifurca; I call it, to cor-
respond with the first, the processus internus mesosterni, or arcus ster-
nales interni.

The metathorax has the most developed skeleton, and is in ge-
genral in the beetles the largest of the thoracic segments, whereas it
was the central one in the flies, butterflies, Hymenoptera, and Cicada.
We observe, at the metanotum, the meso- and metaphragma, two parti-
tions descending perpendicularly from the anterior and posterior limits
of this plate; they are not very high, but to them the large dorsal
muscles are attached. In apterous genera (Carabus) the entire meta-
otum, and with it both partitions are very small. We find, besides
these two partitions, no other elevated process at the metanotum,
whereas there is a very large one at the metasternum. This originates
as a thin, frequently merely pergamentaceous, triangular partition from
its central line, and projects freely into the cavity of the thorax, but
with its apex more directed towards the abdomen. The thither directed
edge of the triangle is thicker, like a ridge; it is placed upon its pos-
terior margin, and originates from the spot where both the cavities of
the posterior coxae are united. When this ridge reaches the upper
point of the triangle it sends off on each side a strong process, which
together form a direct cross with the ridge itself. A third process,
which is, as it were, the continuation of this ridge, originates between
both, and runs in a direct line parallel with the carina of the sternum
as far as the mesothoracic segment, gradually decreasing to a point.
This central process is excavated above, and thus forms a small channel,
in which the intestinal canal rests. In Dyticus it even furcates, and
with both prongs of the fork it encloses the intestine, and lower down
the nervous cord. In Oryctes, however, all three processes, the two
transverse ones and the central one, equal both in form and size,
thus construct a three-rayed star; in Hydrophilus the central process
is wanting, as well as in Carabus and Callichroma, where the whole
frame is much smaller, and is placed between the cavities of the coxae,
whereas in others, at least in Dyticus and Oryctes, it projects as far as
the base of the abdomen. To this skeleton numerous muscles are
attached; posteriorly the muscles of the coxae; at its lateral points
delicate muscles, which rise to the limits of the back; to its anterior
points likewise two delicate muscles, which pass through the cavities
of the meso- and prothorax, and affix themselves to the horny plates
of the membrane of the neck (see § 167. 4). Besides this large pro-
cess, which Kirby and Spence call the postfurca, Audouin, on the contrary, styles it, in connection with the preceding ones of the pro- and mesothorax, the entothorax *, we find but a few other ridges produced by the sutural connection of the pleurae with the sternum; these are Audouin's apodema, which vary in their course according to the varying forms of the parts, and are of much less importance.

§ 166.

INTERNAL SKELETON OF THE ABDOMEN.

The abdomen has no internal skeleton, but consists of horny rings connected together by a flexible membrane, each of which is divided into a dorsal and a ventral plate. In the grasshoppers, at least Gryllus and Locusta, horny half circles arise from the lateral edges of each dorsal plate, which are about one-third of its width, and extend as high as the dorsal depression. It is to these arches that the long air bags are attached, which form a zigzag, and which we have fully described above. Marcel de Serres †, who first discovered and described them, called them ribs, a comparison which in so far is not inappropriate, from their encompassing and protecting the air bags of these creatures. But they are properly elastic processes, which are in a directly opposite action to that of the oval air bags, which they distend by springing back, when the contraction of the spiral fibre has shortened them, and has thereby removed the process to which the bag is attached from the abdominal plate. They consequently belong to the respiratory system, and were considered under it by their first discoverer.

§ 167.

SKELETON OF THE LIMBS—MODE OF ARTICULATION.

The skeleton of the limbs is merely external, and as such it has been sufficiently described above (§ 79) in a preceding division; we have also there indicated the way in which the different parts of a limb are connected together, it therefore remains merely necessary here to give a special description of all the different kinds of articulation both of the limbs as well as of the other portions of the skeleton.

1. CONNECTION WITHOUT MOTION. (SYNARTHROSIS).—This kind of

* See Miekel's Deutsche Archiv, &c., tom. xii. p. 440.
† Mem. de Musée, tom. iv. (1819).
connexion of the parts of the skeleton we find chiefly in the thorax, in the sutures by which the several plates are united together. We may distinguish two descriptions of it:—

1. The SUTURE is the connexion of two plates of the skeleton by insertion, a projecting ridge of the one corresponding with a channel in the other, and the connexion is thus made without the intervention of membranes. This mode of connexion is found between the several plates of the thorax. Where both join they bend inwards, and thus form an even suture. All sutures in insects are therefore simple, smooth, without teeth, or interchanging processes.

2. SYMPHYSIS is a connexion upon the whole resembling a suture, but which is produced chiefly by the intervention of a soft membrane. This admits of a slight separation of the connected parts, which is increased in proportion to the elasticity of that membrane. It is by means of this that the posterior wing of the scapula is connected with the parapleura. This sort of connexion, thus admitting some degree of separation, was the more necessary here, as the second spiracle of the thorax lies between the two plates, and therefore a firm union would have prevented a free respiration.

A mere variation of this form, which, however, admits of a greater motion of the connected parts, is called by Straus a scaly joint (articulation ecailleuse). It is distinguished chiefly by the lip of the one plate passing over the connecting membrane, and thus covering the lip of the other plate like a scale. This mode of articulation is found in the plates of the abdomen, in which each successive plate is covered by that preceding it. The mobility of parts thus connected is but passive, whereby an extension of the body on all sides, but chiefly longitudinally, is made possible, for example, when its contents swell, as is frequently the case in the female after impregnation.

II. CONNEXION WITH MOTION (Diarthrosis).—All connexions classed under this head are generally called JOINTS. They are found chiefly in the limbs, in the connexion of their several parts. In insects we distinguish the following different forms of articulation:—

1. The FLAP JOINT (syndesis).—When two parts meet at a suture, and are connected together by membranes at the inner side, but so that they may move in the suture to and from each other. This mode of articulation is found, for example, in the under lip, where the mentum joins the gula.
2. Gynghimus.—When two parts are so connected that the one is inserted within the other at its origin, and stands in intimate connexion with it only at two opposite points. The part turns upon these two points as upon its axis. This therefore admits of but one kind of motion, viz., that of its approaching to or receding from the other part. It is thus that the coxae and trochanter, femora and tibia are connected, and the mandible with the head. A more detailed description will more clearly explain the peculiarity of this articulation. Upon examining the upper extremity of the tibia, which has been removed out of its socket, we shall observe upon the exterior as well as interior a precise semicircular furrow, behind it a concentrical but smaller ridge, and beyond this a circular fossulet. The inner surface of the femora displays on each side a ridge accurately corresponding with the furrow, beyond this a furrow corresponding with the preceding ridge, and in the centre a minute elevation, from which a small but very firm band passes into the central fossulet of the tibia. This band appears to pierce transversely through the hole in the tibia, and passing through the opposite side to be affixed to the corresponding central elevation of the femora. Thus, therefore, a very firm connexion and a secure joint is produced. The articulation of the mandible is very similar, but which is distinguished from it by the upper side of the mandible having a semicircular ridge, and upon its under side merely a spherical ball joint.

3. Rotation (rotatio).—Is that kind of articulation when a cylindrical, ovate, or conical part is sunk into a cavity adapted to its convexity. Both the inserted body and the cavity are drilled at one spot, and are united around the aperture by means of a membrane: besides which there are balls at both poles of the axis of rotation adapted to corresponding sockets of the other part; whereby a rotation of the encompassed part upon its axis is made possible within the corresponding cavity. This mode of articulation is found in the coxae of the Coleoptera, Hymenoptera, Hemiptera, or more or less evident in the hip-joints of all insects.

4. A Free Articulation (arthrodia).—Is when a conical part is inserted in a corresponding cavity, both being pierced at one spot, and united by membranes around the circumference of the cavity. This mode of union, which is the most common of all, admits of the freest motion upon all sides; and, indeed, what is still more, the exertion
of the ball out of the socket, as far as the membrane admits of extension. We find thus united the joints of the antennæ, palpi, and tarsi, the head with the thorax, and the prothorax with the mesothorax, in those insects which have a moveable prothorax. At the neck, or the connecting membrane of the head with the thorax, we find, besides, in the Coleoptera, two bean-shaped horny plates (pièces jugulaires of Straus), upon which the occiput moves. These plates, which might be called throat plates (jugularia), lie transversely in the posterior portion of the membrane which spans the large aperture of the prothorax like a drum-head, and serve for the insertion of several small thin muscles, and, among others, to the two which originate from the central point of the internal metathoracic process which passes through the cavity of the thorax. Their true function is doubtlessly to retain the membrane of the neck distended, and to offer to the occiput a smooth surface, upon which it may turn with facility. In black or dark beetles it is of the colour of the exterior integument (Hydrophilus piceus, Oryctes nasicornis), and is therefore very perceptible when the head has been removed from its articulating cavity. In Dyticus I likewise found similar plates between the meso- and meta-notum. A small horny piece, similar in function, lies also in the membrane between the coxae and the sternum in the four anterior legs. It is properly a process of the joint become free, and which, in the intermediate legs, in which the motion is less, stands in closer connection with the coxae. Audouin calls it trochantinus. I have been able to find this piece only in Dyticus: it exists also in Melolontha, according to Straus, who calls it rotule.

§ 168.

STRUCTURE OF THE WINGS.

We have already, in a preceding division, sufficiently described the formal differences of the wings and elytra, as well as of the legs, to complete which we have but to give here a detailed explanation of their peculiar structure. In the description above, we have already mentioned that they are bags formed of a simple membrane, in which horny ribs are distributed. This simple membrane is nothing else than the epidermis, which, proceeding from both sides of the thorax, forms the wings. This is most distinctly seen in those wings which have a broad base, as in the Coleoptera, Orthoptera, &c., in which we
even observe at the base a much greater thickness of the wing, which is caused by the two layers of the epidermis not having closely joined together. Upon the margin of the wing the two layers pass into each other, and thus the bag is formed. This bag admits of being distinctly represented as such, if just-developed insects be placed in spirits of wine; the fluid then passes between the still fresh and soft membranes of the wing, and filling their internal space, distends them like a bag. Heusinger* observed this in fresh specimens of butterflies, and I have myself detected it in a young individual of Anthophagus plagiatus, Grav.

However smooth, fine, and transparent the membrane of the wing appears to the naked eye, an investigation with the microscope reverses this, and exhibits it as covered with innumerable small hairs, which rise from bulbous roots upon the wing, and densely cover its whole surface. In some insects, for example, the common gnat, they are longer, broader, and lanceolate, and pass over into the scales of butterflies, which are absolutely nothing else than transformations of the hair peculiar to almost all insects.

The ribs of the wings are hollow, horny tubes, by which the two plates of the wings are supported. Their situation and reciprocal relation, as well as the cells formed by their connection, we have become acquainted with above: we will merely add here, that each rib is filled internally with a soft parenchyma, in which I have detected a vessel very large in compass, and by the side of it a fine nerve. The vessel appeared to come from the cavity of the thorax, and the nerve entered from the same part, coming probably direct from the approximate ganglion; therefore, close to the posterior wings in beetles, upon which I made the observation, and from the third ganglion of the thorax. In the vessel itself I could detect no structure, and, least of all, the spiral fibre observable in the tracheæ, even upon an enlargement of three hundred times†. I thence conclude that it is a blood-vessel, which is supported by Carus' observation of the motion of a fluid in the ribs of Lampyris. How else could the wings be distended, were not the liquid flowing into these vessels the cause of it? But it is not necessary that we should thence conclude upon a

* System der Hystologie, 2 Heft.
† I have since detected the spiral fibre in these vessels, and observed that they are genuine tracheæ.—Author's MS. Note.
connection of these vessels with the heart, it being well known that blood is found in the entire cavity of the body of insects, and, by each contraction, can be injected into the open ribs of the wings. Chabrier describes, besides, a bag in the posterior wings of beetles, which lies at their point of flexure, and which is filled with a fluid during flight. The equilibrium is thereby thus supported. He considers in the other orders the stigma analogous in function to this bag. The clammy fluid contained in this stigma is probably merely parenchyma, but even in insects which had been immersed in spirits of wine, I have found a moisture in the bag, but which, without doubt, was introduced from without.

The connection of the wings with the thorax varies according to the different orders. Broad wings, attached by their entire bases, are found in the Coleoptera, Orthoptera, Dictyoptera, Neuroptera, Hemiptera, and Lepidoptera, consequently in the majority; wings with pedicles, and attached to the thorax by a narrow base, are found in the Hymenoptera, some of the Neuroptera, and the Diptera.

The superior wings, or elytra, of the beetles have at their base two short processes, the one of which originates at the inner margin, and the other at the outer margin. Both articulate with two processes at the mesonotum, which originate from it at the anterior part of the lateral margin, and are united to those of the elytra by means of a flexible membrane. In this membrane several free horny pieces are placed, to which the muscles are attached which move the wings. Straus found in Melolontha four such plates, and called them shoulder pieces (1. pré-épaulière, and 3. épaulières). From the posterior margin of the internal process of the joint of the superior wing, a delicate semicircular membrane springs (frenum of Kirby and Spence), which passes over to the similar process upon the mesonotum, and which retains the expanded wing. In Dyticus it is narrower, fringed upon its margin, very broad in Hydrophilus, and in aperous beetles (Carabus) it is wanting. This membrane, which is present in the majority of insects, and which, for example, in Libellula, is the coloured triangle at the posterior margin of the wing; and appears very similarly in the wings of the grasshopper, is so far of importance, that from it the scale behind the wings of the Diptera derive their significance. They are, namely, the frena of the superior wings, which cannot longer

remain in immediate connection with the base of the wings, from this being contracted and narrowed, whereby the scale is separated from the wing. We nevertheless still find in many Diptera a connection. It is remarkable, and confirmatory of this opinion, that those Diptera which want this scale, are such whose wings stand off in a state of repose, as, for example, in Tipula. But this frenum passes always from the superior wing to the lateral margin of the scutellum, and the scale of the Diptera is always found in this situation. The Lepidoptera are not deficient in this membrane; in the Hemiptera (for example, Cicada, Plate XIII. No. 5. 1.), it is partially horny; in the Hymenoptera it has but small compass, but in these it is not either ever wanting.

The connexion of the posterior wings is still more intimate than that of the anterior pair, whenever they are larger than the latter. The Coleoptera exhibit towards the base of the wing several plates, which lie free in the membrane, and which, like those of the elytra, promote and support their motion. Straus distinguishes five in Melolontha, and calls them axillary pieces (1. préaxillaire, and 4. axillaires). Neither is the connecting membrane which runs from the last portion of the joint to the margin of the metathorax wanting here. This is likewise the case in the large posterior wings of the Orthoptera as well as of the Dictyotoptera and Neuroptera, in which the plates and membrane are also found, and in the latter frequently very much developed. Nor is it wanting in the other orders.

The Diptera are remarkable from having no posterior wings, but instead of them they are provided with two pediculated knobs, which are called halteres. Latreille and other French naturalists will not allow these organs to be considered as the rudiments of the posterior wings, whereas the majority of the earlier entomologists, and many modern ones, particularly the Germans, consider them as such. If we look to the situation of these organs, it speaks incontestibly in favour of this opinion, for they are exactly situated where the posterior wings of other insects are found. Besides, they stand in the same connection with the metathorax; and, indeed, in the larger flies, for example, Tabanus bovinus, we detect the analogue of the connecting membrane. The knob is also sometimes (Tipula gigantea, lutescens) broad, flat, and provided with ribs like the wings, these are all facts which cannot be disputed, and which corroborate the correctness of this opinion. Latreille's decision, therefore, that the last segment of the thorax in
the Diptera belongs to the abdomen, because a spiracle is found upon it, requires no refutation after the description given above of the general situation of the spiracles.

We must still make an observation upon the connection of the wings together. I know but of two of all the orders of insects which exhibit an apparatus for the connection of both the wings together, these are the Hymenoptera and the Lepidoptera.

In the Hymenoptera it consists of a row of minute hooklets, which are bent backwards, and are placed upon the anterior margin of the posterior wing, and which fit to a small groove along the posterior margin of the superior wing.

In the Lepidoptera this apparatus is somewhat more complicated. Giorna, who appropriates to himself the priority of this discovery, although it was made thirty-seven years before him by De Geer *, has, however, given the most detailed account of it †. There is found, namely, at the base of the posterior wings of many of the crepuscular and night moths, a spine projecting from the anterior marginal rib, which is sometimes divided into several radiating branches. This spine is enclosed by a hook placed upon the central main rib of the superior wing, which surrounds the whole circumference of the spine, which passes through it as through the eye of the needle, but which can freely move itself to and fro within it. If the superior wing expands by means of the spine, it draws the inferior wing with it, and both remain in immediate connexion; a provision of nature which is rendered the more necessary, as we shall see below, from the mesothorax being furnished with large muscles of connexion and motion, which are entirely wanting in the metathorax, so that the muscles which distend the superior wings must act likewise upon the inferior ones. We find a similar adaptation in the muscles of the Hymenoptera.

II. THE MUSCULAR SYSTEM.

§ 169.

The muscles of insects, like those of the higher animals, consist of two parts, viz. the tendon and the muscle. Under the name tendon we understand the in general more compact, firmer, and uncontractile

* Mém. pour servir à l'Hist. des Insectes, t. i. p. 173.
† Trans. of Linnean Society, vol. i. No. 7. Lond. 1791.
ends of the muscles, by which they are attached to the parts to be moved: the muscle itself is the contractile fleshy portion lying between these tendons. If the tendon be wanting, the entire generally very broad end of the muscle is affixed to the horny skeleton, and such muscles appear applied more to the strengthening of all the parts than to the motion of individual ones.

The tendons vary much in shape according to the structure of the muscle, but they always consist of a horny mass, distinguished from that of the skeleton by its wanting the epidermis, and the coloured layer of the mucous tunic, and therefore Straus considers them as an elongation of the internal layer of the horny skeleton, to which the epidermis cannot assist, as it lies externally, and this view appears to be correct. The horny tendons, consequently, cannot participate in the external colour of the exterior integument, but they are, like its internal layer, of one uniform black or brown hue, so that they are easily distinguished from the flesh of the muscle. In form they are longer or shorter bones, which, at the side turned to the muscle, gradually distend into a flat surface, to which the muscle is attached. The form of these surfaces varies according to what is required by the muscle, for it is broad and plate-shaped for short thick ones, and for long thin ones we find it also long and resembling a scale.

The muscle itself is a union of delicate white, or yellow and red parallel fibres, which frequently, particularly if the insect has been preserved in spirits of wine, are readily separated from each other. If these fibres be examined under the microscope, we distinguish partitions at short distances, which appear to separate it in equal parts; but upon a careful examination, we find that the fibre consists of small laminae lying one upon the other, and which at one spot are depressed into an angle, and are thereby attached to each other, which consolidates their union. This discovery, for which we are indebted to the careful Straus*, is the more important, as thereby we detect a uniformity of structure of the animal organs in their most minute parts, as the fibres of the nerves likewise consist of consecutive globules. In the muscular fibres these globules have become plates from their firmer connexion together, and their consequent mutual pressure. Straus found this union in all the muscles, but in the larger ones the individual fibres first formed bundles, whereas, in the smaller ones, they lie

* Consid. Général. p. 143.
regularly together. In the Mammalia (the ox) he did not find this structure, whereas he saw it in the eagle, a fact, which, if shown to be the case in all birds, would still increase the evident parallelism of both classes.

With respect to the general form of the muscles, we may in the first place separate those without tendons from those with. Those unprovided with tendons have the peculiarity of retaining throughout their whole course parallel sides, and always take the form of flat bands or thick prisms. Such flat band-shaped muscles we find between the several segments of the abdomen, and which serve to unite them together: the prismatic muscles without tendons we find between the phragmata, and indeed the dorsal ones in general are of this form.

The muscles with tendons, Straus arranges under the following five divisions:

1. **Conical muscles.** The belly of the muscle has the form of a cone, originating from a broad flat base, and proceeding to a smaller point of insertion. From the apex of the cone the long tendon springs, and distends itself in the belly of the muscle, in the direction of its axis, here spreading into a flat surface, to which the individual fasciculi are attached. Sometimes this surface is divided into several lobes.

2. **Pyramidal muscles.** The belly of the muscle is shorter, as is likewise the entire tendon surrounded by it. This is broad and divided into several leaves (for example, the mandibular muscles).

3. **Pseudo-penniform muscles.** Flat triangular muscles, the fibres of which originate all in a row, and attach themselves sometimes at one, and sometimes upon both sides of the long tendon (the muscles of the femora in Locusta).

4. **Penniform muscles** differ, from the margin of their tendon being fibrous. These fibres originate sometimes at one side and sometimes at both sides of the long tendon.

5. **Compound muscles** are those which consist of simple bellies, all the tendons of which unite into one band, or in which one tendon after the other takes up several bundles of muscles.

To these five forms we may add, as a sixth, **cylindrical muscles**, the tendon of which is a flat round plate, to which the fibres are

*Compare Nitzsch in Meckel's Archiv. 1826.*
attached. From the centre of this plate a longer or shorter straight process springs, which unites itself with the part requiring motion. The great muscles of the wings are formed in this manner. Audouin considers these horny tendons as processes of the thorax, and he calls them Epidèmes.

Double-bellied muscles, or such, namely, where two bellies lie behind each other, and are united together by a central tendon, as they are found in the superior animals, are not discoverable in insects.

Besides this division of the muscles, according to their variations of form, we may likewise separate them into three groups, according to their functions.

The first, which we will call connecting muscles, pass within the cavity of a part from one portion of the skeleton to the other, and thus consolidate the connexion of the several plates together. These are in general the largest of all the muscles, and they have no tendons: when they contract, the cavity in which they are found contracts likewise, but when they become flaccid, it again distends. To these belong the large muscles of the back, which are spread between the phragmata, and likewise the large muscles of the sides, which pass from the back to the breast, and then those which lie between the plates of the abdomen.

The others, which may be called distinctively the muscles of motion, pass from a portion of the horny skeleton to the limbs, or from one joint of the latter to the other. They originate with a broad base from a part of the skeleton, and pass on by a thinner apex, terminating in a tendon, to a part of the limb. Their character also divides them into two groups. The first, which are called flexors (adductores seu flexores), lie on the inside of the limb, and draw it to its base, to which it is affixed; the others, or extensors (abductores seu extensores), work in an opposite direction, distending the limb again as soon as they get in action. They lie on the exterior of the limb, and attach themselves to the exterior angle or edge of the parts to be moved.

These are the various general qualities of the muscles; we come now to the investigation of the individual ones, which we will examine in the order of their situation, examining first the muscles of the head and its joints, then those of the thorax and the limbs attached to it, and lastly those of the abdomen.
A. Muscles of the Head.

§ 170.

The muscles of the head may be divided into those appropriated to the motion of the whole head and the muscles of the oral organs and antennæ. The head has the freest motion of all the moveable parts of the body; it has thence the most numerous muscles of motion, namely, such which raise it (extensors), such which sink it (flexors), and such which turn it to the right and left (the rotatory muscles).

The extensors, or raisers of the head (elevatores capitis), are twofold; two bellies originate close together from the central line of the pronotum, they somewhat separate in their course, and attach themselves laterally to the margin of the occipital aperture (thence called external extensors, elevator externi). They are shorter and broader than the two other bellies, which come from the prophragma, proceed contiguously over the pharynx and through the prothorax, and passing between the preceding affix themselves to the central part of the superior margin of the occipital aperture. All four raise the head up, one acting alone draws it somewhat on one side.

The flexors, or depressors (depressores capitis), are two small muscles which lie at the under side of the neck, and originate from the neck-plate, or, where this is wanting, from the inner margin of the prosternum, and affix themselves to the lower margin of the occipital aperture.

Contiguously to them two other small muscles originate, which turn outwardly and attach themselves to the lower part of the lateral margin of the occipital aperture; they correspond with the anterior bellies of the extensors, and might consequently be called external flexors (depressores externi).

The rotatory muscles of the head (rotatores capitis), are two broad flat muscles, which, coming from the lateral margin of the prosternum, affix themselves to the corresponding margin of the occipital aperture, and bend the head outwardly if one only be in action, but in conjunction they assist to draw the head into the cavity of the thorax.

In all insects with a free head, (Diptera, Lepidoptera, Neuroptera, Dictyoptera, and Hymenoptera,) all these muscles are very small, flat, and like a band; the following, on the contrary, which belong to the plates of the throat, are, as well as these plates, entirely wanting.
The muscles which run to the plates of the throat may, properly be classed with the flexors of the head, for, as the true flexors are attached to these plates, a contraction of these plates likewise draws the head downwards and backwards. There are three on each side:

One, the flexor of the throat-plate, originates from the inner process of the prosternum, and affixes itself in the centre of the plate of the throat. The second, or straight extensor, affixes itself internally, contiguously to the other, and passes diagonally from the propragma through the cavity of the prothorax.

The third, or oblique extensor, comes from the exterior margin of the pronotum, and affixes itself to the plate of the throat, between the former and the flexors of the head. The two last retain the plates of the throat in their place, which naturally, from the situation of the flexors of the head, is exposed to greater force; the first assists the head inwards, and also to draw the plate of the throat down, acting in opposition to the two extensors.

§ 171.

MUSCLES OF THE MANDIBLES.

Of the muscles of the joints of the head we will first examine those of the mandibles; we find two, namely, a flexor and an extensor.

The flexor of the mandible originates from the entire posterior and upper side of the skull; it becomes pyramidal and affixes itself, after passing the lateral portion of the brain, by means of a strong and frequently divided tendon to the inner margin of the mandible. In many insects, for example, the grasshopper, the entire muscle consists of two contiguous bellies.

The extensor of the mandible originates beneath the former from the posterior and lower portion of the skull; it is smaller and weaker, it has a long, thin tendon, and affixes itself to the exterior margin of the mandible between the two above-described joint balls.

The maxillæ, which are of a much more complicated structure, have several motive muscles, which may be divided into four groups, according to the part of the maxilla to which they pass.

There are three muscles which move the entire maxilla.

The first, the flexor of the maxilla, is the largest; it originates from the inner side of the throat, closely in front of the occipital aperture,
and is sometimes conical, and affixes itself to the innermost process of the transverse basal portion (p. basilaris s. cardo).

The extensor of the maxillae originates from the inner side of each temple, beneath the eyes; it is the smallest of the three, and affixes itself to the most external process of the base.

The third muscle, which may be called the first contractor of the maxillae, originates from the lower margin of the occipital aperture; passes transversely over the flexor, and inserts itself between the flexor and extensor at the base. Both contractors acting in conjunction draw the maxillae together.

Two other muscles, which likewise move the entire maxillae, are inserted in the piece described as the stem.

The one, which may be called the second contractor, originates likewise from the margin of the occipital aperture, but in the centre, in front of the first, and inserts itself in the lowest most internal angle of the base; the other, or second flexor, originates from the inner wall of the occiput, lies above all the others, and inserts itself with a long thin tendon, likewise at the lower inner angle of the stem, closely contiguous to the second contractor. It is the longest and largest of all the muscles of the maxillae.

The galea, which are, as they have been called, the internal maxillary palpi, receive each two muscles, which lie in the maxillae themselves.

The flexor of the galea is the largest; it originates from the inner side of the stem, and affixes itself to the inner margin of the galea.

The extensor of the galea, which is longer but smaller, originates from the inner side of the exterior wall of the stem, and inserts itself at the exterior margin of the galea. The exterior one gives off also numerous fasciculi to that portion of the maxillae which bears the palpi, and it is thereby united intimately with the stem.

The last muscles of the maxillae, which, like the preceding, lie wholly in it, move the maxillary palpi. Their flexor originates from the inner margin of the palpal plate belonging to the maxillae, and inserts itself at the inner margin of the first joint of the palpus; their extensor comes from the inner side of the exterior wall of the stem, and inserts itself at the exterior margin of the first joint of the palpus.

The joints of the palpi themselves have each two muscles, a flexor and an extensor. The former springs from the inner margin of the
preceding joint, the latter from the exterior, and both insert themselves at the corresponding parts of the basal aperture of the joint which they move.

§ 172.

MUSCLES OF THE LIPS.

The upper lip, or labrum, has in Melolontha but one kind of muscle, namely, the flexor or bender, which originates on each side from the brow, close to the eyes, and runs down to the extreme angle of the labrum. In Locusta, I have distinctly observed two different muscles; both were flat, resembling bands, and originated from the forehead, the anterior one, or adductor of the labrum, originated between the eyes, and inserted itself upon the inner surface of the exterior wall of the labrum; the second, or adductor of the labrum, originated above the former, at the boundary between the forehead and vertex, and ran separated from it as far as the apex of the labrum, leaning against the membrane of the soft palate, and supporting it.

The labium, like the maxillæ, being of a more complicated structure, receives several muscles.

The adductor of the labium originates from the most anterior edge of the skeleton of the head; it has a broad basis, and runs pyramidal to the mentum, joining it in front of the articulation of the palpi. In the Coleoptera there are two adductors, one on each side of the mentum; in Locusta I found but one central one.

In front of it, or between them when there are two adductors to the labium, the muscles of the tongue originate, which are two, likewise short, pyramidal muscles inserted at the lower side of the tongue, and connect this with the labium: I call them the reins of the tongue. In Locusta I found but one muscle of the tongue, resembling that of the labium in its broad flat form, which originated in front of the latter, from the tentorium, and passed to the posterior wall of the tongue. To the anterior wall, or the soft membrane clothing the tongue, on the contrary, another muscle passed, which I call the flexor of the tongue, and which, running likewise closely to the membrane of the tongue and of the palate, originated with a broad base from the anterior boundary of the tentorium.

The first joint of the labial palpus has its flexor and extensor; the
former originates from the centre of the mentum, and passes to its inner margin, and inserts itself at the exterior margin of the joint. The succeeding joints have a similar structure to those of the maxillary palpi.

§ 173.

The antennæ have three muscles which move them—an extensor, which originates from the forehead in front of the eyes, and affixes itself to the exterior margin of the basal joint; a flexor, which originates from the anterior apex of the inside of the skull, and affixes itself to the inner margin of the basal joint; and an elevator, which originates exteriorly contiguous to the extensor from the margin of the eye, and inserts itself at the lower margin of the basal joint.

The individual joints have each two muscles, namely, those known from their situation as extensor and flexor.

Besides the above-named muscles there are other smaller ones, which retain the pharynx and palate in their proper place. In *Locusta* the muscles of the lips and tongue participate in this; in the *Coleoptera* they originate from the inside of the skull, and insert themselves at the pharynx, or from the forehead itself when the processes of the head do not advance so far. In *Dyticus*, from the skull of which two long, bent, horny processes originate, which extend as far as the forehead and enclose the pharynx between them, they originate from the inner margin of these processes. In *Melolontha*, in which this internal frame of the head is smaller, two come from the forehead itself, and two others, smaller, on each side, from the clypeus: it is the same in *Locusta* and *Gryllus*.

§ 174.

In insects with haustellate oral organs the muscles of the mouth are much smaller. The *Hymenoptera* display the greatest conformity, particularly as they have large mandibles, and we can even recognise in their maxillæ analogous muscles. The entire suctorial apparatus, namely, the proboscis, with the maxillæ, palpi, and labium, has a moveable basis, formed of several united bony pieces, which, by means of a soft but tense membrane, stand in connection with the margin of the large oral aperture of the head. According to Treviranus* there lie in this membrane one simple and four double horny bones. The

two first (Pl. VI. f. 5. 1.) lie in the anterior margin of this membrane, in a transverse direction to the proboscis, but linearly with respect to each other, directly behind the mentum. From the exterior ends of each of these two pieces there originates a similar (2) bone, which extends posteriorly upwards, the point of which touches a third (3) bone, which furcates and descends from here to the posterior end of the membrane. Both the prongs of the fork join at their ends a fourth (4) uneven main bone, which lies transversely at the end of the membrane, and opposite to the two first, which lie immediately behind the mentum; the fifth paired main bone (5) originates likewise at each end of this fourth unpaired bone, and runs at the margin of the membrane close to the horny aperture of the head. All nine thus construct one valve, the anterior lobes of which are formed by the two first transverse and anterior lateral bones, and the posterior lobes by the second lateral bones, the fourth transverse and the two marginal bones originating from its end. The articulation takes place at the point of connexion of the two second and third bones. If the mentum (the same, a.) be withdrawn, the membrane and bones lie like a valve together, but if, on the contrary, the suctorial apparatus be distended, the membrane is stretched out by means of the bones, and these push the chin forward before it. The motive apparatus of the butterflies is much more simple; in them a double band-shaped muscle runs along each half of the proboscis, which clothes the entire cavity, leaving merely a narrow central canal. Both these muscles roll up and distend the proboscis, and also unite it with the head, inserting themselves partially upon the horny wall, and partly upon the, indeed very small, internal frame-work of the head. The smallness of their head arises from the disappearance of the muscles of the mandibles. The same may be maintained of the *Hemiptera*; they also have but delicate muscles, which elevate and withdraw the sheath, as well as still smaller ones, which rein the setæ.

The *Diptera*, although they have in general a large head, derive it from the preponderance of their eyes, for the muscles which pass to their mouth are likewise abortive; the fleshy proboscis alone, which we consider as the labium, receives two large and tolerably broad band-shaped muscles, which originate from two ridges placed internally over the aperture of the mouth, and arched from the cheeks to the clypeus, and which extend also to the apex of the proboscis. They withdraw the proboscis within its cavity, and are therefore called the extensors of the haustellum.
§ 175.

B. Muscles of the Thorax.

The muscles of the thorax must be considered under several points of view, which proceeds from the differences of structure displayed in this portion of the body. The muscular system differs in insects with a free prothorax from that of those with an immovable connate one; to which we may add the muscles of the limbs, which likewise all lie in the thorax, and a portion of which pass to the wings and the rest to the legs. We have thus four main divisions into which the muscular system of the thorax may be separated: we will therefore commence with the system observed in insects with a free prothorax.

§ 176.

Muscles of insects with a free prothorax.

The prothorax exhibits on each side four muscles, whereby it is held connected with the meso- and metathorax.

The largest or superior retractor (retractor prothoracis superior) originates from the centre of the mesonotum with a broad basis, and runs pyramidally to the prothorax or the anterior partition of the mesonotum.

Opposite to it there lies a smaller lower retractor (retractor prothoracis inferior), which unites the internal furcate process of the pro- and mesosternum.

The elevator (elevator prothoracis) is a small pyramidal muscle, which originates on each side from the exterior margin of the prothorax, and affixes itself to the corresponding fork of the prosternum.

The fourth and largest of all, the rotator (rotator prothoracis), comes from the posterior margin of the pronotum, passes beneath the prothorax, and affixes itself to the exterior edge of the mesothorax or the anterior portion of the metathorax.

The mesothorax, which, in the beetles, is the smallest portion of the thorax, has but few muscles which unite it with the metathorax.

One, the holder of the mesonotum, is a flat, thin but broad muscle, which passes from the posterior wall of the prothorax to
the mesophragma. Another, which may be called the withdrawer, goes from the lower margin of the prothorax to the wings; passing in its course closely to the exterior margin of the meso-
phragma, it assists to expand the wings, and at the same time
drags the mesothorax closer to the metathorax. Another holder of
the mesosternum, corresponding with that of the mesonotum, originates
from the posterior wall of the furcate process, and passes to the an-
terior portion upon the metasternum. (Le prétracteur de l’apophyse
épisternale postérieure of Straus.)

The muscles of the metathorax are considerably larger. They may
be considered as the stem of the entire trunk of the beetle, to which
the other parts are all attached. It is thence that the true muscles of
the metathorax serve only for its own consolidation and strength, and
not for its connexion with other parts.

The largest and strongest of all is the dorsal muscle (musculus
metanoti, l’abaisseur de l’aile of Straus), a thick powerful fleshy
bundle, which passes from the entire mesophragma to the metathorax.
It falls properly into two halves, one of which belongs to each side of
the thorax, but both join together at the central line.

The lateral dorsal muscles (musculi laterales metanoti, les prétrac-
teurs de l’aile of Straus) do not much yield in size. These originate
from the lateral portion of the metanotum, descend obliquely to the
metaphragma, and thus consolidate the dorsal plates.

The third connecting muscles of the metathorax run from the sides
of the metanotum to the side of the metasternum, but so that they
originate at the anterior margin of the metanotum, in front of the last-
named muscle, and pass obliquely to the posterior lateral part of the
sternum, and, consequently, to the cavity of the posterior legs. They
are divided into several bellies lying contiguously, all of which closely
unite the dorsal plate and sternum together, and, by their contraction,
they appear very much to promote respiration. I call them the lateral
muscles of the metathorax. They are what Straus calls les elevateurs
de l’aile.

We have already mentioned one muscle connecting the meta- with
the mesothorax. Besides which, we find thin prismatical muscles,
which, originating at the furcate branches of the internal process of the
sternum, pass transversely to the sides of the dorsal plates, and thereby
unite it still more strongly with the sternum. They encompass below
the intestinal canal and above the straight dorsal muscles, and insert
THE MUSCULAR SYSTEM.

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themselves contiguously to them at the mesothorax. They are most
distinct in the grasshoppers and Termites. In the Coleoptera several
are found upon each side, some of which come from the front and others
from behind from the back. I call them furcate dorsal muscles (mus-
culi furci-dorsales.) They are the fléchisseur latéral de l'apophyse
épisternale postérieure, l'abaisseur du tergum, et l'abaisseur du dia-
phragme, of Straus.

§ 177.

THE MUSCULAR SYSTEM OF INSECTS WITH A CONNATE THORAX.

While in insects with a free prothorax the greatest portion of the
entire thorax is occupied by the metathorax, in those orders in which
the thoracic case is closely united together, the mesothorax preponderates
in a like manner. The Cicada make the transit to this conformation,
for in these insects, although they possess a free and moveable pro-
thorax, still the greatest space is occupied by the mesothorax. The
large muscles of attachment and muscles of connection consequently lie
in the mesothorax in insects of this structure and in the Hymenoptera,
and indeed between the prothragma and the mesophragma, or, when the
former is very small, between the mesonotum and the mesosternal plate.
In the first case, it is the dorsal muscles which are chiefly developed,
and, in the latter case, the lateral muscles of the back. We thus find it
in Cicada, whose enormous lateral muscles of the back nearly entirely
supplant the true muscles of the sides. In the Lepidoptera, on the
contrary, the true dorsal muscles are the largest, although the pro-
thragma is but small: they consequently originate from the anterior
portion of the mesonotum, and so increase that they occupy two-thirds
of the thoracic cavity. In the Diptera, lastly, the lateral muscles are
very large. They originate, as is always the case, from the lateral
ridges of the mesonotum, and pass on to the mesosternum in front of
the cavities of the coxae. In Eristalis tenax I have distinguished two
separated lateral muscles on each side, the most posterior of which
inserts itself between the cavities of the intermediate and posterior
coxae. But this is possible in the Diptera only, for in them the meso-
thragma is wanting, or, rather, is so small, that it may be considered as
deficient. The dorsal muscles, therefore, are also distended between
the mesonotum and the metathragma, but do not run parallely with
the former, but incline more obliquely downwards.

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The connecting muscles of the sternal processes exhibit no other differences than that the smaller these processes become, the more they also decrease in size. In general, these processes are very small in the above orders, and it is thence, probably, that I could never discover in them the furcate dorsal muscles, if these positively exist, which I feel much inclined to doubt from the course of my observations.

§ 178.

MUSCLES OF THE WINGS.

The true muscles of the wings originate, like the lateral muscles, from the lateral parts of the sternum, and pass on with pointed tendons to the ribs of the wings. We find their extensor the most developed, and their flexor the least so.

The large extensor of the wing (extensor alae magnus) originates inwardly from the lateral portion of the sternum, closely contiguous to its internal process, and proceeds transversely to the large marginal rib of the wing, inserting itself at a plate-shaped tendon, which hangs in immediate connection with the base of this marginal rib. (Pl. XI. No. 3. f. 3. a.) If the anterior wings be the largest, as in the Hymenoptera and Lepidoptera, the dorsal muscle of the anterior wing is likewise the largest; but if the posterior wings are wanting, as in the Diptera, their extensor is also wanting; and if both are of equal size, as in the Libellulae and the majority of the Neuroptera, their extensors also are of equal size; but if the posterior wings are the largest, as in the Coleoptera and Orthoptera, this is likewise the case with their extensors. The extensor of the elytra is, for instance, very small, whereas the extensor of the wing is of great size.

The small extensor (extensor alae parvus) originates behind the larger one from the lateral part of the sternum, or, frequently, from its inflexion, formed by the cavity of the coxa, it runs contiguously and parallel with the larger one as far as the articulation of the wing, and likewise inserts itself, by means of a plate-shaped but smaller tendon, to the second or posterior chief rib of the wing.

The flexors of the wing (flexores alae) are much smaller: they originate from the parapleura, or, where this is not separated, from the superior part of the lateral process of the sternum, and insert themselves at the posterior margin, or upon the horny plates lying at the base of the wing. In the Coleoptera, the flexor of the posterior wing consists
of three bellies, which pass like three rays from the pleura, and insert themselves at the most posterior horny piece lying at the base of the wing (the *axillaire troisième* of Straus).

Besides which, small muscles support the bending back of the wing, and which originate from the plate-shaped tendon of the large extensor, inserting themselves at other horny plates at the base of the wing: when in action they cause the relaxation of the extensors, and are thence called *relaxalores extensorum*.

§ 179.

**MUSCLES OF THE LEGS.**

The motive apparatus of the legs is much more complicated, both from their being so much more moveable, and from their consisting of several consecutive joints.

The coxae or hips receive the majority of muscles, but which are adapted to the variations of their connection with the sternum.

If they, as in the *Coleoptera*, consist of a cylinder revolving upon its axis, the flexor of the fore legs are placed at the posterior margin of their inner aperture, and the extensors at the anterior margin; but in the posterior pair, the latter are placed at the posterior margin, and the former at their anterior. Both come from the lateral parts of the notum, or from the internal processes of the sternum. In *Melolontha*, Straus found in the fore legs, which, in all beetles, have the freest motion, four extensors, which differed in size, and all came from the posterior part of the pronotum, and but one flexor; in the intermediate pair, three flexors and two extensors, the longest of which came from the margin of the prothorax, and the shortest from the internal process of the sternum: the posterior coxae had, again, four extensors and three flexors, some of which originated from the internal process of the sternum, and the others from the dorsal and lateral plates. In the water beetles, the very large posterior coxae are intimately connected with the metasternum, and not articulated, from its receiving the enormous muscles which move the remaining portion of the leg. The muscles of the coxae are compressed by them, and the muscles which move the leg pass from the internal process direct to the trochanter.

Such coxae as are free do not differ in structure from those which are received within a cavity of the sternum, with the exception, that their aperture exactly corresponds with the aperture of the sternum.
Their motion is rendered thereby indeed somewhat greater, but it consists chiefly in revolving about the axis of the superior aperture of the coxa; and in such coxae we find likewise flexors which are inserted at the posterior, and extensors at the anterior margin of the aperture, or reversed, the latter behind and the former before; and between both, the articulating balls are found. But the muscles of motion appear merely to proceed from the inner processes of the sternum.

The muscles which move the trochanters lie in the coxae, the extensors on the exterior, and the flexors at the interior. In Melolontha, Straus found in the first pair of legs three extensors and one flexor; in the two posterior pairs, however, but one flexor and one extensor. The Dytici possess the largest muscles to the trochanters. In these insects I found the extensor originate not from the coxa, but from the lateral branch of the large furcate process, whereas, the weaker flexors sprung from the inner-surface of the coxae.

In the trochanter there is but one muscle the tendon of which is inserted upon the head of the femur protruding into the cavity of the trochanter, and it thereby lifts the thigh when it contracts, but lets it fall again when lax.

In the thigh itself there are two muscles, one extensor, which lies at the upper margin of the thigh, and which is attached to the superior head of the tibia, by means of a long tendon, that lies within the muscle, and one flexor, which lies opposed to it at the lower margin, and which is correspondingly attached to a lower ball of the tibia. In Locusta these muscles are very large, and have large bellies at their base, varying according to the form of the thigh; the thin membrane lies quite free for about one-third of the length of the femur, but it receives above, close to its connexion with the tibia, where the thigh is somewhat broader, a narrow flat auxiliary muscle, which springs obliquely from the case of the thigh, and attaches itself to the tendon.

In the tibia there are also two muscles, which move the whole foot. The extensor of the foot is the smallest; it originates from the lower half of the posterior and lower margin with a broad basal surface, it becomes pyramidal, and attaches itself to the superior margin of the first joint of the tarsus. The flexor of the foot originates above it at the same spot; it soon becomes more slender, and with its free tendon it passes into the cavity of the first joint of the tarsus, it sends its tendon on through this as through all the consecutive joints, and inserts itself at an arch in the last joint, where the two claws are internally
connected; it consequently bends the whole foot, whereas the extensor, by drawing the first joint, again extends it.

In the last tarsal joint we again find peculiar muscles, viz., one which originates from the base of the claw, and affixes itself to the tendon of the tarsal flexor. It helps to bend the claws, and is thence called flexor unguinum. The other originates with a broad base from the inner wall of the superior surface of the claw-joint, and runs, becoming pyramidal, to an arch connecting the two claws. It raises the claw, and is therefore styled extensor unguinum.

§ 180.

C. Muscles of the Abdomen.

The collective muscles of the abdomen serve partly to connect it with the thorax and partly to unite the internal organs with it, and they are thence divided into three groups.

The muscles which unite the abdomen with the thorax are, when the abdomen is sessile, like all the abdominal muscles, flat, and like bands, and originate from the posterior and lateral margins of the thorax, affixing themselves to the first segment of the abdomen.

Those situated at the dorsal surface, which we call the superior connecting muscles of the abdomen (musc. conjungentes superiores, s. dorsales), are divided into several contiguous bellies, which run flatly from the metanotum and metaphragma to the first dorsal plate. The lower connecting muscles, which lie upon the ventral surface (musc. conjung. inferiores, s. ventrales), come from below, from the posterior margin of the metasternum, and pass between the femoral cavities to the first ventral plate.

Between both lie the lateral connecting muscles (m. conjung. late-

rales), which come from the lateral margin of the metasternum and the lateral plates, and, passing into the cavity of the abdomen, uniting themselves to the lateral wings of the first or second ventral plate.

In insects with a petiolated abdomen all these muscles, it is evident, cannot be present, but instead of the dorsal muscles we find a single large band (funiculus of Kirby and Spence), which originates from the inside of the metaphragma as a pyramidal muscle, passing with its point through the hole at the end of the metaphragma, and affixing itself to a short tooth which lies at the anterior margin of the first dorsal plate (Pl. XII. No. 2. f. 9. a.). The dorsal and ventral plates of the first abdominal segment are prolonged into a broad upwardly
bent and gradually widening process, which is provided on each side with a longitudinal groove (the same, b.), to which a corresponding process of the inner margin of the metaphragma fits. Besides the abdomen and thorax are still more intimately bound by means of a flexible membrane surrounding the large aperture (the same, fig. 7 and 8, a, a.). I have also plainly distinguished two flat lateral muscles, which pass from one part to the other.

The connecting muscles of the abdominal plates may be divided into the dorsal and ventral muscles.

The dorsal muscles are two large, broad, but flat band-shaped muscles, which run from the first to the last abdominal segment, and are throughout intimately united with the connecting membrane of every pair of plates.

The ventral muscles are smaller, and do not pass in one line, but only between every two contiguous ventral plates, taking an inward oblique direction, so that their exterior boundary forms a zig-zag line.

I also found in Locusta transverse ventral muscles, which originating from the descending ends of the dorsal plates, run transversely across the ventral plates. They contract the cavity of the abdomen, and thereby especially promote expiration. The abdominal muscles in general seem less to connect the segments than to promote the freer expiration of the air.

The remaining muscles of the abdomen, which raise and sink the last plate, and at the same time unite the cloaca with the surrounding parts, are subjected, like that organ itself, to so many differences, that a general description will be possible only when a tolerable number of insects of all orders and families shall have been examined. From all observations hitherto made it appears that both the dorsal and ventral plates receive an extensor and a flexor, which originates from the penultimate plate, and affixes itself to the terminal one, the former more exteriorly and anteriorly, and the latter more interiorly between the preceding, and extending further to the apex.

The muscles of the cloaca and of the colon originate from the circumference of those organs, and pass as broad and flat bands to the dorsal and ventral plates, surrounding them. Both only serve to retain the cloaca and colon in their places when the faeces are voided from the latter, or when the vagina or penis are protruded from the former.

The muscles peculiar to the penis and the vagina, lastly, differ as
much in form as those organs themselves. We have already taken a general notice of them in our description of those organs. Different layers are detected in them, the exterior of which retains and turns back the prepuce; the inner ones, which lie between the valves themselves or pass on to them, open and shut them. Straus, in his anatomy of the cockchafer, has given a very elaborate description of all these muscles as they are found in that insect, and which is the less desirable to be repeated here, as from the (indeed but limited) investigations made by myself in other insects, they are subjected to very considerable differences. The more comprehensive representations of all the modifications of the external as well as internal sexual organs, which it purpose one day undertaking, will then serve to fill this gap, and until then these indications may suffice.

§ 181.

THE MUSCULAR SYSTEM OF LARVAE.

The muscular system of the larvae of those orders of insects having an imperfect metamorphosis agrees with that of the perfected creature, with the exception of the mere indication of the presence of the muscles of the wings; we have therefore nothing further to say of them than that these muscles of the wings, during the several moltings, and particularly during the pupa state, acquire the size they are intended to retain during the imago state of the insect.

But the muscular system of the other orders, particularly of the Lepidoptera and Hymenoptera, is very different; the larva of the Coleoptera display much more conformity with that of the developed beetle, for they are of all the most perfect larvae, and in the structure of their feet agree very much with their perfected state.

The most conformable muscular distribution in all larvae is found in the abdomen, in which two straight, broad, band-shaped muscles descend both the ventral and dorsal sides and connect every two segments together, the muscle itself being intimately united with the connecting membrane of the several segments.

Beneath these two large muscles, which may be called the longitudinal muscles of the back and belly, lie smaller ones, which pass obliquely from the connecting membrane at the anterior margin of a joint to the corresponding part of the posterior margin of the same joint, which may be therefore called the oblique dorsal and ventral muscles. They strengthen the connexion of the joints together, and
contract the body during expiration. They appear to be wanting in smaller coleopterous larvae, which are enveloped in a horny case; in the robust fleshy caterpillars there lies beneath them a third layer of muscles, which take the same direction as the preceding, but differ from them by their shortness and their separation into several parallel fasciculi. They may be called the smaller oblique dorsal and ventral muscles, and those above described as the larger superficial ones, and the smaller ones as the deeper.

We observe, besides these ventral muscles which run parallely in the longitudinal axis of the body, others which connect the dorsal plate of each segment with the ventral plate. They originate contiguously to the deep oblique ventral muscles with a broad basis, contract pyramidal by degrees, come then outwards, close to the direct ventral muscles, and ascend on the outside of the straight dorsal muscles to the dorsal plates, inserting themselves contiguously to the deep oblique dorsal muscles upon the dorsal plate. I call them musculi ventrodorsales. In larger caterpillars, for example, the Cossus ligniperda *, we can distinguish several layers and bundles of these muscles, and it consequently is not difficult to make the number of the muscles of a caterpillar amount to 4061 if, as Lyonet maintains of the goat-moth caterpillar, each particular fasciculus be a distinct muscle †.

Exteriorly, contiguous to these muscles, there lie beneath each other, and close to the lateral wall of each segment, several fasciculi of oblique and crossing muscles, which strengthen still more the connexion, and which, from their situation, may be called the lateral muscles. With their diverging ends they embrace the spiracles of the caterpillar, and they appear to assist chiefly in closing them after expiration.

The muscles of the three first segments, which subsequently form the thorax, are more numerous, for besides the usual connecting muscles we here also find those of the legs, as well as the commencement of the future muscles of the wings.

The longitudinal dorsal and ventral muscles are here in general narrower, that they may make room for the other muscles, yet they so

* Consult Lyonet, Traité Anatomique, &c. à la Haye, 1760, 4to. Pl. vi. vii. & viii.
† According to Lyonet, the number of muscles found in the head amount to 228, those of the body to 1647, and those of the internal organs to 2186, making an aggregate of 4061. Traité Anal. p. 584.
develope themselves, at least the dorsal ones, and particularly during the pupa state, that they subsequently present themselves as the large dorsal muscles, distended between the phragmata. The straight ventral muscles, on the contrary, so contract together, that they transform themselves into the small connecting muscles of the internal sternal process. The lateral muscles again enlarge, and then exhibit themselves as the large lateral muscles of the thorax.

The crossing pectoral muscles are peculiar to the thoracic segment. They are the small band-shaped muscular strips on the pectoral side, originating from the posterior margin of the first thoracic segment, and running obliquely to the lateral parts of the following thoracic segment. With their lower shanks they embrace the nervous cord, and cross each other precisely over it, that coming from the left passing over to the right and those from the right to the left; each passes directly through the straight ventral muscle, and affixes itself to the exterior wall of the segment. In the perfect insect they exhibit themselves as the above described furcate dorsal muscles. In the larva of Coleoptera I found besides transverse pectoral muscles, which originating at one side of each of the three thoracic segments passed over to the opposite side, and in the first and third segments covered the nervous cord, but in the second were covered by it. I have not detected its development and conformable appearance in the perfected insect.

The muscles of the legs correspond evidently with those of the perfect insect. The profoundest, or muscles of the coxae, come from the lateral parts of each segment, and insert themselves at the inner margin of the ring of the coxa. In larva with long and large legs there is found at the inner lateral part of each thoracic segment a projecting horny ridge, which passes over the cavity of the coxa, whence spring all, or at least the more deeply seated, muscles of the coxae, whereas the superior ones pass over this ridge, coming from higher situated parts of the thoracic case. The muscles which move the thighs lie in the ring of the coxa, and form three or four narrow fasciculi; thus also in each successive joint is found the muscles of the third in advance. The last joint, or claw, the preformation of the subsequent tarsus, receives two muscles, which originate with several heads from the several rings of the foot, both from their superior and inferior sides, and all are attached to two tendons which are again attached to the inferior margin of the claw. Their common contrac-
tion bends the claw with great force, and retains it in this situation. We find no extensors of the claw joints.

The ventral feet of caterpillars receive, according to Meckel, three muscles, an anterior and a posterior one, which spring from the corresponding membrane of the ring, and attach themselves to the inner wall of the tube of the foot. The central one is larger than both the others, and originates from a higher spot of the lateral part of the segment of the body. It here originates with a broad basal surface, and runs down, contracting gradually as far as the centre of the foot sole. It admits of being divided into two halves, and has consequently been described by Lyonet and Cuvier as double.

The rudiments of the muscles of the wings are upon the whole very indistinct, and very difficult to discover with certainty among the many muscular strips of the thoracic segment. In the caterpillar of the Cossus I consider those muscular strips which pass obliquely from the posterior lateral margin, and anteriorly ascending upwards, as such incipient muscles of the wings; particularly as in the following ventral segments no corresponding muscles are found. I found similar strips in other larvae which I investigated, for example, in that of Calosoma sycophanta.

The muscles, lastly, which bend the head to the thoracic segment, and which move it, may, as in the perfect insect, be divided into an extensor, a flexor, and a rotator of the head.

The extensors of the head form several layers over each other, the most profound of which is nothing else than a continuation of the dorsal muscle, and which attach themselves to the superior margin of the large occipital aperture. Above these lies a narrower one, which distends posteriorly, being attached at the occipital aperture between the preceding, and originating at the anterior margin of the second thoracic segment. Other small strips, which lie above it, originate from the centre of the pronotum, and pass over it to the corresponding margin of the occipital aperture.

The flexors form three similar layers. The innermost layer is a continuation of the longitudinal ventral muscle; the second, which runs obliquely, comes from the anterior margin of the second thoracic segment, and affixes itself between and beneath the former, at the
inferior margin of the occipital aperture. The third is formed by small muscular strips, which originate from the pectoral plate of the first segment of the body, and affix themselves beneath the former at the large occipital aperture.

The rotators are divided on each side into two fasciculi, the superior one of which springs more from the dorsal side, and the inferior one from the pectoral side of the first segment of the body, and insert themselves in the skull, closely contiguous to the margin of the occipital aperture. The inferior ones are in general the shortest bundles, and the superior ones the weakest. They both appear to me to be merely modifications of the oblique lateral muscles, as those profounder extensors and flexors may possibly be merely transformations of the oblique dorsal and pectoral muscles.

The muscles lying in the head itself, which move the oral organs and the antennae, agree so much in form, situation, and insertion with those above described belonging to the perfect insect, that their small divergences, which proceed from the less developed state of the skeleton of the head, require no further notice, particularly as they stand in precise connexion with the various forms of the head, and their special description consequently exceeds the boundaries of our object. We must here, however, notice of the apparently headless larvae of the Diptera, that the most anterior membranous segment of the body takes the place of the head, and that its anterior orifice is the mouth, which is armed with several, generally four, frequently bent setae, which receive their peculiar extending and withdrawing muscles. They lie withdrawn in the bag-shaped oral cavity, and appear, from their darker colour, through the pointed anterior end of the larva as a black body.

FOURTH CHAPTER.

OF THE ORGANS OF SENSATION.

§ 182.

The organs of sensation are the last portions of the bodies of insects that we have to examine, and at the same time also the most simple; for the commerce of insects with the external world, although consi-
derably more multifarious than in any other invertebrate animal; yet it does not unfold itself to that universal intercourse found in the superior animals. But they are nevertheless sensible to every possible external impression, and indeed for many more sensibly than the class of fish immediately above them, which, however, and this supports the above assertion, are provided with distinct organs of hearing and of smell, which are wanting in insects, although they require them much more in the so considerably more tenuous element they inhabit, than the fish, which pass their lives as it were concealed.

It is thence evident what we understand by organs of sensation, namely, all forms which may be considered either as direct conductors of immediate feelings, or as the recipients of higher and more distant perceptions. To the first we may class the nerves, to the last the organs of the senses, and in insects especially, the eye.

The nerves, which are the foundation of all the organs of sensation, consist of fine fibres, which appear to be composed of the consecutive disposition of solid globules. These atoms, from which all nerves appear to be originally formed, preponderate so much in insects, that we never detect in the ganglia and in the nervous cords but rarely a fibrous formation, which would admit of the conclusion of its being formed of a concourse of individual threads. The nervous mass is contained within a very delicate structureless and perfectly transparent membrane, the nervous sheath (neurilema), which appears to be the mould of the entire nervous system, at least in insects. In it the nervous mass is enclosed, which is a soft pulpy substance which flows out when the sheath is opened. Upon a first superficial examination, the chief nervous cords of insects, at least both the large ventral cords, appear to be formed of several contiguous fibres, parallel stripes being observable in them; but these disappear upon a closer inspection, and each nervous cord is found to be nothing else than a tube formed of the nervous sheath filled with the nervous mass. The apparent striature proceeds from the globules not being irregularly placed, but disposed in longitudinal rows. Thus individual nervous cords appear, and they even become so when, as in the superior animals, the mass thickens, and thereby presses the globules together, and the neurilema falls down between the striae.

The nervous mass itself consists of two different substances, namely, the firmer, white central mass, and the softer, darker-coloured cortical substance, and which is sometimes of a beautiful carmine, according to
my observations in the caterpillar of Noctua Verbasci*. But they can be clearly distinguished only in recently opened insects: in those which have been long immersed in spirits of wine, the former darkens by degrees, and the latter becomes discoloured, so that neither exhibit any longer a difference. The cortical substance appears to be deficient in the filaments, and merely the white milk-coloured core appears to be present: these, therefore, are in general brighter, and do not at all participate in the colouring of the ganglia.

With respect to the general form of the nervous system of insects, it presents itself as a double cord running along the ventral side, which from segment to segment is re-united by ganglia. Two of these ganglia lie in the head, one above the pharynx, the other beneath it, and together form the brain, whence pass the nerves of the senses to the eyes, antennæ and oral organs. In the same way there spring from each of the successive ganglia a number of lateral branches, which are subjected to manifold differences, the three first of which pass to the legs, wings, and muscles of the thorax; those of the following ganglia to the muscles of the abdomen, to the posterior end of the intestinal canal, and to the organs of generation. The anterior portion of the canal, namely, the crop and the stomach, has its peculiar nervous system, which is formed by several auxiliary ganglia lying in the head.

Our investigation of the nervous system will thence fall into the following subdivisions.

1. The brain with the nerves of the senses originating from it.
2. The ganglionic ventral cord with its branches.
3. The nervous system of the oesophagus and stomach.

To this we may add the organs of the senses themselves, of which the eye alone will require a particular description; as for the majority of the remaining senses, no determinate organs have yet been fully ascertained.

* This reminds us of the red nervous points in many of the lower animals, namely, the Infusoria, especially the Rotatoria. Ehrenberg, in his admirable work upon these beginnings of organisation, considers these red points as eyes, but they are evidently nothing but a mass of the nervous substance.
I. THE BRAIN.

§ 183.

The brain (encephalum) of insects consists of two ganglia, one of which passes over the pharynx and the other beneath it; both are connected by means of nervous cords, which run from the upper to the under, and which embrace the oesophagus. I consider that which lies above as the cerebrum of the higher animals; the lower one, on the contrary, as the cerebellum: and, indeed, because, as in the higher animals, the nerves of the superior organs of the senses, namely, of the eye, spring from the upper ganglion; and from the lower one, on the contrary, the nerves of the mandibles, lips, and tongue proceed. It must not appear strange that the nutrimental canal passes through the brain, particularly as the entire spinal cord lies beneath the intestinal canal, and that the entire dorsal side of the higher animals is transferred to the ventral side of insects. We are convinced of this by the situation of the limbs and their connexion with the thorax, which also takes place at the ventral side, whereas, in the superior animals, they pass from the back, and, besides, the structure of the plates of the breast, which so completely imitate the spine of the superior animals that no doubt can be fairly entertained of their analogy, and of which we shall speak more fully below. But whosoever should think the assertion absurd that the oesophagus passes through the brain, we will merely remind him of the certainly still more striking circumstance in the mollusca, in which the colon passes through the heart, an assertion which has found no contradiction, although both organs in the higher animals are far more distant from each other than the brain and oesophagus.

§ 184.

The Cerebrum.

The cerebrum (Pl. XXXI. and XXXII. A, A, A) is a nervous cord of a yellowish white colour, lying transversely across the oesophagus.
THE CEREBRUM.

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generally forming two ganglia. This cord sends off a branch on the opposite sides to each eye, which is the optic nerve. Its entire circumference is covered by a thin transparent membrane, which loosely surrounds it, and which in many cases, as for example, in Dyticus, is beset with small darker knots, placed in regular squares (Pl. XXXI. f. 1). The large muscles of the upper jaw spread above it, extending upwards to the skull, so that it is entirely covered by soft parts. The general form of the brain varies in as far as the two hemispheres are more or less separated. In the Coleoptera they approach closely together, and indeed so closely that they form but one stripe, which is merely swollen on each side near the middle; in other instances, as for example in Gryllus migratorius, the two hemispheres are nearly entirely separated, and are attached together by a central thin nervous cord only, analogous to the corpus callosum of the superior animals. The nerves which pass from the cerebrum are:

1. The nerve of the antennæ (nervus antennalis). It originates from the anterior margin of each hemisphere, but more exteriorly when the antennæ are lateral, and centrically when those organs are inserted in the face. It runs as a simple undivided filament, which in the first case passes over the tendon of the mandibles, and in the last proceeds contiguously to the great flexor of the mandibles, to the root of the antennæ, immediately beneath the membrane which connects it with the clypeus, but yet without sending off branches. In many cases it is equally thick throughout, in others, for example in the bees and the cockchafer, it is more or less swollen at its base. When arrived at the antennæ the main stem still runs in this direction, and very distinctly to the apex of the organ, and between the muscles, but it gives off on all sides delicate auxiliary branches to the muscles themselves. It is accompanied by a single branch of the trachea, which originates on each side from the superior stem of the head, running between the flexors of the mandibles, and branching off according to the ramifications of the nerve itself.

2. The optic nerve which originates from the lateral margin of each hemisphere, with either a thicker or a thinner base, and extends to the orbit, becoming gradually clavate. It varies much in form, but it always retains the general characteristic of gradually distending. In Dyticus it originates with a thin base, then suddenly distends, and afterwards runs as a straight cylinder to the orbit; in Melolontha it is not perceptibly distinguished from the hemisphere of the brain, nor is its dis-
tension towards the orbit very distinct; in Locusta the cerebrum is smaller than the optic nerve, which springs from it with a very narrow base, but which then very suddenly widens into a cone; this is precisely the case also in the Libellulae and flies which possess large eyes and a small skull, and in which the optic nerve of one eye is generally much larger than the entire cerebral ganglion. When arrived in the orbit it radiates into many branches, as we shall describe more fully below, in the detailed description of the eye. The auxiliary optic nerves (nervi optici secundarii), which are peculiar to such insects only that possess stemmata, originate from the central portion of the cerebrum, and extend as simple and very thin filaments to the spot where the stemmata are situated, and gradually diverge from each other. Thus each eye receives a distinct nerve, but which with its colleagues originate from one portion of the brain. It is well known that all the larvae of insects with an imperfect metamorphosis possess merely stemmata, which are placed where subsequently in the perfect insect the large reticulated eyes are found. The nerves of these stemmata spring from the lappet-shaped distension of the cerebrum, sometimes separated (Calosoma, Pl. XXXII. f. 1), sometimes united at the base (caterpillars of the Lepidoptera), and run, each singly, to an eye. In Vespa the nerves of the stemmata have a common stem (Pl. XXXII. f. 7.); in the bees they sit upon short clavate projections of the cerebrum, and a distinct nerve does not seem to originate from these knobs *. In the neuter bees we find close to these large knobs two other small ones on each side, but which do not rise to the stemmata.

Besides these two main branches no other true nerves of the senses originate from the cerebrum; we observe merely smaller ramifications, which give off branches partly to the muscles and partly form filaments connected with the nerves of the cerebrum, and lastly, they may be partly considered as the commencement of the nervus sympathetic. But as below we shall devote our attention to this last system we will reserve our investigation of its origin from the nerves of the cerebrum until then.

The cords which connect the cerebrum with the cerebellum originate from the lower or deeper portion of the ganglion, as the nerves of the antennæ do from the anterior or superior portion, and after the optic
nerve the former are the thickest of all the nerves it gives off. Their
direction as well as origin depends upon the situation of the head, for
upon its horizontal position they spring further below from the cere-
brum, but upon its vertical position we find them originate from its lower
surface. Their length also stands in direct proportion to the form of the
oesophagus; they are long in broad and expansive ones, and shorter in
narrower ones. This is peculiar to haustellate insects, and in them
therefore both the ganglia lie closely together. We observe this
approximation of the two very distinctly in the bees, in which the
connecting cord is nearly deficient, so that the cerebrum and cerebellum
are quite contiguous, and there only remains in the middle between
both a small aperture for the oesophagus. These connecting cords of
the two brains very rarely give off auxiliary branches. I have observed
the only instance of this kind in Gryllus migratorius, in which a
smaller auxiliary branch originates at a little beyond half its length
upon the inner side, which is united with its opponent beneath the
oesophagus, running closely to that organ itself. Immediately in front
of their point of connexion each again gives off a smaller branch, which
runs back to the main connecting nerve of the two ganglia (Pl. XXXI.
f. 7. d, d. and d*, d*).

§ 185.

THE CEREBELLUM.

The cerebellum (Pl. XXXI. and XXXII. b, b,) is generally a
cordiform or longitudinal ganglion; it lies at the base of the cavity of
the skull, between the two projecting ridges of the previously described
internal skeleton of the head, and is entirely covered by the tentorium.
At the anterior portion of its lateral margin two strong nervous cords
originate from it, which rise to the cerebrum, running contiguously to
the tentorium, and enclose the oesophagus between them, forming the
nervous loop described above as encircling it. At its posterior end,
however, it again runs in two equal and very approximate filaments,
which pass through the occipital aperture, beneath the transverse bone
which divides it when present, out of the head into the thorax; they
lie consequently very low in the neck, closely above the membrane of
the neck and the flexor muscles of the head. They are the origin of
the ganglionic nervous cord which runs along the pectoral and ventral
sides of the body.

Between these two connecting nerves of the cerebellum with the
portions of the nervous system lying before and behind it, there originate from it on each side from two to four nervous stems, which pass to the mouth and the muscles of the head, and terminate in the various organs constituting the mouth; they are:

1. The nerves of the mandibles (Pl. XXXI. and XXXII. e, e), which pass out of the anterior portion of the cerebellum, sometimes between the branches of the loop of the oesophagus (Melolontha, Pl. XXXI. f. 5.), sometimes from the exterior margin, contiguously to them (Calosoma, Pl. XXXII. f. 1.), and sometimes closer to the posterior margin, beyond them (Gryllus, Pl. XXXI. f. 7.). They give off several delicate auxiliary branches to the flexor and extensor muscles of the mandibles; and lastly, accompanied by branches of the trachea, they pass into the cavity of the mandibles themselves, between the tendons of both muscles. In the caterpillar of Cossus, according to Lyonet, the nerve of the mandible comes in a remarkable manner as a branch from the labium, and this receives four main stems (Pl. XXXI. f. 2. e, e).

2. The nerves of the maxillae (Pl. XXXI. and XXXII. f, f, and f*, f*) originate sometimes in front (Calosoma, Pl. XXXII. f. 1.), sometimes behind (Melolontha and Gryllus, Pl. XXXI. f. 4. and 7.), the nerves of the mandibles from the cerebellum, and run closely to these to the maxillae, taking their course between the muscles, and passing into the maxillae themselves. Here each divides, one branch going to the palpus and extending to its apex, the other remaining in the maxillae, spreading itself between its muscles. Sometimes (as in Calosoma, Pl. XXXII. f. 1. f, f and f*, f*) these branches are divided at their origin, and then the anterior one belongs to the maxillae and the posterior one to the palpi; both give off, even in the cavity of the head, several branches, which pass to the neighbouring muscles.

3. The nerve of the labium (Pl. XXXI. and XXXII. g, g.) comes, when separated from those of the maxillae, from the centre of the anterior margin of the cerebellum, and runs from here, very closely to its opponent, direct to the labium, and here divides itself into several, generally two, main branches, the inner one of which goes into the tongue and the outer one to the labial palpus. Where this nerve is wanting (Melolontha, Pl. XXXI. f. 5.) branches of the nerves of the maxillae supply its place, and this is precisely the case where the tongue is small, hard, and cartilaginous. But it struck me as more singular in the Locusta (the same, f. 7.), which, notwithstanding that
it is furnished with a large fleshy tongue, I could find neither lingual
nor labial nerves. In the caterpillar of *Cossus ligniperda* Lyonet,
observed a connexion of the two labial nerves before they passed into
the labium; from this point of connexion other branches originated,
which spread to the labium. Besides these the labium receives another
nerve (the same, f. 2. g, g.), which originates quite posteriorly, close to
the nerves of the maxillae, and gives off in front of the labium an auxi-
liary branch for the muscles lying in the head.

§ 186.

II. THE VENTRAL CORD.

The ventral cord (*medulla spinalis, s. ventralis*) presents itself as a
consecutive series of ganglia, every approximate two of which are
united by one or two equal nervous cords. In the last case, conse-
quently, this ventral cord consists of two equal nervous threads, which
from spot to spot are connected together, and form a common ganglion.
We have already spoken above of the structure of these ganglia and
threads, we will here merely add that I have never detected a crossing
of the two threads in the ganglion; they seem rather, upon their
entrance into it, to terminate, and the ganglion itself appears to con-
sist of a soft, uniform, granulated, nervous mass, which is enveloped
within a softer, frequently darker (for example, of a carmine colour in
the caterpillar of *Noctua verbasoi* ) cortical substance.

The numbers of the ganglia differ in the several orders and families,
but we may consider that there is properly one to every segment; hence
their number would amount at most to thirteen, and we find, in fact,
this number in many larvae, namely, in all the larvae of the *Lepi-
doptera*. Two of these ganglia lie in the head, and form the brain, the
three following in the thorax, and the last eight in the abdomen. Each
of them sends off two or three radiating nervous filaments, which or-
ginate at both its anterior and posterior extremities, diverge from each
other throughout their whole course, and distribute themselves to the
muscles, limbs, and several of the internal organs.

Besides the main cords which the ganglia form in conjunction, we
find between those which are chiefly seated in the segments of the thorax
other connecting filaments, as, for example, I have observed in the larva
of *Calosoma sycophanta*, and shall therefore particularly describe.
The first pair of these auxiliary connecting filaments originates from
the posterior portion of the cerebellum (Pl. XXXII. f. 1. a, b, h.),
closely contiguous to both the main stems; each diverges from the main stem in its course to about half its length, and then approaches it again as far as the spot where the main stem passes into the first thoracic ganglion, and then rejoins it. A delicate auxiliary branch of this exterior connecting nerve originates from it closely beyond its middle, passing to the first radiating nerve of the first thoracic ganglion, which it joins. The second connecting nerve (the same, i.e.) originates in the same manner from the first ganglion of the thorax as the first does from the cerebellum, and unites itself at a right angle with the first radiating nerve of the second thoracic ganglion. At their point of union a small ganglion is formed, from which two new radiating branches proceed, distributing themselves between the thoracic muscles. The third auxiliary connecting nerve (the same, k.k) springs from the posterior end of the second thoracic ganglion, and passes into the third ganglion, forming an arch near the main stem, from which from two to three small nerves originate, and distribute themselves to the muscles. An auxiliary nerve connecting the third thoracic ganglion with the first abdominal one is not to be detected.

§ 187.

If we turn back from this general inspection of the auxiliary connecting nerves of these ganglia, which, as far as I know, have not hitherto been observed in any other insect, and certainly do not exist in many, particularly the larvae of Lepidoptera, as may be adduced from Lyonet’s accurate anatomy of the caterpillar of the great willow moth, to the differences of the chief form of the nervous system, we may adopt the following as a very general law:—

The ventral cord has as many ganglia as there are freely moveable divisions of the body.

This law is everywhere confirmed. The caterpillars of the Lepidoptera, whose similar segments have an equal motion, have as many ganglia as segments. In the Diptera, in which the three segments of the thorax are united into one, we find but a single large ganglion; lastly, in the larvae whose thick fat bodies exhibit no distinct segments, the ganglia entirely disappear, and instead of a ganglionic we here find a simple thoracic cord, from which the fine nerves pass off on each side. We will inspect this in greater detail in the several forms of the nervous system and their transformation during the metamorphosis.

A simple short ventral cord, destitute of ganglia, is found in many
larvae of the *Diptera, Hymenoptera, and Coleoptera.* Among the larvae of the *Diptera* I have found it in the rat-tailed maggot, and have represented it in Pl. XXXII. f. 3. It commences with two branches, which spring from the large cerebral ganglion lying over the oesophagus. These branches, which embrace the oesophagus, unite beneath it into one flat, tolerably broad, nervous cord, which extends to about the third pair of feet on the pectoral side, within the thoracic cavity, and here obtusely terminates. On each side of this cord there are from eight to nine small ganglia, whence the nervous filaments, as also at the obtuse apex of the cord, radiate posteriorly. The last, proceeding from the end of the cord, are the thickest; they extend downwards to the end of the abdominal cavity, and here distribute themselves with their terminal branches to the colon and the convoluted tracheae lying at the end of the abdomen.

We should doubtlessly find a similar structure of the nervous system in the maggots of all the *Diptera* whose body is not divided into distinct segments. Upon the same principle, I think, I may conclude that the fat and irregularly-jointed larvae of the *Hymenoptera,* namely, of the bees and of the wasps, have a similar nervous system without ganglia, and thence it would be explained how Swammerdam could discover no nervous cord in the honey-bee *. In the larvae of Stratiomys Chamaleon the nervous cord is likewise indeed considerably shorter than the body, but it exhibits distinct ganglia, which, however, follow immediately upon each other, and display no long connecting cords, which we observe in the fly itself. According to Swammerdam's figure †, we find besides the cerebrum and cerebellum ten consecutive and contiguous ganglia, and each sends off radiating lateral nerves.

Among the *Coleoptera* we perceive a similar nervous system without ganglia among the larvae of the *Lamellicornia.* Swammerdam ‡ and Rösel observed it in the larva of the rhinoceros-beetle (*Oryctes nasicornis*); in these also it is a very short ventral cord, which extends as far as the proximity of the third pair of legs, and from the lateral margins of which innumerable delicate nervous filaments proceed. In this larva also the body is not separated into distinct segments and joints, it exhibits rather irregular folds and constrictions, which are

* Biblia Natura, p. 166. a.
† Ibid. Pl. XL f. 5.
‡ Ibid. Pl. XXVIII. f. 1.
very evident anteriorly, but nearly obliterated posteriorly. In the larvae of the Dytici I likewise found a short nervous cord with closely contiguous ganglia, whence the auxiliary nerves proceed, and yet their bodies exhibit twelve distinct segments without the head. Perhaps this imperfect development of their nervous system is in relation to their constantly dwelling in water; at least the same structure in the equally distinctly jointed larva of Stratiomys, which likewise constantly lives in the water, points to one and the same cause of an analogous imperfection.

The positive opposition to this abortion of the nervous cord is found in the caterpillars of the Lepidoptera and the larvae of many beetles. All these exhibit a ventral cord, which has as many ganglia as the body has segments, and in which, like the segments of the body, all the ganglia are of equal size. We must, however, here remark that a ganglion is not found in each segment, but that they gradually approximate together, so that the last ganglion, which follows immediately upon the preceding one without any connecting cord, is found as far advanced as the anterior margin of the penultimate segment. Each ganglion sends off four nervous filaments, the first pair of which extend more anteriorly, and the posterior pair furnish the parts lying behind the ganglion with their nerves. But the nerves of the ventral cord are almost exclusively destined to the organs of motion, and they consequently distribute themselves with their branches between the upper and lower layers of the muscles. In some cases the most internal muscles, particularly those lying about the cavity of the abdomen, receive a peculiar nervous branch, and which is found in the larva of Cossus ligniperda, and which here does not originate from the ganglion itself, but closely in front of it, from the there simple undivided connecting cord; it commences with a small root, which speedily divides into two equal branches, which take an opposite direction. In the larva of Calosoma sycophaanta I found six nervous filaments proceed from each ganglion, the middle pair of which likewise remained above the ventral muscles, whereas the anterior and posterior pairs passed beneath. The nerves for the anterior portion of the intestinal canal come from the cerebrum, and form a peculiar system, which descends that canal; the nerves of the sexual organs proceed indeed from the ventral cord, but merely from the branches of the

* Lyonet, Pl. IX. f. 1, 2, 2.
much-radiated terminal ganglion. We observe a nervous system composed of thirteen ganglia not only in the caterpillars of the Lepidoptera, but also in the larva of the Carabodea, the predacious beetles, the majority of the Heteromera (Meloë, Lytta), the capricorns, and probably also in the Chrysomela; in the fat footless larvae of the Curculios. I surmise there is only a short ventral cord destitute of ganglia.

§ 183.

We find every variety of number between these extremes of ganglionic structure. The law which regulates the number of these ganglia is still undiscovered; for that adduced byStraus, of its being regulated by the relative greater or smaller mobility of the segments, appears not to suffice: he maintains, namely, in general, that the immobility of the segments together causes the disappearance of all the ganglia; and as a proof he cites the families of the Dytici and Lamellicornia, whose abdomen has no ganglia; but is motion less in them than in the very approximate Carabodea and in the genus Lucanus? Certainly not! This less degree of motion might be ascribed to the ventral plates, and yet we find in the abdomen distinct ganglia. The number of active organs found in a segment would seem rather to influence it; at least we observe the ganglia of the thorax of perfect insects always larger when they are furnished with perfect organs of flight, but smaller than those of the abdomen when the wings and the muscles which move them are wanting, for example, Meloë*. It therefore appears preferable to describe the different forms of the nervous cord of perfect insects in the series of their orders and families, for within those boundaries we seldom observe variations.

The greatest number of ganglia is found in the nervous system of the Orthoptera, Termites, Libellulae, and many families of the Coleoptera, viz. the Carabodea, Staphylini, Elaters, Buprestis, and the Capricorns. In these the ventral cord exhibits immediately three ganglia, which lie in the three segments of the thorax. These differ in size, inter se, and indeed the smallest is found in the prothorax, the largest in the metathorax, and the intermediate size in the mesothorax. The ganglion of the prothorax lies immediately in front of the internal furcate branches of the sternum, at the very base of the horny plate, covered by the muscles which run from here partly to the head

and partly to the coxae. Between the branches of this process, or when it is distinctly furcate between the fork, the nervous cords pass, proceeding over the connecting membrane of the pro- and mesothorax, running closely to it, and thus proceed into the mesothorax, again forming the second ganglion in front of the internal process of its sternum. If the branches of the first sternal process be united in an arch the nervous cord runs beneath this arch, and above, the muscles affix themselves to the process of the arch (Locusta viridissima, Termes fatalis, Callidochromas moschatum). The branches of the second sternal process are not in general closed, the ganglion and cord consequently lie here freely, which is the case also in the third process. This, however, is higher than the preceding, often as it were pediculated, so that the ventral cord must raise itself that it may pass over this process into the abdomen. In front of this elevation the third ganglion then lies, immediately upon the surface of the sternum: it is the largest, and sends off the thickest nerves, and the second ganglion lies nearer to it than it does to the first, and thus, even in the nervous system, the more intimate connexion of the two posterior thoracic segments is clearly shown.

The nerves which originate from this ganglion vary in number; the first thoracic ganglion sometimes sends off two and sometimes three branches on each side. In the first case the first branch runs to the legs, the second to the muscles in the prothorax; in the second case both the first and third on each side are nerves of muscles, whereas the central one is the leg-nerve. Three branches are also found on each side of the second ganglion, the central one of which is a nerve of a leg, and the first and third pass on to muscles. It is probable that the anterior one gives off fine nerves for those contained within the hollow cavities of the ribs of the wings. The third thoracic ganglion also sends off three branches, which distribute themselves in a like manner. Of these the central or leg nerve is always the thickest, and most deeply seated, in as far as the direct muscles of the thorax, or the connecting muscles of the thoracic processes, pass over it; the others, on the contrary, raise themselves over these muscles.

The number of the abdominal ganglia varies considerably in the different groups. Insects with an imperfect metamorphosis, as the Locusta, Termites, and Libellulae, exhibit as many ganglia as segments, viz., from seven to eight, the two last of which, however, are so closely contiguous that they form one ganglion of a figure of eight. In the
coleopterous families with abdominal ganglia we find in general not merely fewer than the first named instances, but also fewer than in their larvae. During their metamorphosis, namely, either two ganglia appear to grow together, or else some wholly disappear; that may be the reason why the ganglia of the thorax are larger than those of the abdomen; at least the growing together of the third and fourth ganglia of the larvae of the Coleoptera is very probable, particularly as this union is proved to take place in the Lepidoptera during their metamorphosis by Herold’s history of that state of them. We therefore find in general in the perfected beetle only five ganglia, the two last of which are drawn so closely together that they form an eight-shaped ganglion. From each of these ganglia two undivided pairs of nerves proceed, which are rarely ramose at their extremity, and which, as well as the cord lying on the ventral plates, distribute themselves among all the viscera of the abdominal cavity near the surface of the plates. The radiating nerves of the last ganglion alone, which forms the analogue of the cauda equina of the superior animals, distribute themselves to the internal sexual organs and to the colon. In Carabus, Hydrophilus, Cerambyx, Lytta, and Meloë there are but these five ganglia, and never more.

Having observed in all these insects three distinct thoracic ganglia, one for each thoracic segment, we now come to those orders and families which have but two separated ganglia in the thorax. In the Coleoptera the large family of the Lamellicornia belong here. The accurate representation of the nervous system in Melolontha vulgaris in Straus* exhibits a heart-shaped ganglion lying in the prothorax, from which a robust nerve originates on each side, which speedily divides into several branches, the central thickest of which passes to the anterior leg, whereas the smaller ones distribute themselves between the muscles of the prothorax. The second ganglion, lying in front of the mesothorax, appears to consist properly of two closely contiguous ones, at least the aperture perceived in its centre evidently indicates an original separation. From the anterior division proceed the nerve of the intermediate foot and several branches for the muscles, as well as a nerve originating completely in front, which passes to the elytra; from the posterior division springs the nerve of the wing, which gives off branches to the muscles and the nerve of the posterior leg, which like-

* Straus, Pl. IX.
wise, sends off many branches to the muscles. A third, also cordiform ganglion, lies closely to the posterior division of the second, and is seated, as well as that, in front of the tridentiform process of the mesosternum; from it, as well as from the posterior margin of the preceding ganglion, fine radiating branches extend, all of which pass over the sternal process into the abdomen, and proceed to its ventral plates; two central thicker ones, the cauda equina, proceed to the sexual organs and the colon, distributing themselves there with many fine branches. The structure of the nervous system is similar in *Dyticus marginalis*: the prothorax has its own ganglion, which, by means of two thick and tolerably long nervous cords, is united to the cerebellum (Pl. XXXII. f. 2.). This ganglion lies always in front of the internal sternal process, and runs with its posterior cords through both its branches. The second ganglion, still larger than the first, lies precisely upon the mesosternum, in front of the commencement of its internal process; from it originate, as well as from the anterior, several nerves among which we distinguish at the first ganglion two large ones for the anterior legs (a, a), and at the second four thicker ones for the posterior legs (b, b. and c, c.). The nervous cord rises from this ganglion, runs between the branches of the sternal process, and lies here between the coxae as a short nervous cord with four ganglia, which somewhat increase in size, whereas the first is scarcely one quarter so large as the second thoracic ganglion. From the circumference of these four ganglia numerous nerves originate, particularly from the last, which, radiating, proceed to the apex of the abdomen, and especially distribute themselves about the sexual organs. These last four ganglia consequently belong, as well as the third in *Melolontha*, to the abdomen, but they, however, rise as high as the coxae, for here the most important muscles are found, whereas in the abdomen but few large ones are to be met with; on which account also in both cases the ganglia are wholly wanting in the abdomen.

This is not the case in the *Lepidoptera* and *Hymenoptera*, which likewise have but two ganglia in the thorax, but in them the abdomen also exhibits ganglia, namely, five in both orders, of which, however, the two last are also very approximate; and indeed in some cases, for example in *Philanthus pictus*, they are grown into one, so that in it we can detect but four distinct ganglia. The decrease of the ganglia in the thorax arises in the *Lepidoptera* from the growing together of most approximate ones, which takes place by degrees during the pupa
state. Thus, from the first and second ganglia of the caterpillar the ganglion of the prothorax originates, from the third and fourth the common very large ganglion for the connate meso- and metathorax; the fifth ganglion of the caterpillar, as well as the sixth, entirely disappear; the seventh to the eleventh are found likewise in the imago. The ganglion of the prothorax lies in both orders between the branches of the internal sternal process, and gives off, besides the thick nerve for the anterior legs, finer branches for the muscles; the ganglion of the meso- and metathorax lies upon the central surface of the sternum, it is very large, and somewhat long; many nerves spring from it, eight of which are particularly distinguished. Two and two form an equal pair; the first and third pairs go to the wings, the second and fourth to the feet, the remaining finer ones distribute themselves among the muscles; the last pair, lying closely to the connecting cord, passes with this into the abdomen, and distributes itself in its first segment by means of several filaments. In Bombus muscorum, according to Treviranus' figure *, the second thoracic ganglion consists of an anterior larger and a posterior smaller half; but in many of the Hymenoptera inspected by me, for example, in Vespa Germanica, I could not distinguish them, there was but a single large ganglion visible.

Lastly, there are insects in which but one ganglion is found in the thorax, these are the Diptera. In them it is known that the thorax is formed of but one undivided piece, which consists especially of the mesothorax, to which the very small pro- and metathorax are but appended. In the mesothorax also we find the chief muscles, namely, the large direct dorsal and alary muscles, and accordingly a single large ganglion, which lies upon the centre of the sternum, between the intermediate and posterior legs. It takes the form of a long ganglion (Pl. XXXII. f. 4.), from which spring six main nerves for the legs. I have not yet detected nerves for the wings proceeding directly from the ganglion; perhaps they may be branches of the nerves of the feet. From the posterior margin of the ganglion a simple strong nervous filament passes, which, running between the apertures of the coxae, proceed into the abdomen; closely before its entrance it gives off on each side a fine nerve, but in the abdomen itself it has no branch as far as the middle of its course. Here it first distends into a small ganglion, from which on each side a fine furcate nerve originates.

* Biologie, vol. v. Pl. L, II. and III.
second somewhat larger ganglion lies some little distance beyond the first, exactly between the sexual organs, and gives off branches to this as well as to the colon. This description has been sketched from the Eristalis tenax of Meigen; in Musca vomitoria I found precisely the same structure.

§ 189.

III. THE SYMPATHIC SYSTEM.

A peculiar nervous system, which hung connected with the cerebrum by means of fine branches, and in its course spread itself about the anterior portion of the intestinal canal, was formerly discovered by Swammerdam in the larve of the rhinoceros-beetle (Oryctes nasicornis *), and by Lyonet in the larva of the large Cossus †. Subsequent anatomists took no further heed of this discovery; and until Cuvier, who described some of the forms of these nerves, it was not again thought of. Since then J. F. Meckel, Treviranus, and Marcel de Serres have described this system in individual insects; but Joh. Müller claims the greatest merit for giving the details of this system in a distinct treatise ‡, having proved these nerves to be peculiar to many insects, and for having represented them in several orders. J. Brandt § has likewise completed the observations of Müller, and has given a well-executed representation of the various relations of the nerves in the caterpillar and imago of the silkworm. From these earlier contributions, and from my own individual observations, I deduce the following results:

§ 190.

The sympathetic system is peculiar to all insects, but in the several orders it takes a different form: we may distinguish in it two main divisions. A single cord, which runs upon the surface of the oesophagus and stomach, giving off delicate branches on all sides, and where the oesophagus passes through the brain running with the oesophagus beneath the cerebrum; and a double nervous web, consisting of ganglia,

* Biblia Natura, Pl. XXVIII. f. 2 and 3.
† Lyonet, Pl. XII. f. 1. h.
which originates on each side by one branch from the posterior portion of the cerebrum running down the oesophagus, and giving off here and there fine auxiliary branches to the single nervous cord. Both stand in a certain reciprocal relation to each other, in so far as where the double system preponderates the former diminishes, and where the single cord is considerably developed the double ganglia with their branches shrink up.

The single nervous cord is considerably most developed in the Coleoptera, Lepidoptera, and Libellulae. It here originates with two branches arched towards each other, springing from the anterior portion of the cerebrum, contiguous to the nerves of the antennæ. Both branches unite at the centre, and form a small ganglion (ganglium frontale), and from this the single nerve proceeds beneath the brain (Pl. XXXII. f. 6—8. a, a.). This, from its bending form, Swammerdam and Cuvier called the nervus recurrens. The arch is sometimes double, as in the silkworm (Pl. XXXII. f. 6 and 7.). In the Coleoptera, on the contrary, always simple (the same, f. 8.) ; but yet in both finer branches originate from this arch, which sink to the anterior wall of the oesophagus, and pass even into the labrum. In some Coleoptera, for example, Melolontha, these arching branches are so fine that they even escaped the accurate Straus; he detected but two delicate filaments to arise from the frontal ganglion, lying in front of the cerebrum, which appeared to bend about the oesophagus. I also have not been able distinctly to perceive in several beetles this connexion of the frontal ganglion with the cerebrum. When the filament has passed behind the brain it runs along the oesophagus as a simple cord, which nevertheless gives off everywhere very delicate auxiliary branches to the tunics of the oesophagus, as far as the stomach, and here divides itself into two equal branches, forming at the point of division a small ganglion, from which, besides the two main stems, many other smaller filaments proceed. Where the stomach commences in the craw, consequently in the predaceous insects, and at the anterior half of the large simple stomach in the vegetable feeders, its last very delicate branches terminate, for they sink between the tunics of the stomach, and there lose themselves; indeed, in the cases in which the oesophagus is tolerably long, they but just reach the stomach itself, without spreading themselves over it. This description of the distribution of the single nervous cord will suit also the Lepidoptera, for in them also it never extends beyond the commencement of the
stomach, but furcates shortly before this spot, and ramifies into the finest threads.

The double nervous system in these orders consists of four small ganglia, which lie directly behind the brain upon the oesophagus. The anterior generally somewhat larger ganglion (f. 6—8. b. b.) arises with one (Coleoptera) or two (Lepidoptera) branches from one half of the cerebrum, and sends outwards delicate branches about the oesophagus, but inwards a branch which unites itself with the single nervous cord lying between the two ganglia. The second smaller ganglion (the same, b*. b.*) stands in connexion with the first by means of a nerve of communication; it also sends off fine branches, which run along the oesophagus: indeed, in the Lepidoptera, it also unites itself again with the unequal cord. This last ganglion of the double system was discovered at the same time by Straus Durkheim, and Brandt: the first was discovered by Lyonet in the Cossus caterpillar, but its connexion with the single cord escaped him.

§ 191.

The double nervous system attains its most complete development in the Orthoptera, namely, in Locusta and Gryllus. In Gryllus migratorius (Pl. XXXI. f. 6.), there are found immediately behind the brain, upon the superior surface of the oesophagus, five different ganglia. The central and smallest (b.) lies nearest the brain, in which its two halves make considerable constrictions, being united on each side by means of a fine branch within each hemisphere. Between these two connecting branches this ganglion meets the single cord, which, coming from the frontal ganglion beneath the brain, originates likewise with two arched branches from the anterior side of the brain, and from the frontal ganglion itself sends off delicate branches forwards. Posteriorly this single nerve does not quit the central ganglion, but wholly terminates in it. Two other ganglia, which lie closely to the central one (c. c.), are the largest of all, and have the form of a figure of eight, and stand in connexion with the central one by means of one, and with the brain by means of two branches. At its posterior end two other branches originate from it, the exterior of which is the longest; both furcate, the latter after it has first swollen at the point of separation into a small ganglion (e.). Close to these two ganglia, we find at the lateral margins of the oesophagus two other oval but somewhat smaller ones (d. d.), which are connected with the central one by means of two, and
with the brain by one only, but tolerably robust nerves. Two branches originate posteriorly from them, but which speedily reunite in a smaller ganglion ($d^*d^*$), which then sends off a long, rather strong filament. This filament runs down by the side of the oesophagus, and passes with it into the prothorax. The oesophagus here distends into the crop, and about the centre of which, each nerve forms a small ganglion ($f.f.$), from which two furcate branches, which embrace the oesophagus, proceed: the nerve then runs undivided on until it attains the end of the crop. Here it forms the second ganglion ($g.g.$), which again sends off three double branches, each of which furcates. The branches of these furcate nerves, six in number, or twelve on both sides, pass between the six caeca lying at the orifice of the stomach, and distribute themselves over them in the most delicate threads. In Gryllus hieroglyphicus, according to Müller*, the upper ganglion is again found, but its relative proportion is not very evident from his representation; the nerve running down the oesophagus has no ganglia, but many fine branches are given off along its whole course. In Acheta Gryllotalpa†, the downward running nerves are very distinct: both give off auxiliary branches, particularly to the sack-shaped distended crop. In the proventriculus, they again unite to form a tolerably considerable ganglion, whence many branches originate, which distribute themselves over it. Blatta and Mantis have but a central single nervous cord, which appears, however, to proceed from the ganglion lying behind the brain.

IV. THE ORGANS OF THE SENSES.

§ 192.

Of all the several organs of the senses, the eye alone possesses a superior development: nose and ear are not yet proved to exist, and taste likewise can be present only in a few, at least to a degree worthy of investigation; but touch, which never properly possesses a distinct and constant organ, but, according to the differences of animal organisation, is sometimes imparted to one and sometimes to another organ, has, in the majority of the orders, peculiar organs varying in their grade of development.

Of these senses, we will first examine that of sight, as the most perfect.

* Pf. IX. f. 5.  † Ib. f. 2.
The form, situation, number, and external differences of the eyes of insects, have been already sufficiently described in the first division of our present inquiry; we can therefore presume that all these points are known, and proceed at once to its internal structure. Upon turning a preliminary glance to the history of the progress of these observations, we shall find all the earlier investigations unsatisfactory. The facets in the eyes of different insects were numbered, the optic nerve and its radial branches were also known, and a distinction was made between compound and simple eyes, without the peculiar structure of the latter being detected. After such, upon the whole unsatisfactory, preludatory labours*, Marcel de Serres † undertook a more comprehensive investigation of the eyes of insects, in which he, indeed, discovered much that was new, but was far from exhausting the subject, which is evident from the subsequent labours of Joh. Müller ‡. It was reserved to this indefatigable inquirer to give a comprehensible explanation of the eyes of insects, and to lay the foundation of the correct doctrine of the sight of insects with both compound and simple eyes. The following is the result of his admirable investigation, confirmed by Dugas §, in opposition to Straus-Durheim ||.

The simple eyes of insects agree entirely in structure with the eyes of the superior animals, particularly of the fish. It is found in all the larvae of insects with a perfect metamorphosis, and in many families of perfect insects of all orders. The following Table will give a more precise survey.

I. Insects with merely simple eyes.
   a. The larvae of Coleoptera, Lepidoptera, Hymenoptera, Neuroptera, and Diptera (with the exception of Culex and the approximate water larvae, which possess compound eyes).
   b. The Dictyotoptera, Thysanoura (with the exception of Machilis and Mallophaga).

II. Insects with simple and compound eyes.
   a. The majority of insects with an imperfect metamorphosis,—consequently.

* Consult Schelver Versuch einer Naturgeschichte der Sinneswerkzeuge bei den Insekten. Gotting. 1798. 8vo.
† Mém. sur les Yeux composés, et les Yeux lissés des Insectes. Montp. 1813. 8vo.
‡ Zur Vergleichende Physiologie des Gesichtssinnes. Leip. 1826. 8vo., and Suppt. to it, in Meckel's Archiv. 1828.
1. Orthoptera collectively, without Forficula.
2. Dictyoptera, Libellula, and Ephemera, have three simple eyes, Termes but two.
3. Hemiptera. The majority of bugs have two simple eyes; some, for example, Lygaeus apterus, none. The majority of Cicada have three simple eyes; some, for example, Membracis Flata, but two. The water bugs, as Nepa, Ranatra, Nauco, Notonecla, Sigara, display no simple eyes.

b. Of insects with a perfect metamorphosis:
1. The Diptera. Generally three, seldom two (Mycetophilia) simple eyes. The Tipularia, Culicina, and Gallifica, are excepted, as they possess no simple eyes.
2. The Lepidoptera. Two simple eyes in the crepuscular moths and Noctua (perhaps in all?)
3. All Hymenoptera have three simple eyes upon the vertex (some neuter ants are blind, as well as the majority of larvae).
4. Neuroptera. Three simple eyes as well as compound ones in Phryganea, Semblis, Raphidia, Panorpa, Osmymius.
5. Coleoptera. Two simple eyes in Onthophagus, Omalium, and Paussus.

III. Insects with merely compound eyes.
a. All Coleoptera, with the exception of the above-named genera, Anthophagus, Omalium, and Paussus, the two points upon whose vertex are supposed to be simple eyes.
b. Besides, several already-named genera and families of other orders, as, Machilis, Forficula, Hydrocorides, Tipularia, Culicina, Gallifica, Hemerobius, Myrmecoleon, Ascalaphus, &c.
c. The larvae of insects with an imperfect metamorphosis. In the larvae of the Cicada and Gryllus, the simple eyes are indicated by spots, and the compound ones have fewer facets than in the imago.

With respect to the internal structure of the simple eye, there is found beneath the very smooth hemispherical, or, at least, convex transparent horny integument, a small globular transparent lens, which lies closely attached to the horny integument, and fits into a corresponding cavity in the inner surface of that integument. Behind the lens lies a truly lens-shaped glassy body, larger in compass than the lens, corre-
sponding with the entire circumference of the eye, but proportionately less convex. Both hemispherical divisions of the glassy body are of a different convexity, and, indeed, the upper is the flatter, and the lower the most convex side. The rete or superior bowl-shaped distended end of the optic nerve spreads itself at the posterior margin of the glassy body. It closely embraces this body, which lies in it as in a shell. It is again exteriorly covered by the pigment. This bends itself in the entire circumference of the eye, up to the horny tunic, and forms around the lens a small iris beneath that tunic. Where the optic nerve spreads into the rete, the pigment covers it, but thus far it comes entirely free from the cerebrum, as was shown above. The pigment varies much in colour: in the majority of cases it is of a brown red or dark cherry brown, sometimes black, or of a bright blood red. In this case, or, rather, in general, the margin lying next to the horny integument shines through it, and thus forms in the circumference of the lens a beautifully coloured iris. It is more evident in the large eyes of the scorpions and of the Solpugeae, but even the small eyes of insects exhibit an annular iris.

§ 194.

The presence of compound eyes is shown by the above Table. Regarding their structure, the horny integument consists of many small hexagonal surfaces, which correspond exactly with each other, and cause the hemispherical, or, at least, convex figure of the superior surface of the eye. Each of these hexagonal facets, the number of which varies, and is sometimes very considerable, as the following list of them shows,

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mordella</td>
<td>25,083</td>
</tr>
<tr>
<td>Libellula</td>
<td>12,544</td>
</tr>
<tr>
<td>Papilio</td>
<td>17,355</td>
</tr>
<tr>
<td>Sphinx Convolvulus</td>
<td>1,300</td>
</tr>
<tr>
<td>Cossus ligniperda</td>
<td>11,300</td>
</tr>
<tr>
<td>Æstrus</td>
<td>7,000</td>
</tr>
<tr>
<td>Liparis Mori</td>
<td>6,236</td>
</tr>
<tr>
<td>Musca Domestica</td>
<td>4,000</td>
</tr>
<tr>
<td>Formica</td>
<td>50</td>
</tr>
</tbody>
</table>

forms a distinct lens, convex on both sides, varying in thickness. The proportion of its thickness to its transverse diameter is, for example, in a sphinx, 1:2; in others, this lens is still thicker, which is especially
the case in all insects with an imperfect metamorphosis. Nevertheless, each lens is flatter in them than in other insects, and we must here consequently regard every individual lens as cut at its margin, so that merely the central most elevated portion remains. Were this not the case in thick and flattish lenses, objects would necessarily appear indistinct. In *Gryllus hieroglyphicus*, Joh. Müller * detected the proportion of the breadth to the thickness to be 1 : 7. The space at the circumference of the facets is covered by the pigment collected between the filaments of the optic nerve, so that each individual facet is surrounded with a ring of pigment or kind of iris; the disk, however, remains free and transparent. Upon the superior surface we occasionally observe, particularly in the bees and flies, fine hairs projecting, which may be considered as analogous to the eye-lashes, as they doubtlessly prevent the approach of external bodies, but at the same time limit the visual circle of each facet to the space itself occupies.

Upon the inner surface of each individual lens we find a transparent crystalline cone, the convex surface of which touches merely the centre of each facet, but leaves a small space around the circumference free for the ring of pigment. The circumference of each of these cones is for a certain space not inclined but perpendicular, thus giving the crystalline body a more cylindrical form, which, however, gradually diminishes, and they internally run to a point, to which a delicate filament of the radiating optic nerve passes. The pigment or peculiar colouring matter, which occupies the whole inner space of the eye, passes between these cones, enveloping the filaments of the optic nerve as far as the facets forming the iris around the circumference of the base of the cone. In this manner each individual facet with its crystalline body is separated from the other, and may therefore be considered as a distinct eye. The length of these cones varies not only in different insects, but often in the same, from its position being either marginal or central. We may consider, in general, that, in such eyes which form no segment of a circle, those cones which are found at the flattest part of the eye are the longest, and the others situated at the more convex parts, the shortest, but the basal surface of the cone does not vary, but is always regulated by the form of the facet. Their length cannot be precisely determined, but, in such eyes which form the

segment of a circle, or which are hemispherical, it is regulated by the size of the entire sphere: larger and consequently flatter spheres, receive longer ones, and smaller, and, therefore, more convex ones, receive shorter cones. In one of the Noctua, Joh. Müller found the proportions of length to the breadth of the base to be as 5 to 1. In Eschna, these relations, according to Dugès' figure, are as 10 to 1; the base itself also rises so much, that it even appears conical.

As we have mentioned above, a filament of the optic nerve stands in connexion with the apex of each cone. These filaments are thin, extremely delicate nerves, which, like the rays of a sphere, originate from the exterior surface of the optic nerve, and spread themselves to the circumference, one passing to each cone. Nothing further can be remarked of them; a separation or radiating division of them has never been observed. They bring the external portion of the eye into connexion with the cerebrum, and may be therefore considered as the most important conductors of the sense of sight. According to the figure of Straus, this nerve somewhat distends where it joins the crystalline body, and encompasses its apex, there forming a kind of retina; but Müller and Dugès never detected this distension of the filaments of the optic nerve.

The dark pigment spreads all over the entire eye between the filaments of the optic nerve. It is a variously coloured, generally a dark purple red, sometimes brighter (Mantis), thickish fluid, which is transpierced throughout by fine tracheal branches, which proceed from a trachea surrounding the inner circumference of the eye like a ring. This layer of colour consequently corresponds with the choroidea of the higher animals, which is both colouring matter and a vascular tunic. The pigment in the majority of insects admits of being divided into two layers, from its difference of colour. The external brighter pigment displays very various colours, as is proved by the mere appearance of the eyes. All bright, glittering metallic eyes, or such as are ornamented with stripes and spots, derive their painting and markings from this superficial pigment. I will cite here merely the green yellow eyes of the butterflies of the genus Pontia and the banded metallic eyes of the Tabani, the brassy coloured ones of the Hemerobia, and the beautifully coloured eyes of so many other insects. The internal pigment is uniformly dark, but, likewise, it is not entirely similar in all insects, but varies according to the families and genera. Mantis exhibits it bright red, the moths violet, many butterflies of a blue violet, and other butter-
flies, the *Hymenoptera* and *Coleoptera*, of a dark blue or entirely black. Even in insects which possess but one pigment, the colour is not entirely the same, but darker nearer the centre, brighter at its circumference in the vicinity of the glass cone and lens. In some cases we discover more than two layers of pigment, as, for example, in *Gryllus hieroglyphicus*, an exterior pale orange colour, a central bright red, and a dark violet. The first and second were very thin, each thinner than the lenses; the innermost entirely filled the remaining portion of the eye.

Thus much upon the structure of the eye. We may here once more repeat that this entire description is but an extract of Joh. Müller's admirable treatise upon this subject, and that here merely the most interesting portion of his results are stated. The subsequent labours of Straus Durkheim† and Dügès do not equal those of the above distinguished entomotomist, nor have they been able to add many new discoveries or corrections of his.

§ 195.

Much obscurity still invests our knowledge of the hearing of insects. G. R. Treviranus‡ has, indeed, discovered and described the organ of hearing of the moths; it consists of a simple thin drum, which is seated at the forehead in front of the base of each antenna, and to which the nerves of hearing, which are branches of the nerves of the antennæ, spread themselves without the intermedium of a hearing bladder filled with water; but this admirable discovery of his has not been confirmed in insects of other orders, for a similar organ has not yet been detected in them. After him, Joh. Müller§ described the peculiar organ of the grasshopper, which is seated on each side at the base of the abdomen; he considered it the organ of hearing, but incorrectly, as will be shown below: it is more likely to be an organ of sound. Other earlier opinions, for example, those of Ramdohrǁ, who considered the anterior salivary glands of the bees as organs of hearing, are partly, as this latter, recalled, or else, as unsatisfactory, require no further notice. To these may be classed Comparetti's observations of bags and passages in the heads of

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* Müller, p. 355.† Considerations Général, &c., p. 409
individual insects, to which cavities nervous filaments were said to be distributed.* It is evident that some misconception was here at work, for no entomotomist, either before him or since, has seen any thing of the kind. But as insects doubtlessly hear, as some, for example, the Cicada, grasshoppers, many beetles, &c., produce a peculiar sound, which serves to attract the attention of the female, they must evidently be provided with an organ of hearing, which is either very recondite, or referred to organs whose form does not evince their function. The antennæ are doubtlessly of this class, and, indeed, Sulzer, Scarpa, Schneider, Borkhausen, Reaumur, and Bonndorf, considered them as organs of hearing. That they are not organs of touch, is proved anatomically by their horny hard upper surface, and physiologically by the observation that insects never use them as such, this function being exercised by other organs, namely, the palpi. Besides, the analogy of the crabs, in which it is well known that the organ of hearing lies at the base of the large antennæ, speaks in favour of the adoption of the opinion of their being in general organs of hearing. If after this hint we look to the insertion of the antennæ, we likewise detect here a soft articulating membrane, which lies exposed, and which is rendered tense by the motion of the antennæ. This membrane, beneath which the nerve of the antennæ runs, might, without much inconsistency, be explained as the drum of the ear, and thus would the antennæ be transformed pelices, which, as very moveable parts, would receive the vibrations of the air, caused by sound, and act as a conductor to it. Whoever has observed a tranquilly proceeding capricorn beetle, which is suddenly surprised by a loud sound, will have seen how immoveably outwards it spreads its antennæ, and holds them porrect as it were with the greatest attention as long as it listens, and how carelessly the insect proceeds in its course when it conceives that no danger threatens it from the unusual noise. Carus †, Straus Durkheim §, and Oken ‖, are of the same opinion, and which I have entertained for years, and endeavoured to confirm myself in by numerous experiments.

* Schelver, as above, p. 51. † Ib. p. 24. ‡ Zootomic, p. 65.
§ Consid. Générales, p. 415, &c.
‖ It was not unpleasing to me to find in the recent edition of Oken's Naturphilosophie, my opinion stated in almost the same words in which I wrote them down. Consult that work, p. 421, No. 3355. The earlier edition of this work did not contain the idea. See Vol. iii. p. 274, No. 3100.
Much more doubt and uncertainty attends the observations and opinions upon the organ of smell of insects. Reaumur, Lyonet, and several modern French naturalists, consider the antennæ as such, but I would ask with what right? A hard, horny organ, displaying no nerve upon its surface, cannot possibly be the instrument of smell, for we always find in the olfactory organ a soft, moist, mucous membrane, furnished with numerous nerves. No such tunic is to be found in insects, at least in their head, or upon the surface of their bodies. Marcel de Serres *, and before him, Bonndorf †, endeavoured to prove the palpi organs of smell, he described pores at their extremities, namely, in the Orthoptera, which passed through its soft apex into the interior, and here distributed nervous branches; he also considered that the tracheae of the palpi opened into the mouth, and that thereby a constant stream of air was kept through them; but it is all fanciful without any satisfactory foundation. The palpi have no pores at their extremity, and their tracheae have no external orifice. Comparetti ‡ found cavities and cells beneath the frons, which nobody ever saw, either since or before, and these he considers organs of smell. More recently, F. Rosenthal § described a folded skin at the forehead, beneath the antennæ, to which two fine nerves passed, and which he considers as the organs of smell of Musca domestica and vomitoria; and he observed, after the destruction of the part, a deficiency of the function which had previously strongly exhibited itself. But it is with this as with the discovery of the organ of hearing in Blatta; we cannot reason from it, as similar structures have not been observed in other insects, and precisely in the dung beetles, which have the sense so acute, the forehead is covered with a horny shield, that it is wholly impossible odours should pass through it. Indeed, in the burying beetles (Necrophori), which decidedly possess the most acute smell of all the Coleoptera, have above the mouth, upon the clypeus, a triangular yellow somewhat deep spot, having the appearance of a membrane stretched over it, and this might be considered the analogue of the organ of smell discovered by Rosenthal; but, upon closer inspection, this spot appears to consist also of a horny material, and we therefore cannot conceive it possible.

† De fabrica et usu Palporum in Insectis. Aboe, 1792.
‡ Schelver, p. 46.
for scents to pass through it. This difficulty was endeavoured to be obviated by imagining that they passed through the mucous membrane of the mouth to that smelling membrane, in which case it might be common to all insects, but which is not the case. For this explanation of it appears to me forced, as well as a second advanced by Treviranus*, who wishes to persuade us that the entire mucous membrane of the mouth is the organ of smell, but then especially ascribes this sense to haustellate insects.

A different opinion is that formerly advanced by Baster, Dumeril, and, latterly, by Straus Durkheim †, namely, that the margins of the stigmata are smelling organs. We have, it is true, in favour of it, the analogy of the organ of smell in the superior animals being seated at the orifice of the respiratory organs, but that is absolutely all. The mucous membrane, the nervous rete, and the nerves of smell, are all wanting, or, at least, are not shown to exist. Perhaps, however, the tracheæ may possibly be organs of smell, if not at their aperture, yet in their terminal ramifications, as they conduct air to all the organs, and particularly likewise to the brain. Hence would follow the deficiency of a peculiar organ of smell, which, however, must strike as singular when we reflect upon the lower situated crab. But water organs and organs of humidity, and such the organ of smell evidently is ‡, for it is only with a moist nose that we can smell, more easily attain a certain degree of perfection than in those which live in a rarer medium. I will merely refer to the difference of the organs of smell in water and land birds, as well as to the observation that the organs of smell in birds are proportionally less perfect than in the amphibia and fishes, which evidently helps to confirm the law, and serves to explain the deficiency of these organs in insects. Thus insects, according to my opinion, would smell with the internal superior surface, if I may so call it, which is provided all over with ramifications and nets of nerves, since this is always retained moist by the blood distributed through the body and by the transpired chyle, the same as is surmised of the superior mollusca, namely, the Pulmobranchia and Cephalopoda, that their sense of smell is seated in their exterior integument and thus in a universally distributed smelling tunic.

† Considerations, p. 421.
‡ The whales want the auxiliary cavities of the nose, which secrete the fluid, because, living in water, they do not require them. See Rudolfi Physiol. Vol. ii. Pl. I., p. 118.
The tongue is always the organ of taste where present. We have seen above that many insects, namely, the Orthoptera, Libellulae, the majority of beetles, many Hymenoptera, and, indeed, all mandibulate insects, possess a more or less distinct tongue; we have but to ask, may we consider this tongue as the organ of taste?—Taste can be of importance only to such animals as feed upon a variety of substances and masticate them. In haustellate insects this is not the case; they always subsist upon one and the same food, and generally inhabit what they feed on, and consequently less require this sense. Indeed, they are wholly deficient in a fleshy tongue, which can alone taste, and when present as stiff setae, taste cannot be spoken of. But that the fleshy tongue which we find in the Libellulae and grasshoppers is certainly an organ of taste, is corroborated by its delicate and soft superior surface, its greater abundance of nerves, and, lastly, the various nature of their food, which is visibly slowly masticated, and furnished with saliva from the mouths of the ducts of the glands lying beneath the tongue. To these we may add the wasps and bees, which suck the honey of various flowers by means of their tongue, which is provided at its apex with distinct glandular points, that, besides the business of ingestion, serve doubtlessly to taste and distinguish the various kinds of honey. This may also doubtlessly be maintained of the in general soft membranous tongue of the Staphylini. Some physiologists, for example, Rudolphi, deny the sense of taste to insects; others seat it in the palpi, where it certainly does not belong; and others, again, Straus, for instance, discover it in the tongue, where it is doubtlessly to be sought, and frequently sufficiently distinctly exhibited. The abortion of the tongue in many mandibulate insects ought not to surprise us; its cause, as well as the abortion of the organ of smell, is the preponderance of the function of respiration, as the tongue is likewise a humid organ, for, in insects, every organ, by reason of the universal distribution of air in them, has a tendency to become dry and horny. In this they again find their parallelism in the birds, whose tongue is small, imperfect, almost cartilaginous, indeed frequently (Pteroglossus) perfectly horny, and resembling a feather, exactly like the tongue of many beetles, for example, the Capricorns, in the internal organs of which there is a strong disposition to become horny.
Everybody will admit that insects, more than many other animals, require a peculiar organ of touch, from their being encased in a hard insensible integument. It is true the antennæ have long had this function ascribed to them, but incorrectly; the hard horny antennæ may possibly well detect the presence of objects, but certainly arrive at no other precise perception, for this requires a soft organ clothed with a very delicate covering. Straus Durkheim * therefore justly wonders how this function could have been ascribed to the antennæ; but he astonishes us still more by considering the still harder feet as organs of touch. By far the majority of insects have hard, horny, perfectly closed foot-joints, and the few which are furnished with setæ, feathers, or pulvilli at their planta or apex of their tarsi do not use them as organs of touch, but merely to assist in climbing; indeed, there are some genera whose feet have soft fleshy balls (Xenos, Thrips, Gryllus, Locusta), but these instances cannot prove it throughout an entire class. For the rest, his opinion loses still more probability, when, instead of his tarsal joints other organs can be shown as instruments of touch. These organs are the palpi, already indicated by their name. If we inspect the palpi of the larger insects, for example, of the predatory beetles, the grasshoppers, humble-bees, and many others, we observe at its apex a white, transparent, distended bladder, which, after the death of the creature, dries into a concavity seated at the apex of the palpus. This bladder is the true organ of touch, the main nerve of the maxillæ and of the tongue spreads to it, and distributes itself upon its superior surface with the finest branches. Straus †, who carefully observed this bladder, explains it as a sense of a peculiar description, analogous to the taste-smell sense (Geruchsgeschmacksinn) of the Ruminantia, discovered by Jacobson, but just as little as a union of the senses of smell and taste conditionates the presence of a peculiar sense may we explain the palpi as sensual organs of a peculiar description; they are, whence they were named, namely, purely organs of touch. The deficiency of palpi in haustellate insects may be objected to here; but have not these in their long proboscis a better organ of touch, and do not we find everywhere in nature in all the organs an evident adaptation to

* Considerations, p. 425.
† Ibid., p. 427.
their object? Where the palpi are the sheaths of the proboscis, as in the Lepidoptera and Hemiptera, they could no longer remain true organs of touch; and where they have grown into a fleshy proboscideal sheath, as in the flies, this sheath is the organ of touch, and properly, also, the palpus itself is considered as contained in it. If, however, living insects have been observed, no further objection will be taken to the exclusive function of touch exercised by the palpi; who still doubts who has observed the play of the palpi of the spiders previous to copulation, or seen predatory insects fall upon an unexpected prey, and feeling it upon all sides? The common, well-known, domestic fly, lastly, can daily convince us, when we perceive it moving from spot to spot, and detect every drop of liquid and every atom of sugar with the sheath of its proboscis formed of the labial palpi. It first feels them, and then ravenously swallows them; but this touch is never exercised by its tarsi, but invariably by the sheath of its proboscis.