A manual of entomology

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MANUAL OF ENTOMOLOGY

A

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If we take a retrospection of the whole process of the development of the germ to the egg we shall find that there are three distinct periods in its progress. The filiform superior appendage of the egg-tube is the first, for in it takes place the secretion of the formative matter, and from here it descends into the egg-tube as a germen. The remainder, probably albuminous portion, of the secretion, remains, as placentula, between every two egg germs. The second period is the loosening of the placentula by copulation. By means of it the internal tunic comes into close contact with the exterior vascular one, in consequence of which the ring is formed; and at the same time the impregnation of the germ takes place by the male semen imbibed from the placentula. The ring, lastly, is the third period; it promotes, by supplying the placentula with atmospheric air, its capacity of appearing as a new organic mass, so that it may be gradually imbibed by the growing egg. The yolk thus becomes perfectly formed, and envelopes itself with its second tunic, and then with its shell, which is hardened also by means of the air from the ring. The formation of the egg is then completed, and the period of laying comes, which takes place immediately, to make room for a still immature egg. It is from this circumstance that some insects, namely, those with many egg tubes, for example, the queen bee, require a long time to lay all their eggs, and only in those with bag and bladder-shaped ovaries, which are furnished upon their surface with short egg-tubes (as, for example, *Lytta* and *Meloë*,) can the eggs be almost all matured at the same time.

§ 211.

When, after all this procedure, the egg has quitted the maternal sphere, a distinct life, namely, that of the embryo, commences in it. If we first survey the structure of the laid egg we shall observe that it consists externally of a horny shell, which becomes tolerably hard in the air, and is in general transparent or colourless, but less frequently decorated with particular markings and colours. Beneath this external covering lies a second, finer, more delicate membrane, which forms the case of the fluid contained within the egg. This fluid is the yolk, (*vitellus*,) a yellow, whitish, or green, thick, granulated mass, which in *Phasma* is dotted with purple, and it chemically consists of albumen, some animal glue, a yellow fat oil and sulphate and phosphate of natron*.

* See John's Chemische Schrift, vol. ii. p. 112.

The separate albumen which is observed in the eggs of the *Mollusca*, *Arachnida*, *Crustacea*, many fish, and the *Amphibia*, and birds, is therefore wholly wanting in the eggs of insects, which consist solely of yolk.

We have as yet but little information of the progress of the formation of the embryo from this fluid; we only know from Suckow's * observation in *Gastrophaga pini* that a small dark spot is formed in the centre of the originally tolerably clear yolk, which he considers as the commencement of the embryo. From this point, which we prefer considering upon the surface of the yolk analogously to the development of other animals, and not as would appear from Suckow's observation in its middle, the formation of the embryo so proceeds that the ventral surface along which the nervous cord runs first presents itself. This ventral plate distends on all sides, gradually growing completely over the yolk, which is thereby enclosed completely within the ventral cavity. This mode of development has not yet indeed been observed in true insects, but the development of the *Crustacea* and of the *Arachnida* speaks in favour of it. After a short period the embryo appears distinctly as a half moon-shaped body, at the end of which the head is already perceived (Pl. I. f. 24. A.). The embryo swims in a bright green but clear fluid, the liquor amnii, and it is enclosed by two other membranes besides the shell. The innermost, the amnion, which contains the water, is spongy, and exhibits upon its inner surface small glands that are surrounded by a bright margin, and it is covered exteriorly by a cluster of webbed vessels (the same, *c*, *c*, *c*), which all proceed from a thicker main stem, which opens into the orbicular portion of the egg filled with air. These vessels, which doubtlessly convey air, consist, according to Suckow, of but a single transparent membrane, and therefore differ considerably in structure from true tracheæ. Michelotti's † experiments upon the eggs of *Liparis dispar* and *L. mori* have proved that the eggs, during their development, decompose air, viz., imbibe oxygen, and give out carbonic acid, but only in a temperature of from 15° to 20°, whereas beneath zero they leave the atmospheric air unaltered. This absorption of oxygen is necessary to their development, for the eggs speedily die in miasmatic gases, which are free from it. If now, as appears neces-

* See his Anatomisch. Physiologischen Untersuchungen der Insekten und Krustenthiere, vol. i. part i. Heidelb. 1818. 4to.

† See Pfaff and Friedländer französische Annalen, part iv. p. 48, &c.

sary, this oxygen be imbibed from the above-mentioned orbit of the egg germ, it can only be distributed by means of the vessels in the circumference of the entire yolk. The second external membrane lying over the amnion (the same, *b*, *b*,) is a transparent, colourless, simple, structureless tunic, which lies next to the egg shell, and clothes this throughout, with the exception of the above-named space containing air. It consequently corresponds with the membrane lying beneath the shell in birds, viz., the *chorion*, which is here also as deficient in vessels as among the birds. The resemblance to birds is very evident; a similar space containing air is also observable in birds' eggs, and, the same as here, the embryo imbibes the oxygen, which it requires for respiration, from the air contained in that space. The allantoid is wanting, and consequently the air vessels take their course upon the exterior surface of the amnion, the yolk bag however is contained within the ventral cavity. A canal to correspond with the navel cord is consequently likewise wanting; the entire yolk bag lies within the ventral cavity, and becomes the intestinal canal and stomach, and it is thence perhaps that the stomach of caterpillars is so monstrously large.

The larger the embryo becomes the more distinctly do the several organs display themselves. Interiorly Suckow first observed the intestinal canal, almost contemporaneously with the external formation, from the simple reason that so soon as the ventral plates had united at the back the yolk bag must necessarily present itself as the internal nutrimental canal. It is evident that the closing of the anus in many larvæ stands in close relation to this reception of the entire yolk bag. Suckow also observed, towards the close of the embryo life, constrictions upon this internal nutrimental canal, which separated the œsophagus and intestine from the stomach; until then it remained what it was, a longitudinally distended simple bag. Now appear the first traces of air vessels, in the form of tubes, one of which runs on each side of the body, and from division to division sends forth fasciculi of branches, which spread themselves to the intestinal canal. But during the embryo life the tracheæ do not enter into action, the stigmata are consequently closed, and their function commences only upon the exclusion from the egg. The dorsal vessel also developes itself and gradually commences action, at least distinct pulsations have been observed in embryos shortly prior to their quitting the egg shell. The sexual organs are also observed during the last few days of the embryo period, they present themselves in both sexes as small knobs with delicate ducts, which unite beneath the intestine into a short clavate evacuating duct. The commencement of the nervous system consists of two extremely delicate scarcely perceptible filaments into which the nervous matter by degrees accumulates; they then approach together, and connect themselves at different spots, thus forming the ganglia, and anteriorly the brain, which in the embryo is still very soft and almost fluid, and therefore very destructible. The muscular layers beneath the skin are also indicated, and particularly the head, with its mandibles, the legs and the anal horn become developed, as the most important external organs. In clothed caterpillars insulated hairs appear also upon the skin. We thus frequently see the matured embryo in its convoluted position through the thin egg shell (Pl. I. f. 22). After the termination of these evolutions the young larva strives for freedom and greater independency, it bores through the shell at its most delicate part, namely, at the orbit, and then comes forth from out its prison, and immediately commences its first appointed occupation, feeding voraciously. Producing this object many larvæ devour their own egg-shell immediately after quitting it.

§ 212.

In some few insects the exclusion from the egg takes place in the mother's body, and these therefore bear living young. Such insects are called ovoviviparous.

One of the most common instances of this kind is presented by the *Aphis*. In these the female bears through the summer living young ones, and in autumn it lays eggs. According to Bonnet, nevertheless, egg germs are found in the ovaries, as in all other insects; these developе themselves in the duct, here the young creeps forth, and is thus born living. Bonnet assures us that, upon an anatomical inspection, he discovered egg shells and young ones in the duct. According to other observers, viz., Kyber, upon *Aphis Dianthi*, eggs are never laid, but young ones constantly born, so long as the individual has not copulated; a copulated and consequently impregnated female lays only eggs; but Bonnet has nevertheless made it probable that the egg laying (as was remarked above, § 204,) is the consequence of the colder autumnal temperature, since the eggs more easily bear the intensity of winter than the young. Kyber's *Aphis* might therefore have continued producing living young ones in consequence of its being kept in a warmed apartment. De Geer, however, observed *Aphis Abietis* never to produce living young ones, but always eggs.

The flesh flies exhibit another instance of ovoviviparous production in insects. It is well known that these flies (*Sarcophagæ*) deposit their larvæ upon putrifying flesh, and the young immediately after their birth proceed with the removal of the substance upon which they were deposited. According to Reaumur*, who has described and figured the ovary, the larvæ may be found in the spirally twisted egg tube, and which, we may remark incidentally, according to him contains more than twenty thousand larvæ. According to De Geer †, the eggs first descend the egg duct after their development at the base of the egg tube is completed, and each ovary contains but from fifty to eighty germs. Their increase is nevertheless very rapid, for in from eight to ten days the larva is grown, and again after eighteen or twenty days the fly appears. If we admit merely the smallest number of eggs, and allow four weeks to the development of every individual, we find, upon supposing an equality of both sexes in each generation, in one summer (from June to October) a produce of more than five hundred millions, therefore about half as many individuals as there are human beings upon the whole earth, according to the received opinion. Meantime, how many are destroyed as larvæ by their multitudes of enemies? how many also as flies are there not consumed by birds?

Similar cases of an early exclusion from the egg within the body of the mother has been observed in other genera. Reaumur ‡ found the larvæ of a small *Tipula*, which, to judge from his figure, apparently belongs to Meigen's genus *Ceratopogon*, in one of his boxes, where also they changed into nymphæ. He obtained from these the fly which subsequently produced long worm-shaped larvæ; indeed, upon a slight pressure, he squeezed them fully developed from the body of the mother. According to Kirby and Spence § also many *Cocci* and bugs bring forth living young ones; the latter from the observation of Busch, upon which, however, I have not been able to obtain more detailed particulars.

But we have, more positive observation upon the development of the *Diptera pupipara*. The remarkable form of the ovary of the female is shortly indicated above (§ 136. III. 2.). The egg descends from the small ovary through the egg duct into the large, bag-shaped,

* Mémoires, &c., vol. iv. part ii. p. 153. Pl. XXIV. f. 1. Edit. in 12mo.

† Ib. vol. vi. p. 31. Pl. III. f. 5—18.

‡ Ib. vol. iv. part ii. p 168. Pl. XXIX. f. 10—15.

§ Introd. to Entom. vol. iii.

distended uterus, into the superior narrow aperture of which two ramose vessels, which terminate in blind filaments, open themselves, and which, according to Ramdohr *, are secreting vessels that convey nutriment to the larvæ, and in this uterus the egg changes into the larva, and subsequently into the pupa. As such the young is born, nearly of the size of the mother, and enclosed in a hard, simple, smooth shell, without any annular constrictions, and which shell is furnished at one extremity with a cover. This springs off so soon as the pupa has passed through this stage of its existence, and the perfect insect then issues from the pupa case. We therefore here observe a true development in the uterus similar to that of the mammalia, the larva receives within the body of the mother, and by means of her, its first nutriment, and in its state of puberty, consequently much later than the young mammal, it comes forth into the world. This period also quickly transpires, so that we may almost assert that the young one is capable of re-producing the very moment it is born; a solitary instance unparalleled throughout the whole organic world.

§ 213.

The number of the eggs laid by a female insect is generally very great. We have above very recently shown the possibility, at least, of a monstrous posterity in the flesh fly (*Sarcophaga carnaria*), and yet the female, according to De Geer, lays at the greatest number not more than 160 eggs. This number, which may be considered as a very general average, is in many instances exceeded; in fact, we must feel astounded at the incalculable multitudes which different authors give as the produce of a single individual, numbers which are exceeded only by the almost incredible productive powers of fishes. According to Smeathman, the female of a *Termites* lays in one minute sixty eggs, and therefore in one day more than 86,000, which, however, does not by far terminate her period of laying. A small insect, which is found in numbers upon the *Chelidonium majus*, Lin., namely, *Aleyrodes Chelidonii*, Latr., (*Tinea proletella*, Lin.), lays, according to Reaumur, 20,000 eggs (but the number of eggs is much exaggerated, it is only between twenty and thirty †); in the queen bee it varies from 5,000 to 6,000: the ant lays from 4,000 to 5,000, the common wasp (*Vespa*

* Magaz. der Gesellsch Naturf. Freunde zu Berlin, 6. B. s. 131.

† Author's MS. addition.

vulgaris) about 3,000, the *Coccus* from 2,000 to 4,000. If even these considerable multitudes are to be classed among the rare instances, yet a posterity of a thousand individuals in one generation is very common among insects. We find this number among the majority of *Noctuæ;* Lyonet considers this number as usual in *Cossus ligniperda. Euprepia caja* lays about 1,600. In the silkworm the average is about 500. Other orders are less fertile, for example, the *Coleoptera;* in these the average is fifty: many, as the *Chrysomelæ,* lay more (viz., *Chrysomelæ polygoni*); others, for example, *Meloë, Lytta,* which have baccate ovaries, also lay many eggs, namely, from 600 to 800. The burying beetle (*Necrophorus vespillo*) is said to lay only thirty eggs, and the flea, according to Roesel, only twelve; many *Diptera,* as the gnats, some dozens; others, particularly flies, very few, from six to eight: *Musca meridiana,* according to Reaumur, lays only two eggs, but certainly not in the whole, but at one time. The *Diptera pupipara,* the account of whose development we have given in the preceding paragraph, always lays but one egg, or rather brings forth but one at a time; and it is the same with the *Aphidæ,* who bring forth a numerous progeny, but only one at a time, at longer or shorter intervals, whereas insects which lay eggs continue to lay until their entire stock is exhausted. We may readily comprehend the incalculable number of insects from this multitude of eggs laid by a single one. Reaumur observed a *Phalena* from whose numerous eggs 350 living young ones were developed; many of them died as caterpillars, so that only sixty-five females were found among those that passed through their several metamorphoses; but even this number were calculated to produce the following year a posterity of 22,750, which in the succeeding one, by the same calculation, would give a succession of 1,492,750 young ones. A single *Aphis* likewise, by Reaumur's calculation, produces in the fifth generation a succession of 5,904,000,000, and it is well known that the great great grandmother still lays eggs when the ninth member of her descendants is capable of re-production.

SECOND CHAPTER.

OF NUTRITION.

§ 214.

Having now, in the preceding chapter, pursued the history of the formation and development of the insect embryo, proceeding from the most general phenomena of generation, and then directly applying them to the class of insects, I shall therefore now closely investigate the progressive advancement of the young, now rendered independent and excluded from the egg, and investigate the means whereby its development is attained. For this purpose we take the insect in its present stage, as it now exhibits itself, either as maggot, caterpillar, or larva, without asking why it assumes this or that peculiar form, reserving the answer to that question to the following chapter of "Somatic Physiology," where it will receive its reply, in connexion with the inquiry into the forms of perfect insects in general; and we therefore now direct our attention to the means appointed for the fuller development of the individual itself.

These are found to consist in its nutriment, namely, in the assimilation of the newly received organic substances. The young larva must feed upon fresh organic matter, either vegetable or animal, and transform it into its own substance if it is to live. An inquiry into the several kinds of food, and their modes of reception and assimilation, will constitute the subject of the ensuing chapter.

§ 215.

If we take a general survey of the process of nutrition in general, as we find it in the progressive development of animal organisation, we shall perceive that an internal cavity presents itself as its first organ. In this cavity, which is called the stomach, the food is received, transformed, and the unassimilating portions rejected either through the same orifice at which it was received (the mouth), or at another aperture placed at the opposite extremity of the cavity of the stomach (the anus). So long as the food remains in this sometimes simple or tubular cavity, which is occasionally furnished with auxiliary distensions and pockets like so many lateral purses, the digestible matter is imbibed by the parietes of the cavity, and so transformed into the substance of the body. We find this first and most simple mode of nutrition in the lowest animals, the *Infusoria*, the *Polypi*, the *Acalephæ*, and many of the intestinal worms.

The digestion of the food can only be perfectly accomplished when it has been previously adapted thereto by the secretions of peculiar organs, which, as it were, kill and decompose it. Where such auxiliary organs present themselves we find the cavity of the stomach more complex, longer, and tubular, and making several convolutions in the body. The first of the secreting organs that is added to the digesting cavity, which we may henceforth call the intestinal canal, is the liver, which is a glandular body that pours its secretion into the anterior half of the intestine beyond the stomach, and which thereby renders the chyme fit for absorption. The second secreting organs are the salivary glands: they first present themselves in such animals which take hard food, and by their secretion cause the transformation of the coarse materials into a uniformly fluid pap. We find upon this grade of the development of the digestive apparatus the muscles, snails, *Crustacea*, *Arachnidæ*, *Myriapodes*, and insects. Many of them want the salivary glands; many have a multilobed liver, as the snails; others have a small one, in the form of tubular canals. The deficiency of an anus is a rarity in this grade of organisation, but we however find it among insects.

Upon the third and last grade we observe not only the preceding secreting organs both more perfect and numerous, but other new ones present themselves, some of which pour fluids into the intestine, as the pancreas; and others rectify the absorbed chyle, as the milt and kidneys; of the last, however, we observe occasional prefigurations in the snails and insects. This most perfect development of the digestive apparatus is found in the *Vertebrata*.

§ 216.

It does not suffice that the digestive organ should thus become by degrees more perfect, thereby facilitating the separation of the nutritive matter, but the imbibed and decomposed chyle must be subjected to another change before it can be transformed into the organic mass. This change is produced by means of respiration, a function which consists in adding to the nutriment a new substance present in the atmosphere, viz., oxygen. This is, as it were, a second repeated killing of the nutriment, or, in its true sense, a real consuming of it. Where this consuming attains its culmination the blood and consequently the whole body becomes warm, and thence arises, at least chiefly, the uniform heat of birds and mammalia.

A distinct organ of respiration is entirely wanting in the lowest animals, viz., in the *Infusoria*, *Polypi*, *Acalephæ*, and many of the intestinal worms; and if they really breathe it can only be by means of the exterior integument, in the same way as the internal skin imbibes the nutrimental juices from the food. The first instance of a true respiratory apparatus speaks in favour of this opinion, for where found it is a continuation of the exterior integument, a sort of tufted or ramose fold of the skin, which projects into the medium, loaded with oxygen. Such respiratory organs, which are called branchiæ, we find in the muscles, the majority of snails, and in all the crustacea, and even among fishes and the naked amphibia, either throughout their whole lives or during the time they remain in the water. The respiratory organ being merely at one part of the body, a motion of the juices to this spot is requisite, and thus originate the vessels as new organs connecting the functions of the intestinal canal and branchiæ. Vessels must consequently be found in all animals with a partial respiratory apparatus, and they may therefore be deficient in such as have this apparatus universally distributed.

If the fold of skin which becomes developed to the respiratory organ pass inwardly, it is then called not gill, but lung (*pulmo*). The medium, which is generally the air that contains the oxygen, is received into the lung, wherein the oxygen becomes incorporated with the nutritive fluid. This also is in general merely partial, and then consists of membranous bags, which in its highest grade of organisation consists of a web of small cells, that by degrees unite into common ducts, the last and largest of which, the trachea, opens outwardly. Vessels convey the nutritive fluid (the blood) to the surface of these cells and bags, and by means of other vessels it is conducted hence to all the parts of the body. These organs of respiration are common to the majority of amphibia, all the birds, and mammalia; their first indication is found in the pulmonary *Mollusca* and in the *Arachnida*. A universally distributed lung, the analogue of the similar branchia, would require no vessels, as the oxydisation of the nutritive fluid would take place everywhere. We also absolutely find that animals whose body is traversed throughout by tracheæ, which may be considered as separated pulmonary passages, are deficient in a vascular system, and the fragment of it which is present more serves to promote a motion in the fluid that decomposition may be prevented by its stagnating during repose. Such animals are insects, as well as a portion of the *Arachnida* and *Myriapoda*.

We have thus become acquainted with the general mode of nutrition: we have seen that it requires two agents, viz., one to prepare the nutritive fluid (the intestinal canal), and another to make it organisable (branchiæ, or lungs), as well as frequently a third to conduct the fluid, and which acts as a connecting member between the two others. We will now investigate in detail the functions of these three agents in insects in the order in which we have above noticed them.

§ 217.

I. FUNCTION OF THE INTESTINAL CANAL, DIGESTION.

The activity of the digestive organs commences with the reception of food. This in insects takes place in a double manner, namely, by biting and chewing, or by the suction of fluids.

All the mandibulate orders, it is very natural to suppose, take their food by manducation; consequently the *Coleoptera, Orthoptera, Dictyotoptera, Neuroptera*, and a portion of the *Hymenoptera*. In them the horny mandibles, which move horizontally in opposition to each other, bite the portion off which it is the function of the labrum to retain, thus holding it between them; the same is done beneath by the maxillæ and labium. When the part is separated it passes between the maxillæ, where it is readily comminuted, during which operation it is held by the labium. It is then passed to the posterior parts of the cavity of the mouth, whence it glides down through the pharynx and œsophagus to the stomach. In many insects, namely, the *Coleoptera*, the mouth and pharynx are upon the same plane, so that it merely requires to be pushed forward to get into the stomach. Such beetles as the *Carabodea* and *Dytici* chew but little, perhaps from their possessing a proventriculus in which the food undergoes a second comminution. They also feed only upon flesh, which, as in the carnivora among the mammalia, requires no mastication previous to its being swallowed. In the herbivora, for example, the grasshoppers, particularly of the genus *Gryllus*, which possess no true proventriculus, but merely a crop provided with teeth, the food is longer chewed. The pharynx therefore lies higher than the cavity of the mouth, and the meal has to describe an arch, and to pass over the internal skeleton of the head before it can get into the crop. It is very easy to convince oneself of the continued chewing motion of the broad molar-shaped mandibles of these insects, and in which the maxillæ also take an active part. They are therefore analogous, both in this respect as well as in many others, to the graminivorous birds, particularly the *Gallinæ*, or, to indicate a higher parallelism, to the ruminants amongst the mammals, only that their rumination does not take place in the mouth, but as in the birds, in the proventriculus, or crop. In the *Lamellicornia, Pelodea,* and *Capricorns,* which all have complete oral organs, the power of mastication decreases in proportion to the decrease of the proventriculus. Their food also is partly more fluid and more decomposable, so that the hairy maxillæ laps it up, and it is thus readily taken into the mouth. A striking instance of this mode of feeding is exhibited by the stag-beetle, which, as is well known, laps up the exuding juices of the oak, and for this purpose is provided with very hairy maxillæ. In the *onthophagous Petalocera* the mandibles exhibit an analogous form adapted to their purpose, being flat, thin, lamellate, or rather shovel-shaped, to take up their thin food and convey it to the mouth. The *Chrysomelæ* either devour leaves, or as in the *Gallerucæ,* (*G. Alni, Viburni,* &c.), sweep off the pollen of flowers with their maxillæ. They want the proventriculus, and consequently their food requires to be masticated in the mouth; but as they bite off but small pieces the chewing is of shorter duration. This is the case also with the larvæ of the *Lepidoptera,* which, without exception, bite and chew, but they separate such small pieces that they can swallow them without their requiring much comminution; at least they continue biting off fresh pieces without stopping to masticate that already in their mouths. The masticating *Hymenoptera,* for example, the *Tenthredonodea* and *Ichneumons,* devour the pollen of flowers, and their honey, which they lap up with their flat, thin, shovel-shaped maxillæ, or else bite off in larger pieces by means of their dentate mandibles. They masticate certainly but slightly, and yet they want a proventriculus, which has always more or less relation to the duration of the mastication of the food. The *Dictyoloptera* and the *Libellulæ* masticate longer: but they are predaceous, and devour insects which they capture. For this purpose they are furnished with long hook-shaped mandibles and short but broad maxillæ armed with long teeth. It is distinctly seen how they masticate small insects with their maxillæ, swallowing them gradually, holding their bodies the while with their mandibles. The hard parts, namely, the wings and feet, they drop after they have devoured the soft body. They want the proventriculus, and therefore the maxillæ completely comminute all their food. The *Dictyoloptera mallophaga* likewise masticate, as, according to Nitzsch, they feed upon the down of feathers; they want the proventriculus, but they have a large crop, in which their swallowed food softens for a time and is prepared for digestion.

Upon reducing the different modes of mastication of insects to one general view we shall find it to present the following:—

Mandibulate insects devour,

1. Firm materials, which they bite off piecemeal, and which are masticated.
   - *a.* Merely in the mouth. *Libellulæ.*
   - *b.* Less in the mouth, but more in the proventriculus. *Carabodea*, water beetles, and *Staphylini.*
   - *c.* Both in the mouth and proventriculus. *Grylli.*
   - *d.* Neither in the mouth nor in the proventriculus, as the latter is wanting, whereas the creature bites off but small pieces, which can be swallowed entire. The caterpillars of the *Lepidoptera;* the *Chrysomelæ.*
2. Fluids or substances which easily dissolve.
   - *a.* They are swallowed as separated by the mandibles. *Onthophagous Petalocera, Peltodea, Capricorns.*
   - *b.* They are lapped up by the pencillate maxillæ and sucked out in the mouth. *Lucani, Tenthredonodea, Ichneumons.*

§ 218.

Many kinds of sucking approximate to this last mode of taking food. The *Phryganæ* make, as it were, the passage from the mandibulate to the haustellate insects, their oral organs being formed wholly upon the type of the mandibulates, although they only take their food by suction. Their mandibles are small, and entirely unadapted to biting, and have the appearance of two little knobs at the base of the labrum (Pl. VI. f. 9. *a*, *a*), whereas the upper lip, or labrum, is long, narrow, lancet-shaped, internally canaliculated (the same, f. 9.), the same as the still longer labium, which is distended at its extremity into a spoon-shape (the same, f. 10. *d.*); with it the two-jointed, flat, lobate maxillæ (the same, *c, c.*) stand in close connexion, as well as the four-jointed maxillary palpi (*e, e.*), at the base of these maxillæ, whereas the three-jointed labial palpi hang in front of the apex of the labium closely to the bone of the tongue (the same, f. 11. *f, f.*). We consequently find all the organs of mandibulate insects, and yet nothing is more certain than that the *Phryganea* do not bite, but only suck. Their food consists of the sweet juices of flowers, and we meet with the perfect insect only upon flowers, particularly upon the *umbelliferæ*, *syngenistæ*, *nymphecæ*, and similar plants, which grow in the vicinity of water, whereas the larvæ live in water and have distinct and separate manducatory organs, and prey upon other minute water insects.

We now proceed with the general mode of taking food in haustellate insects. Their oral organs are thrust into the material which supplies them with food, and is sucked by means of the sucking stomach through the canal formed of the labrum and labium. The sucking stomach, according to Ramdohr's * representation, is a double bladder-shaped appendage at the lower end of the œsophagus. When distended the air within it, as in the œsophagus, is rarefied, which causes the ascent of the juices of flowers into the oral tube; it then comes into the œsophagus, which swallows it into the stomach, and this continues so long as the sucking bladder is distended, and only upon its contraction does it cease. This sucking stomach is found (see § 103) in almost all insects provided with haustellate organs, and by its distension the ascent of the liquid nutriment is occasioned. It appears to be peculiar to haustellate insects, and to present itself in this form in no other animals. The swimming bladder of fishes only has by its opening into the œsophagus some resemblance to the sucking stomach of the *Diptera*, and Treviranus † therefore compares it with that organ, a parallelism which, although not supported by the functions of the two organs, yet by their corresponding situation, form, and structure deserves consideration. The other *Dictyoptera*, as *Hemerobius*, *Myrmecoleon*, *Ascalaphus*, and *Semblis*, have no sucking bladder, and therefore do not suck, but bite. They are in general carnivorous, and are therefore made to bite and manducate their food.

The wasps and the bees may be classed next to the *Phryganea*, from their mode of sucking their food. The conformity is greatest in the wasps. Their labium and maxillæ form a similar apparatus, but they are pro-

* Verdauungswerkz. Pl. XVI. f. 2.

† Vermischte Schriften, vol. ii. p. 156, &c.

portionally longer, and project beyond the anterior four-lobed portion called by entomologists the tongue. At the base of the labium lies the pharynx, covered by a triangular valve, which Treviranus * calls the second tongue; but it is impossible that this valve should be a tongue, as it lies over the orifice of the pharynx, and evidently serves to close that organ, comparable in form and function to the uvula of the mammalia. The sucking stomach is not so distinctly separated from the œsophagus, but rather an anterior crop-like distension of it (see § 103), and into this crop the funnel-shaped orifice of the mouth projects. When it distends itself this orifice of the stomach approaches closer to the upper thinner commencement of the œsophagus, and the passage of the food into the stomach is thereby promoted. This distension also causes the ascent of the honey into the oral tube, and when it has arrived at the pharynx deglutition passes it on. Treviranus has convinced himself of the correctness of considering this crop as a sucking stomach, as well as of its corresponding function, or at least of that of a similar appendage to the œsophagus of the majority of haustellate insects, by dissecting them alive; he always found this bladder empty, and it, as well as the pharynx, in a peristaltic motion, or interchanging distension and contraction, which was likewise observed before him by Malpighi † and Swammerdam ‡, who, however, did not detect its function. According to Meckel § the sucking bladder contains also, at least in the *Diptera*, fluids of different colours; Ramdohr || calls it a food bag, and ascribes it exclusively to the *Diptera*. But whosoever shall follow Treviranus in his description, without predilection or preconceived ideas, must, I am sure, be speedily convinced; it would be absolute obstinacy, after such clearness and such a distinct insight into the suctorial apparatus of insects, to require further proofs; an hypothesis which explains everything is no longer an hypothesis even if, as however is not the case here, it is not supported by observation.

Let us turn to the bees, in which, with a very similar form of the oral apparatus, it is however more difficult to comprehend their mode of sucking. Instead of a lobate tongue we find in the bees a long, filiform, hairy, hollow proboscis, which at its base has two membranous lobes (Latreille's *Paraglossæ*, Pl. VI. f. 7. *a, a.*); the aperture of the

* Vermischte Schriften, vol. ii. p. 134.

† Opera Omnia, Lugd. Bat. 1687, tom. ii. p. 44.

‡ Biblia Naturæ, p. 138. *a.*

§ Vergl. Anat. vol. iv. p. 92.

|| Abhand. über die Verdauungswerkz. p. 11.

mouth or pharynx likewise lies at the base of this proboscis covered by a valve, as in the wasps. From it the simple proboscis passes on to the stomach, distending in front of the latter into the sucking bladder. A peculiar vessel originates from the canal of the proboscis, the course of which indeed Treviranus could not completely follow, but which probably passes beneath the cerebellum and opens into the œsophagus; the ducts of the salivary glands also appear to open into the œsophagus. Treviranus therefore considers that this canal within the proboscis is the organ which imbibes the nectar, but he passes over in silence the function of the mouth, or orifice of the pharynx. If, however, I shall not undertake to question the justice of his remarks without adequate investigation, it yet strikes me as evident that the oral aperture or orifice of the pharynx must have some particular and important relation to the mechanism of nutrition, perhaps harder and larger particles of food, such as the grains of pollen, are swallowed by it, or, which is yet more probable, that the honey, which the neuter bees are known to cast up, is rejected through this aperture.

The suctorial apparatus of the *Lepidoptera* differs still more widely. Their oral organs consist of two spirally convoluted hollow probosces, which represent the maxillæ of other insects (see the detailed description of these organs at § 70). Into each of these sucking tubes a branch of the furcate œsophagus opens (§ 102). This itself is a narrow tube, which becomes the stomach at the commencement of the abdomen; and here, closely in front of this transition, it has a simple or double sucking bladder. The two probosces form, united, a central canal, into which the ducts of the salivary glands open. In these insects therefore the simple oral orifice has entirely disappeared, instead of which we find two proboscideal sucking mouths, through which the nectar, which is the universal food of the *Lepidoptera*, ascends, by the aid of the sucking bladder, and by means of the above described mechanism. Another corroboration of the correctly supposed function of the bladder, and of its connexion with the business of sucking the aliment, is found in its being very small in those *Lepidoptera* which have a short conical proboscis, as in *Euprepia caja* and *Cossus ligniperda*, whereas in the butterflies, which have a long proboscis, and also in the sphinges, it is of large compass.

The proboscis of the *Diptera* has been already above (§ 70) amply described; and we have also learnt from the anatomical description of the intestinal canal (§ 103) that they have a large sucking bladder, which opens into the œsophagus through a long narrow canal. Consequently they suck their fluid aliment in the same manner. The setæ, which lie in the sheath of the labium, are thrust into the substance which they suck, moving up and down like a pump during the operation, and thus the fluids ascend into the stomach by the alternating distension and contraction of the sucking bladder. If we attentively observe a gnat or fly thus occupied, the opposed motion of the setæ may be distinctly seen, and we also detect that the blood does not flow in a continued stream, but at distinct intervals; so that when the gnat has swallowed a drop a fresh drop follows it, but there is a momentary cessation of the operation between.

The flea and the *Diptera pupipara* do not possess this sucking bladder, and their proboscis differs by not possessing the lower fleshy sheath; they hereby approximate to the *Hemiptera*, whose rostrum is articulated, and they likewise have no sucking bladder. According to Treviranus * the setæ (see § 70), of which their rostrum is formed, are hollow, and vessels originate from their cavities which open into the first stomach by means of narrow canals (see Pl. XX. f. 3.); the œsophagus itself opens into or beneath the tongue, seated between the setæ, whither also the ducts of the salivary glands pass. He therefore assumes that the liquid ascends the hollow setæ, as in capillary tubes, and passes into the stomach through the vessels. I consider this opinion doubtful, as it appears to me too mechanical, for hereby the œsophagus would become superfluous, and particularly as the *Hemiptera* thus imbibe their food throughout their whole lives. I should prefer considering the lateral distension, which is found at the commencement of the stomach in many bugs, and the pyriform distension at the end of the œsophagus, into which the second stomach returns, as the analogue of the sucking bladder, and thus suppose in them a mechanism conformable to that found in the other orders. Ramdohr also, who has figured the intestines of many bugs, never found tubes conducting from the setæ to the stomach.

§ 219.

Their own variety conforms tolerably with the various modes of their taking food. Thus naturally fluid aliment can only be imbibed, and that which is of a firm consistency must be bitten off and masticated.

* Annalen der Wetterauschen Gesellsch. f. d. Ges. Nat. I. 2, p. 171.

But more important than these differences, derived from the external quality of their nutriment, are those which refer to their being either of vegetable or animal origin. Thus the food of insects may be divided into two groups, so that we can class it into four different kinds, each of which again admits of subdivision, according to whether it be fresh or whether putrefaction have already commenced, which we thus arrange:—

I. From substances requiring comminution. These are,

1. Of the Animal Kingdom, and are,

a. Fresh and uncorrupted, and generally consisting of living individuals obtained by force.

The predaceous beetles, viz., the *Cicindelæ*, *Carabodea*, *Hydrocanthari*, and *Staphylini*, support themselves by this kind of food. All devour other insects, chiefly larvæ, which they obtain by capture, or the flesh of dead and fresh vertebrata to which they can procure access. Some, as the *Dytici*, are said to attack living fish, and eat out their eyes; others, as *Hydrophili*, devour the spawn of fishes and frogs, and even such young frogs and tadpoles as they can master.

b. Animal substances in which putrefaction has already commenced, particularly carrion.

The large family of carrion beetles (*Peltodea*), especially feed upon such substances. Their larvæ live wholly in putrescent vertebrata, and devour their flesh, and the perfect insect also derives its nutriment from it. The burying beetle (*Necrophorus*) buries small vertebrata, depositing its eggs in their body; thus innumerable carcases are destroyed. Smaller beetles, for example, the *Aleochara*, many *Staphylini*, *Corynetes*, &c. assist them in this business. Others, again, consume only the dried skins of animals and their clothing, as the fur beetles (*Dermestodea*) and the clothes moths (*Tinea pellionella*, &c.).

c. Excrementitial substances, animal excrements.

The majority of onthophagous insects are extremely fond of the excrements of the herbivora. But this cannot be considered as distinctly animal or vegetable matter, but as an intimate mixture of both; therefore all beetles which devour such excrements are fed upon both animal and vegetable substances. To these belong all the onthophagous *Petalocera*, viz., *Copris, Onthophagus, Ateuchus, Gymnopleurus, Onitis, Aphodius,* and many others; then the *Histerodea,* many *Staphylini,* the genus *Spheridium,* as well as the larvæ of innumerable *Culices* and flies. But as these substances have considerable affinity with carrion, and the onthophagous insects with the *Peltodea,* many species of both kinds feed indiscriminately upon both substances.

2. From the VEGETABLE KINGDOM.

a. Corrupt vegetable substances.

Many insects live upon the rotten portions of trees, as the larvæ of *Lucanus* and *Oryctes;* others devour the corrupt substances which are deposited beneath the bark of dead trees, for example, *Hypophleus, Engis, Ditoma, Colydium, Rhyzophagus,* and other genera of this family. The larvæ especially appear to derive their nutriment from such corrupting, fermenting, or decomposed portions of plants. Lastly, according to Reaumur*, the larvæ of the *Tipula* feed upon earth only, but it is doubtlessly the vegetable extract which is mixed with the mould, and which is produced by annual plants that putrify yearly, and from the fallen leaves of others, that constitutes their nutriment, which during digestion is taken up from the earthy matter.

b. Fresh vegetable substances.

These yield doubtlessly the most nutriment. Some insects, as the larvæ of *Melolontha,* gnaw the roots of plants; others devour and bore into the hard stem; to those belong the *Ptini, Anobia,* and in general the entire family of *Deperditora,* the *Cerambycina,* and the bark beetles *Hylesinus, Bostrichus, Apate,* &c. Others again, and by far the majority, consume fresh leaves, for example, almost all the caterpillars of the *Lepidoptera,* the larvæ of the *Chrysomelina,* even the perfect beetles of this family, and the grasshoppers. Others again, the larva of *Noctua Tanaceti, Artemisia,* &c., feed only upon the petals of flowers, many upon pollen only and the internal parts of flowers; very many, lastly, feed exclusively upon ripe fruits, as the fruit moth (*Tinea* [*Carpocapsa,* Tr.] *pomana, Pyralis pomana,* Fab., or

* Mem. tom. v. p. 1. pages 14, 15, edit. in 12mo.

upon seeds. To these the larvæ of the *Curculios* especially have recourse. The *Apion frumentarum* and black *Calandra granaria* have acquired a fearful celebrity from this circumstance; the nut weevil also, *Balaninus nucum*, which bores the kernel of the hazel, and the cherry weevil, *Anthonomus druparum*, which devours the kernel of the sour cherry (*Prunus cerasus*), and which are frequently found fully developed in cherry-stones, are well enough known.

II. Fluid aliments which are taken up by suction or lapping. These are,

1. From the animal kingdom, and consist of,

a. Fresh animal juices.

These substances support the majority of toothless parasites which are distributed upon all the warm-blooded animals. They consist of all true lice and bed bugs, which imbibe only blood. Some are parasites only during certain portions of their lives, for example, the flea and the *Diptera pupipara* in their last stage; others, as *Œstrus* and the *Ichneumons*, only as larvæ. The remarkable *Rhiphidoptera* also are parasites chiefly as larvæ, for, inserted between the abdominal segments of many wasps and bees, they project into the abdominal cavities of these insects, but push their heads outwardly. It is still uncertain how they feed. The perfect winged insect appears not to be a parasite. The *Ichneumons* have a similar mode of life, for they live as larvæ in the larvæ of other insects, and are fed by their fat; but subsequently, when they are full grown, they attack the nobler organs, and thereby kill them. The perfect winged insect sucks the juices of flowers. Other genera, which are parasitic as larvæ upon insects and cold-blooded animals, are, in the *Coleoptera*, *Drilus*, which is parasitic upon snails, and *Symbius*, Sund., whose larva feeds upon cockroaches. The parasitic state of the larva of *Meloë* is still more remarkable, it lives upon bees only until its first moult, and in this state has been formed into the apterous genus *Triungulinus*, by Desmoulin; it is probable that it subsequently goes into the earth, and lives upon the roots of plants. There is a beauty in the almost constant law which makes the parasites of warm-blooded animals so during their whole lives, and they therefore always remain apterous, whereas those of insects and mollusca are parasitic only as larvæ, and acquire wings after quitting this mode of life. The former belong in general to orders with an imperfect metamorphosis, and the latter to those with a perfect transformation. The remarkable genus *Braula*, discovered by Nitzsch, which most probably belongs to the family of *Diptera pupipara*, and which is parasitic upon the honey bee, makes an exception; it is parasitic during its whole life upon cold-blooded creatures, but is also apterous, whereas the allied genera *Hippobosca* and *Ornithomya*, although dwelling upon warm-blooded ones, yet have wings. There are many other insects besides the parasites which feed upon animal juices, for example, the *Asilica*, which seize other insects, and by means of their long proboscis suck out all their juices; the *Tabanica*, which sting men and animals, and derive sustenance from their blood, besides many genera and species of the numerous family of gnats, for example, *Culex*, *Ceratopogon*, as well as the allied genus *Simulia*; lastly, the larvæ of the *Dytici*, which suck out insects, like spiders, by means of their large hollow mandibles, which are opened at their apex: the only analogy among perfect insects to this structure of the mandibles is to be found in the hollow proboscis of the *Lepidoptera*, whereas in the spiders it is the usual and most common form.

b. Corrupt animal juices.

These are the same as those mentioned under I. 1. *b.*, viz., the impure juices of carrion and dung; they are voraciously sucked up by many flies, for instance, *Musca Cæsar*, *Scatophaga putris*, *Scybalaria*, &c., and are even lapped up by the *Coleoptera*, whose oral organs are less adapted to manducation, as was fully shown in the preceding paragraph.

2. From the vegetable kingdom.

a. Fresh vegetable juices are sucked up by many insects, viz., the *Cicada*, bugs, and *Aphidæ*, as well as the species of *Chermes* and *Coccus*. The majority pierce young one-year shoots, and thereby so exhaust them that they die, particularly when, as in the *Aphides*, they are found in hosts upon one shoot. Almost each species selects a distinct plant, and it is frequently the case that they are to be found upon that alone. The same is the case with the parasites, particularly the constant ones, whereas those which are merely partially so, for instance, the gnats, the flea, &c., frequent all the warm-blooded mammalia of various families and orders. The partial parasites of insects and the *Mollusca* are also found tolerably limited to one species, or at least to but few, but two or three. Few animals are so much restricted to one and the same kind of food as insects. Thus the leaf-consuming caterpillars have generally each its distinct plant, and indeed some are so scrupulous that they reject all other plants, and will even starve to death rather than touch any but their usual food. Besides the crude unprepared juices which are found in the stem the more fully developed ones of the flower yield nutriment to many insects. All the *Lepidoptera*, without exception, suck the nectar of blossoms, the same with the wasps, bees, and many other *Hymenoptera*, and, lastly, among the *Diptera*, the *Bombylodea*, and *Syrphodea*, but they do not restrict themselves to certain plants, but frequent all, and those which are the richest in honey are the most agreeable to them. Some, as the wasps, lap also the fresh juices of ripe fleshy fruits, particularly those which are sweetened by the influence of the sun upon a wounded part.

We may also here briefly state that many beetles, for instance, the *Lepturæ*, *Coccinellæ*, &c., lap the honey of flowers, and that others prefer the crude juices of the stem, as *Lucanus*, &c. that of the oak.

b. Corrupt vegetable substances.

There are not many insects which resort to these. If we did not here include the juices produced by the rapid putrefaction of fungi, or the in general almost fermenting juices of mature fungi, upon which the larvæ and perfect insects of the numerous family of *Mycetophthires* feed, we should scarcely find genera that have recourse to such nutriment.

§ 220.

The first change of the food, and which is as it were a preparation for digestion, takes place during the mastication or sucking by the intermixture of the secretion of the salivary glands. These organs, as we find at § 112, are found in all haustellate and many mandibulate insects, particularly in those which feed upon vegetable substances, they secrete a peculiar white, frequently perfectly hyaline fluid, which appears to be of an alkaline nature, and becomes intermixed with the food in the mouth itself. This intermixture has a threefold purpose, namely,

1. The mechanical dilution of the nutriment. This attenuation is the more necessary, particularly in such insects which feed upon hard vegetable substances, from their containing very generally but little moisture, and their comminution in the mouth must necessarily be more difficult than when the food consists of soft animal substances. Thus by manducation, and being mixed with the saliva, it becomes changed into a thick pap, upon which the stomach can more easily act. The grasshoppers, *Grylli*, larvæ of the *Capricorns*, the wood borers, and the caterpillars of the *Cossus*, appear especially to require this mechanical attenuation of the food, from its generally consisting of hard wood.

2. The chemical effect of the saliva upon the nutriment is still more apparent. The saliva, by its very constitution, is a poison which as it were kills the food, depriving it of its natural living quality, and thereby transforming it into a scalded state. This is proved by the bite of poisonous serpents, whose poison is nothing else than the saliva secreted by peculiar glands. According to Humboldt * the saliva of serpents alone suffices to change the flesh of recently killed animals into a gelatinous substance, and they therefore lick their prey all over before they swallow it. The saliva of insects has a similar effect. Immediately after swallowing and the intermixture with the saliva in the mouth, the green leaves upon which caterpillars feed lose their bright colour and acquire by degrees a darker dirty colour, resembling that of boiled vegetables. The puncture also of blood-sucking insects convinces us, most distinctly, by the pain of the wound, of the corrosive effects of the saliva, and the inflammation attendant upon it, of its transforming power.

3. The dynamical effect of the saliva, under which we understand its faculty of changing the food into that state that the requisite nutrimental substances can be separated from it. It therefore requires no further proof, for it is evinced by too many experiments that the saliva does not always act in the same way, but that its effects are different according to the differences of individuals; consequently a variety of insects may feed upon the same materials and yet produce very different effects

* Ansicht der Natur, tom. i. p. 141.

from the action of the saliva and the other fluids which flow into the stomach: for example, the true *Cantharides* (*Lytta vesicatoria*) and *Sphinx Ligustri* feed upon the same plant, viz., *Ligustrum vulgare*, Lin., and yet in the *Sphinx* we do not find the least trace of the blistering principle which so greatly distinguishes the Spanish fly. And this is peculiar also to other species of Spanish flies, which however feed upon very different plants, and in the most distinct climates. With respect to the puncture of blood-sucking insects, everybody knows the difference of its effects from different insects. The puncture of the bed bug (*Acanthia lectularia*, Fab.) leaves behind it a small, whitish, projecting swelling; that of the flea a spot made red by the wound, but which is not painful. The puncture of our water bugs is painful; for example, the *Notonectæ*, *Naucoris*, and *Sigara*, the pain of which must especially be attributed to the saliva which is inserted in the wound. This is the case also in the puncture of the common gnat, for the mechanical injury is too trifling to produce such sensible pain. How very different however is the inflammation after the puncture of this creature than in the before named insects. The difference in tropical insects is still greater. St. Pierre, in his voyage to the Mauritius, relates an instance of a bug whose puncture produced a swelling of the size of a pigeon's egg, which lasted five days *. The large exotic *Tabani* also cause severe inflammation by their punctures, as Kirby and Spence have shown in an instance; with us also the species of the genera *Chrysops* and *Hæmatopota*, of the family of the *Tabani*, make painful punctures. The sting also of the smaller genera of *Culices* are sometimes very painful, as that for instance of the notorious *Simuliæ*, particularly when they attack man and animals in hosts; by the multitude of their stings they then set the skin in such an inflamed state that it produces severe illness, which frequently terminates in death. The same may be said of the mosquitos, which are small *Culices* that belong probably to the same genus, and which between the tropics are complete pests by reason of the intolerable itching produced by their punctures. The anthrax, or pustula maligna, which has been occasionally observed to arise after the puncture of an insect is scarcely to be considered as the consequence of its mere puncture, but of a poisonous lymph that has probably still adhered to the proboscis of such a fly, which immediately before may have punctured a diseased animal. The puncture therefore

* Kirby and Spence, Introduction, vol. i. p. 171.

of a particular species of fly cannot be considered as the cause of this malady.

These three different qualities of the saliva do not present themselves separately, but more or less contemporaneously. The vegetable fibres are by its admixture softened and loosened, then chemically changed and made tender, or, as it were, scalded, and, lastly, by its intimate incorporation it is rendered fit for assimilation and digestion. After this preliminary change a second comminution takes place in the crop when this organ exists. We consequently find among the mandibulate insects salivary glands only in such species, genera, and families, which are more or less strictly herbivorous, for example, the grasshoppers, *Grylli*, *Termites*, and they are entirely deficient in the carnivorous ones. In them the larger quantity of gastric juice that is secreted supplants the function of the saliva, whence it is that their intestine beyond the crop is beset with a multitude of blind, doubtlessly glandular, appendages; and even if such appendages are found in the herbivora, for example, in the grasshoppers and others, they are fewer in number and smaller in size. Where both salivary vessels and these appendages are wanting the long stomach is then entirely covered with glands, as in *Hydrophilus*. In haustellate insects the saliva attenuates the imbibed juices and becomes intermixed with it in the process of sucking. Thus in the bees the salivary duct opens into the same duct through which the honey is sucked; in the *Lepidoptera*, through the central canal which is formed by the union of the two probosces, and it drops down out of this channel whilst the insect is sucking. Reaumur and Treviranus have both seen it fall in drops. In the *Hemiptera* and flies it also opens into the proboscis, probably here also, as in general, beneath the tongue; by means of it the hard setæ are kept constantly lubricated, which facilitate their reciprocal motion. It is also intermixed with the imbibed nutriment in the mouth, it kills and scalds it, and thus prepares it for digestion, which then next takes place in the long or subdivided stomach. In the *Cicada* and bugs, the majority of which imbibe crude vegetable juices, this preparation for digestion is of considerable importance, and we therefore find in them very large salivary glands.

§ 221.

The remaining function of digestion, subsequent to manducation and the intermixture of the saliva, is exhibited less uniformly in insects than the functions just indicated. The most striking differences have already been exhibited in the remarkably divaricating form of the stomach. These divarications admit of being, as well as their functions, classed into the following three chief heads:—

A. The digestion of FIRM, partly animal, partly vegetable substances. These take place,

a. By the aid of a crop,

b. Without a crop.

B. The digestion of LIQUID substances always takes place without the assistance of a crop.

The form of the intestinal canal is thence adapted as far as the opening of the biliary vessels, and we therefore find

In the FIRST case a crop, a proventriculus, and a stomach, but which we shall call henceforth the duodenum, as it corresponds in function with that organ of the higher animals. In a thus formed intestine the hardest animal and vegetable substances are digested.

In the SECOND case, in which the proventriculus is wanting, the crop and duodenum are united in a single narrow and equally wide tube, which may be here properly called the stomach. We find this stomach in all insects which feed upon light vegetable, or even corrupt pappy animal substances. Sometimes this entire stomach, like the duodenum of the carnivora, is throughout shaggy.

In the THIRD case a true proventriculus is indeed wanting, but we sometimes observe an analogous form. These are wholly deficient in the *Lepidoptera;* their small oval food bag is both stomach and duodenum, and the crop is changed into the sucking bladder. In caterpillars the long, broad, cylindrical stomach is likewise stomach and duodenum, but the crop is wanting. The same is the case in the *Diptera*, but the stomach, together with that portion of the intestine forming the duodenum, is very long, round, and tubular. The *Hymenoptera* have a wide crop, which serves as a sucking stomach, a funnel-shaped orifice to the stomach, which represents the proventriculus, and a tolerably long transversely ridged duodenum. The *Hemiptera*, lastly, exhibit again all three divisions, but in these they are more widely separated: the crop is the first broad, purse-shaped stomach; the proventriculus we again find as a thin but compact muscular tubular second stomach; the duodenum is thus in the *Cicadaria* the narrow, but in the bugs wider, transversely ridged, third stomach, which is furnished with auxiliary ducts. If but two stomachs are present the middle one, or proventriculus, is wanting. Thus the chylifying portion of the intestine is formed in the several orders according to the differences of their food; for greater detail I refer to § 105.

If we now investigate the digestion of solid substances by the assistance of the proventriculus we shall find that those, when of the animal kingdom, are swallowed wholly unchanged but in pieces, but, when of the vegetable kingdom, they are already much comminuted and intimately mixed with the saliva. They consequently first arrive at the large crop placed in front of the proventriculus, which in some cases, as in the *Dytici*, is thickly beset internally with glands, and the superior surface of the internal tunic is occupied with wrinkles, horny lines, and teeth (Pl. XVII. f. 5—7.). The secretion of these glands, is a dark brown sharp corrosive fluid, which strongly smells like Russia leather, it supplies the place of saliva, envelopes the food, makes it soft, and thus prepares it for digestion. The food, after having thus remained a short time in the crop, advances by degrees into the infundibuliform orifice of the proventriculus, and thence into its narrow cylindrical or star-shaped cavity, where it is easily comminuted, and transformed into a uniform pap-like consistency. To produce this we observe in the crop, and particularly in the proventriculus, a peculiar motion, which consists of an alternating expansion and contraction. This contraction commences at its anterior extremity, and gradually advances to the end of the proventriculus, whilst the earlier contracted portion again expands. It thus greatly resembles the progressive advance of worms and footless larvæ; it is called the peristaltic motion. It is most distinctly observed in the proventriculus, which also, of all the parts of the intestine, is supplied with the largest fasciculi of muscles (§ 104), and it here appears as a contraction and distension of its internal cavity, produced by its rhythmical contraction and expansion. By means of this contraction the teeth and horny plates rub against each other, and thus grind the food into a simple uniform pap, which is called chyme. In this state we then find it in that portion of the intestine lying behind the proventriculus, which, as we have above seen, is supplied throughout or partially with short blind appendages. These appendages, according to Rengger *, become shortened when the intestine is filled with food, and they then appear merely as lumps upon its surface. Its contents is

* Physiologische Untersuchungen uber den Thierischen Haushalt der Insekten. Tubing. 1817. 8vo.

a thick pappy mass, which melts by the addition of acid, and on the application of heat, it is found in the blind appendages as well as in the cavity of the canal. It is of a white colour, and is thereby distinguished from the brown nutriment found in the crop. Ramdohr and the earlier entomotomists call this division of the intestine, behind which the biliary vessels open themselves, the stomach; according to Treviranus, Joh. Müller, and Straus Durckheim *, on the contrary, it should be called duodenum †. This last opinion is doubtlessly the most correct, for the whole business of chymifaction is already over when the food arrives at this portion of the intestine, and the formation of chyle commences here. The resemblance of the crop to the anterior stomach, and the proventriculus to the muscular stomach of birds, is so striking, that the similar situation of that portion of the intestine behind the muscular stomach would oblige us to consider both as analogous forms, even were all other resemblances wanting. The chief difference however is, that the biliary ducts do not, as in the birds, open into this division, but behind it; but in lieu of which other secreting organs, which are the equivalents of the pancreas, namely, the blind appendages, are found around its entire circumference. Rengger does not consider these appendages as secretory organs, but as pockets, whence the lacteal juice is more readily passed into the ventral cavity, and because chyme is also found in them; but that is also found in the pyloric cæcum of fishes. Their abbreviation, however, upon the filling of the intestine, is not an objection, but it merely proceeds from the necessary distension of the intestine produced by the accumulation of more matter. Another reason, however, for not considering that division of the intestinal canal lying behind the proventriculus as the stomach, is the deficiency of a peculiar nerve in its vicinity. The nervus sympathicus descends, we know, from the brain to the pharynx, and distributes itself upon the surface of the crop, with several branches and ganglia, similar to the web of the superior animals. But if there be a proventriculus the branches of the nerves suddenly cease in its vicinity, and that portion of the intestine lying behind the proventriculus receives none; but where the proventriculus is wanting the nerves are distributed only at the anterior portion of the stomach, and the posterior part which corresponds with the duodenum receives none

* See above, § 105.

† The true duodenum of insects is the villose stomach, or, where this is wanting, the long tubular stomach itself.

either. These nerves, however, are a main condition of digestion, and they present themselves, especially, at the stomach and anterior stomach, because it is the most active portion of the intestine in exercising the function of digestion. Both comminute, especially the proventriculus, the remainder of the intestine absorbs; a considerable interruption of the function of digestion has consequently been observed in the superior animals upon the scission of this nerve.

In those insects which possess no proventriculus the digestion of the food is effected less by comminution than by the gastric juice found in the stomach. It also appears to be of an alkaline nature, at least Ramdohr observed a fermentation upon the application of acid, and according to Rengger it stains litmus paper of a brown red; and according to the former it also turns paper blue which has been previously stained red by an acid. Rengger's experiments upon the caterpillar of *Deilephila Euphorbiæ* most distinctly convince us of the purely chemical and dynamical transformation of the food in the stomach. The form of the small bitten pieces of the leaf remains unchanged, but they were somewhat loosened, and they appeared at the lower portion of the stomach to have lost substance. The fluid contained within the stomach was stained green by their extract. In other caterpillars, for example, that of *Pontia brassica*, the chyme appeared more comminuted and more pappy, doubtlessly because the substance of the leaf of the cabbage is more juicy, softer, and more decomposable than that of the *Euphorbia*. The separation and absorption of the chyme is promoted by the constant peristaltic motion of the stomach: this motion intimately intermixes the portions of the food, and gradually subjects them equally to the action of the gastric juice secreted by the glands of the stomach, and it partly helps to move the food from the anterior to the posterior extremity of the stomach. It is here that the elaboration of the food has attained its highest point, and it is therefore here that it least resembles its original quality; it has here become darker and browner, whereas it was originally of almost the same colour as that of the leaf of the plant. But the mechanical advance of the food is not however wholly owing to the peristaltic motion, but it also depends upon whether fresh food has been received. When this is not the case the whole process of digestion appears more slow; the food already in the stomach then remains there, but becomes gradually softer and looser, and loses its colour, and appears decomposing; at least, according to Rengger, it then smells very unpleasantly; it also gradually loses the fluid portion of the chyme. But if the period of fasting be too much prolonged the caterpillar dies, and the food is even then found in the stomach. In general voracious caterpillars, which usually consume daily three times their own weight of food, cannot fast very long, at least not more than eight or ten days; perfect insects, namely, some beetles, can do without food much longer. I myself have seen a *Blaps mortisaga* move about quite briskly after having fasted for three entire months. Other instances have been observed in capricorn beetles which have been enclosed in wood for years; they were in a torpid state, but revived upon being exposed a short time to the air. Predaceous beetles, such as the large *Carabi* and *Dytici*, cannot long fast, at most a few weeks. Caterpillars which are not fed after their last moult do not die, but change into pupæ, but the pupæ are easily killed, particularly if the caterpillar immediately after moulting has been deprived of food; but the voracity of caterpillars decreases with the increase of their age, and it is only during the first period of their existence that they exhibit a hunger which is almost without parallel.

Many beetles, viz., the *Carabi*, the grasshoppers, and the larvæ of the *Lepidoptera*, eject upon being touched a brown, corrosive, gastric juice, and cast it at their enemies. Whoever has collected insects, and especially the *Carabodea*, must be well acquainted with this mode of their defence, as also with the pain which the intrusion of it occasions when by accident, which is not rarely, it comes into the eye. This acute pain, which occasions a gush of tears, distinctly proves the sharp and caustic quality of the gastric juice. In some *Hymenoptera*, namely, in the bees and wasps *, the ejection of the food regularly takes place, for they cast up, farther elaborated, the imbibed nectar of flowers, and supply the young with it as food. The ejection of it is caused by the antiperistaltic motion of the stomach and proventriculus, and thus the gastric juice is passed into the mouth by a contorted motion of the animal, whence by another quick bending it is thrown from it. According to Rengger the muscles of the skin also contribute considerably to the retrograde motion of the stomach, at least the force was considerably diminished when he cut the caterpillar along the back, and then irritated it by pressing and tormenting, causing the ejection of its saliva. In many, the innermost tunic of the stomach, after great

* Spallanzani Versuche uber die Verdauungsgesch, p. 36. Reaumur, Mém. de l'Acad. des Sc. de Paris, A. 1752, p. 472.

efforts was throwu np, whereupon the caterpillar died. After this, air in the shape of bladders broke out. This air appears to be constantly found in the stomach during digestion, and is probably partially swallowed with the food, and is partly evolved from the food in the stomach. The first takes place, according to Rengger, that the gastric juice which is spirted forth as a defence may be the more easily ejected, yet the constant biting and swallowing small pieces of leaves necessarily occasions the passage of some air into the stomach. During the pupa state, the intestine contains only air, or even nothing: we also find in perfect insects, for example, in the *Ephemeræ*, *Libellulæ*, *Grylli*, &c., much air in the stomach and the whole intestinal canal.

The digestion of fluids which haustellate insects imbibe, takes place, doubtlessly, in the same manner as the firmer manducated nutriment, with the alterations only which arise from the difference of food. The more elaborated the juices are, the more simple is the structure of the intestinal canal, whence it follows that the digestion of the nectar of flowers takes place in the *Hymenoptera* in a single cylindrical, but compact, transversely ridged duodenum, whence the chyme, together with the addition of the secretion of the many biliary vessels, passes into the true ilium. In the bugs, this simple duodenum, as the above description of their digestive apparatus (§ 105) has shown, is separated into several intestinal divisions, the first of which corresponds with the crop, the second with the proventriculus, and the third with the true duodenum. In addition to this great perfection of the chymifying portion of the intestinal canal, we must include the long and multifarious salivary vessels as preparatory organs, which very much facilitate the progress of digestion by the contribution of their secretion. The juices are thereby made capable of assimilation, and the assimilating portion is absorbed by the parietes of the ilium. It arises thence, also, that that portion of the intestine which lies beyond the duodenum is, at least in the bugs, extraordinarily short, whereas in the *Hymenoptera* and in the flies it is of the same length, or, as in the *Lepidoptera*, even longer. The smallness of the stomach connected with the duodenum in the *Lepidoptera*, makes us surmise that they take but little, or, indeed, many of them in their perfect state no food at all, or that, as their food consists of the nectar of flowers, it requires but little change. Thence their small stomach and long narrow ilium; and, next to the saliva, the secretion of the biliary vessels may contribute considerably to the transformation of this honey. Among the *Coleoptera* we find a family which agrees entirely with the *Lepidoptera* in requiring but little food, viz. the capricorn beetles. They also, as beetles, probably eat but little; at least, in all those individuals that I have dissected, I found the intestine full of air; and their nutriment likewise consists of the delicate nectareous juices of flowers. But of all haustellate insects the *Diptera* are the most voracious: we observe them the whole day long lapping and tasting every possible substance which contains sweet juices, or such as are agreeable to their palate, and which are frequently nauseous and stinking. They have consequently the longest duodenum of all insects. In front, where it supplants the stomach, it is most compact and muscular; behind it is softer, more delicate and membranous. The food is received into this long intestine, and, as it is generally of a cruder nature than that of the *Lepidoptera*, it consequently requires several different elaborative fluids. We therefore find, besides the oral salivary glands, others which sink into the commencement of the duodenum.

§ 222.

The elaboration of chyle takes place even in the first portion of the intestine, which corresponds in situation with the stomach and ilium, or where a proventriculus is found only in the duodenum lying behind it. The chyle is a whitish or greenish or even brownish, thick liquid, which first presents itself as a flocky substance between the innermost and second tunics of the stomach, and, upon a microscopic inspection, appears to consist of minute globules. It is the produce of digestion and the object of all the functions of the intestinal canal, and it forms the foundation of all the other nutritive fluids. In the higher animals, the chyle is therefore absorbed by the lymphatic vessels placed along the intestine, and conducted into the venous blood, whence it passes into the lungs or gills, here becoming oxydised, and it is then poured forth by the heart as fresh arterial blood. But such a circulation of the juices is not found in insects, for they have neither absorbents nor veins, but merely a single arterial vessel placed along the back. If, therefore, the chyle or lymph is to pass into this vessel, it must be transmitted through the parietes of the intestine and pass through the cavity of the stomach, whence the heart receives it through the above-described valve. This passage of the chyle through the intestinal tunic observation has distinctly detected. Ramdohr saw the chyle which was contained between the mucous membrane and the true skin forced during the peristaltic motion of the stomach through the exterior muscular tunic, and the remainder, which was not thus passed through, was driven towards the end of the stomach, and here distended the exterior tunic in the circumference of the pylorus. In a cockchafer, whose longer ilium was filled only at certain parts with food, he observed, after the stomach was removed from the body, a continued distending of it at those parts where the food was found. Upon opening the external skin at those parts, the brownish green chyle streamed forth. Rengger also observed the transmission of the chyle through the intestine in larvæ, which he opened alive, for, having carefully dried the exposed stomach, he saw it speedily become again moist.

Upon the chemical inspection to which Rengger subjected the chyle, that he found between the tunics of the stomach, it did not exhibit the alkaline property of the saliva and the gastric juice. In weak acid it formed flocks, as also when exposed to heat, which was dissolved in concentrated sulphuric acid; but, upon the addition of water, it re-formed flocks. He found similar flocks when he caused the caterpillar to vomit into diluted acid. Hence it appears that the chyle consists chiefly of albumen, which appears to be suspended in water. Rengger's experiment further confirms this opinion, for he injected water into the stomach of a caterpillar after he had tied up its end, and, upon opening it after a short time, he found the chyle at the anterior end much more full of water than that of the posterior, of which he convinced himself by the coagulation of the albumen by heat.

From the chyle being transmitted through the tunic at that part of the intestine usually called the stomach, is another reason for not considering it the stomach only, for the chyme alone is prepared in the stomach, from which the chyle is separated in the duodenum and ilium. We must, therefore, consider this portion, as in the lower animals, merely as the simple internal digestive cavity, whence gradually, by metamorphosis, different intestinal parts are produced, which present themselves as the crop, proventriculus and duodenum; or where such a division of the simple cylindrical nutrimental canal is not found, that that insect has remained stationary upon a lower grade of the organisation of the digestive apparatus. We should thus find within this single class a progressive succession of the perfection of the intestinal canal, for, commencing with the bag of the larvæ of the bees, which has no anal aperture, it terminates in the perfect structure of the predaceous beetles, and which corresponds distinctly with the development of the nutrimental canal throughout the animal kingdom. They thus represent in their crop and proventriculus the form of the canal of birds, and by means of the blind appendages of the duodenum they are likewise connected with the fishes.

§ 223.

In all the higher and in many of the lower animals, namely, the *Mollusca*, the formation of the chyle is produced by the addition of a peculiar fatty alkaline fluid, namely, the gall, which is secreted by a large lobate gland, called the liver, the duct of which empties itself into the duodenum, sometimes behind the pylorus, but in general in the vicinity of the opening of the ventral salivary glands. The object of this fluid appears to be to decrease the acidity of the chyme, and then by the intermixture of its component parts to prevent a prejudicial corrupt decomposition of the food upon passing through the intestinal canal; to transmit the fat in suspension, in which it is more readily absorbed; and to assimilate the nutriment by means of the gall and other animal matters it contains; and lastly to stimulate the peristaltic motion *. We may now ask if an analogue of these glands is to be found in insects, and whether its secretion when it exists is of such influential effect as the gall in general.

With respect to the existence in insects of such glandular secretory organs which empty themselves into the intestinal canal, we may observe, that but one kind of them is found, which is peculiar to all excepting *Chermes* and *Aphis*, and this is the above described (§ 111) biliary vessels. All other secreting organs which are found in the intestine of insects are peculiar to certain orders and families only. We have characterised them above as salivary organs, and given a detailed account of their form and presence (§ 112).

These gall vessels are actually gall-secreting organs, according to Cuvier, Posselt, Ramdohr, Carus, and the earlier opinions of Treviranus and Meckel. This opinion may be supported by

1. The general form of the secreting organs in insects.
2. By their situation, and by their insertion in the intestinal canal corresponding with that of the gall-secreting organs of other animals.

* Gmelin's Théor. Chimie, vol. ii. part ii. p. 1517. The result of the comprehensive experiments of Tiedemann and Gmelin upon digestion.

3. That at the spot where they empty themselves into the intestine there is frequently a bladder-shaped distension, a kind of gall bladder (for example, in *Lygæus apterus, Cimex baccarum*).
4. That sometimes, as in the secretory organs of other animals, stony concretions are found.
5. That they are very compact, and wholly surrounded by the fatty substance which is the formative matter whence all secreting organs derive the fundamental portion of their secretion.
6. That also the vena porta which conducts the blood to the liver in the higher animals takes its rise from such a fatty matter distributed within the ventral cavity, viz., from the mesenterium.
7. That the liver of the most closely allied animals, namely, of the crabs and many annelides (for example, *Aphrodites*), consists likewise of such blind vascular appendages which empty themselves into the intestine.

Whereas these opinions are contradicted by those of modern naturalists, namely, of Herold, Rengger, Straus Durckheim, Joh. Müller, and by the altered views of Meckel * and Treviranus † upon the following accounts :—

1. The biliary vessels empty themselves at a part of the intestine beyond where the chyle has been commenced to be absorbed, frequently closely before the colon, a short distance from the anus.
2. The chemical analysis of the biliary vessels, and of their contents, exhibits but little resemblance between it and the liver, for uric acid is its chief component. According to Chevreul's analysis ‡, the liquid obtained from the biliary vessels was alkaline, and vegetable colours, which had been turned red by acids, it stained blue; and upon the further addition of acids it precipitated uric acid, and smelt of ammonia when a weak solution of caustic potass was added to it. He thinks, therefore, that this liquid holds urate of potass and ammonia in solution. Wurzer § found also urate of ammonia, and both phosphate and carbonate of lime, which Brugnatelli || and John equally found also in the excrement of *Lepidoptera* immediately after their exclusion from the pupa.
3. Besides these biliary vessels many insects have other secreting

* Archiv. fur Anat. u. Phys. Jahrg. 1826.

† Das organische Lebens neudargestellt, p. 335.

‡ Straus Durk., p. 151.

§ Meckel's Archiv., iv. p. 213.

|| Ib., p. 629.

organs which empty themselves into the intestine, even indeed in front of the chylifying portion of it, namely, those blind appendages indicated as salivary glands behind the proventriculus.

4. In the spiders, secreting organs which resemble the biliary vessels empty themselves into the colon; and other vessels, which are in close connexion with the fatty matter, open into the ilium, and supplant the liver.

To harmonise if possible both views, which then would be the only true and correct one, we must in the first case ascertain if the liver, considering the organisation of insects, be absolutely necessary to their digestion. We find the liver large and of prominent development in all such animals in which the function of respiration is of diminished importance, especially those mollusca which breathe through branchiæ, and the fishes *. If we may thence conclude that animals which respire by means of lungs have a smaller liver, it is evident that insects, as those animals in which the respiration by means of lungs, or rather of pulmonary air-tubes, has attained its highest grade of perfection, must necessarily have the smallest liver of all. This may be caused by, as Carus † has remarked upon a similar occasion, the lungs and liver both separating the same substance, namely, such which contain carbon, by the former from an elastic fluid, and by the latter from a liquid. If, therefore, the lung is so predominant that it is found throughout the body, this separation takes place everywhere, and the liver, which by means of the veins receives the carbonated blood from the different parts of the body, where there is no lungs, is not required to act. The function of the liver as an excretory organ is therefore not requisite in insects, but yet as a secretory organ it is still of importance. Its chief object, viewed thus, is to reduce the acidity of the chyme, by means of the alkaline property of its secretion; but we have seen that the secretions of the salivary glands, and of the proventriculus, are both alkaline, and that the chyme beyond the proventriculus, or at the end of the duodenum, is perfectly neutral, and requires no addition of alkali to neutralise it; consequently even for this purpose the function of the liver is not necessary.

If we have thus shown that insects do not require a liver to promote

* This reciprocal relation appears to me as confirmed, and worthy of consideration, whereas the meritorious G. R. Treviranus denies it. Biologie, tom. iv. p. 420.

† Bootomie, p. 538.

digestion, it may be asked what is the function of the biliary vessels? Are they urinary organs or kidneys? Certainly not; for where shall we find, throughout the whole animal kingdom, an instance of the ureter emptying itself into the middle of the intestinal canal? And is not this the case with the biliary vessels in many, indeed the majority, of instances? The uric acid which chemists have found therein proves nothing, for many parts of the body of insects contain this acid, as Rudolphi * also correctly observes, it is likewise found in many other fluids besides urine †. Lastly, the resemblance of the biliary vessels to the urinary organs is too trifling, and the latter are always in closer connexion with the sexual organs than with the intestinal canal; besides, in some insects, namely, in the *Carabodea*, *Dytici*, and *Staphylini*, distinct urinary organs have been found (§ 113), the secretion of which indeed has not yet been proved by analysis to be urine, but which, both by their resemblance in form, and partly by their situation, have proved themselves urinary crgans. Joh. Müller ‡, who has most strongly supported the consideration of the biliary vessels as kidneys, will not admit of these organs being considered as secreting urine, but explains them to be peculiar glands which secrete a sharp liquid, and compares them with the poison glands of the *Hymenoptera*; but even if we admit of this analogy we must yet oppose his assertion that the insects which are provided with these organs secreting a sharp liquid, for it is supported by no other observation than at most the explosion of the *Brachini*. As this exploding secretion is gaseous, it cannot necessarily be secreted by these organs, but may be merely be the air contained within the broad colon. Whereas the *Dytici*, upon being seized, as I have frequently observed, eject their hyaline livid urine, which has a peculiar pungent smell, very like feverish or corrupt human urine, but which never acts acutely or poisonously, and inflammatory. We may here justly ask why these few insects only have urinary organs, and the majority want them, which is absolutely a difficult problem to solve; but in some others, for example, *Bombylius*, *Leptis*, the same organs are again found, and in *Gryllus migratorius*, Fab., I observed a single serpentine vessel, which originated from a small kidney-shaped organ, and which opened at an analogous spot near the anus. It is therefore

* Physiologie, vol. ii. part ii. p. 145, note 1.

† Gmel. Handb. d. Théor. Chemie, vol. ii. part ii. p. 1473

‡ De Gland. secern. struct. pen., p. 68.

probable that in the other grasshoppers such vessels will be found, as well as in other voracious insects, which, as such, more require excretory organs; whereas in temperate insects, and such as feed upon highly elaborated finer substances, as well as haustellate insects from the greater preparation of their food, and its consequent perfect quality of assimilation, the excretory organs would be wholly superfluous. Wherefore then, it might be objected, have the voracious caterpillars and larvæ no urinary organs? To which we might reply, that it must not be forgotten that larvæ stand upon a much lower grade of animal development than perfect insects, and that they therefore do not display so great a separation and division of their organs; if the anus be wanting in some instances, how much more likely are the urinary organs to be deficient? and, besides, the majority of caterpillars have other excretory organs, viz., the spinning vessels, which take up from the body much useless matter. The unimportance of the urinary organs to the nutriment of larvæ explains their deficiency in those cases in which the beetle exhibits them; at least in the larva of *Calosoma sycophanta* I have not observed such organs.

If, then, the biliary vessels be neither exclusively liver nor exclusively kidneys, it remains to be determined what their function is. To arrive at this we look around us for analogous forms in other animals, and immediately discover the paired cæca of birds. These organs, which Carus* even wished to compare to biliary vessels, diverge in one respect by their frequently considerable shortness (for example, in all the diurnal birds of prey), and in a second respect by their contents differing so much from that of the biliary vessels of insects; they are also of a similar structure with the intestinal canal, which is not the case with the biliary vessels. But it is remarkable that the parallel orders of birds and insects exhibit some approximation in the length of these organs, for the biliary vessels are likewise very short in the carnivorous *Carabodea*, and if not exceedingly long yet they are very numerous in the herbivorous grasshoppers and *Grylli*, which I compare with the gallinaceous birds, into the detail of which I shall go below. We might therefore indicate, if not a strict analogy, at all events a certain approximate relation between these appendages of the intestinal canal.

Besides these paired cæca of birds we find no other appendages to

* Zootomie, p. 388.

the intestine in animals which admit of being compared with the biliary vessels, unless it be precisely the same forms in the *Annelides* and *Crustacea*. These have been, particularly in the *Crustacea*, explained as the liver, and therefore the biliary vessels must be considered as the analogues of these filaments, or at least, as the analogues of the liver. With respect to form, this is doubtlessly correct, the above cited reasons speak too clearly in favour of it; but in function they are not merely liver, indeed not purely secreting organs but more justly excretory organs, which, however, do not separate urine alone, but also a kind of gall, and only in those instances where true urinary organs are wanting undertake as well the function of urinary organs. With respect to what may be objected from their opening higher into the intestinal canal, we may reply, that probably the whole remaining portion of the intestinal canal absorbs but little chyle, but instead, as Joh. Müller also considers, leads off the unassimilating remains. But in those instances where there are actual urinary organs the biliary vessels may be exclusively liver, at least their darker brown red colour in all these cases speaks in favour of it, particularly in the *Carabodea* and *Dytici*. In these then the tolerably long and especially broad and muscular ilium must also separate chyle.

I therefore positively consider the biliary vessels as analogues in form of the liver, but which do not exclusively exercise the function of the liver, but conjunctively, at least in many cases, the function of the kidneys, and of other secreting organs.

An opinion propounded by Oken explains the fatty substance as liver, but it is inapplicable, as has been shown by Meckel. Yet we cannot deny that the fatty substance has some relation to the liver, for the organisation of the *Arachnidæ* speaks distinctly in support of it. The biliary vessels may also, when they secrete bile, derive the foundation of their excretion from the fatty substance only, and we therefore find them everywhere closely enveloped by this fatty substance.

With respect to the direct observations of some physiologists, besides those already cited, upon the function of the biliary vessels, we find, according to Rengger, that they contain a clear fluid, in which the microscope detects a great number of globules. This fluid appeared more transparent and brighter when watery substances were received into the intestinal canal, and he therefore supposes that it is the water separated from the blood. He then observed the fluid, upon pressing the vessels, pour itself into the intestine, and Meckel remarked the same, whereby Ramdohr's opinion is contradicted of the frequent emptying of the biliary vessels into the space between the mucous membrane and the true skin. He further remarked, after this emptying, a refilling of the vessel and an advance of the fluid, without detecting the least motion in the vessel. The substance thus emptied he says he found again in the excrement, in the form of little globules upon its surface; also the reddish brown juice ejected by the *Lepidoptera* immediately after their exclusion from the pupa, consists chiefly of the excrement of the biliary vessels. That this fluid, as well as the excretion of the biliary vessels, contains much uric acid, has been proved by the analysis of Chevreul, Brugnatelli, and John, and which we have mentioned above. According to Rengger, the secretion of the biliary vessels dissolves neither in hot nor in cold water; it becomes firmer in alcohol, dissolves in concentrated acid, and is precipitated from this in a flocky form, upon the addition of water: upon proof paper it exhibits itself neither as acid nor alkaline, nor does it taste bitter, but insipid, like all the parts of a caterpillar. The excretion does not either re-act upon diluted chyme, and in the chyme from the intestinal canal beyond the biliary vessels, there was no fluid matter.

Straus Durckheim considers that there are in the cockchafer two different kinds of vessels which empty themselves into the intestines. The anterior ones which open beyond the stomach have ramose, transverse continuations, and are brownish; the posterior ones, whose orifices * he could not discover, are of a yellowish white and smooth, and without continuation. The anterior ones he considers as biliary organs, and the posterior ones as urinary organs. It is unimaginable how Straus, in so laborious and accurate an inquiry, should make such a mistake, particularly as two anatomists before him had described and figured the intestinal canal of the *Melolontha vulgaris*, namely, Ramdohr † and Leon Dufour ‡. From both, as well as from Suckow's § representation, it results, that in the cockchafer, likewise, there are but four very long biliary vessels, which pass into each other, and which at their anterior half send off ramose appendages, whereas posteriorly they have none. That the biliary vessels in many cases, for example,

* P. 270. † Abhand. uber die Verdauungsorgane, Pl. XVIII. f. 1.

‡ Annales des Sciences Natur. t. iii. p. 234, Pl. XIV. f. 4.

§ In Heusinger Zeitschrift. f. d. o. Phy. vol. iii. Pt. 1. Pl. III.

in the *Capricorns,* stand in connexion with the intestine at a second lower spot, but do not again open into it, has been shown above (§ 111). Joh. Müller has been misled by Straus to speak likewise of double vessels, which, he says, open at different parts of the intestine*, but such second vessels are not found in any insect.

§ 224.

The divisions of the intestinal canal which lie beyond the orifice of the biliary vessels, and which we have described above as the ilium, clavate intestine, cæcum, and colon, occupy a portion of the intestinal canal, which, in the majority of cases, is not half the length of that of the preceding part, and which is indeed often, namely, in the *Hemiptera,* so short, that it does not form one-tenth of the entire intestine. With respect to the law which regulates the proportions of the parts of the intestinal canal, we may consider that it is in general longer in carnivorous insects, but, on the contrary, shorter in the vegetable consumers, and that the larvæ have almost always, with the exception of the larvæ of the *Dytici,* as was remarked above, a very short portion of intestine beyond the orifice of the biliary vessels, whereas in the perfect insect it is longer.

If we inspect the contents as well as the function of this portion of the intestine in vegetable-feeding insects, for example, in the larvæ of the caterpillars, we shall find, according to Rengger's observation, that no further peristaltic motion is detected in it, and that the chyme contained within it separates no longer any chyle, nor, indeed, is any mixed with it. In the larvæ of the *Lamellicornia,* no food is observed in the ilium, but the great gut is closely filled with it. This nutriment is found here further comminuted and more pappy than in the stomach, differing in about the same proportion as the chyme of the stomach does from that of the cæcum in the *Rodentia,* and we must, therefore, at least in this instance, admit of a repeated separation of chyle, which is also confirmed by the dry, thick, excrementitious contents of the short colon. Ramdohr supposes that the biliary vessels, from their in general ascending and descending the duodenum, but subsequently spreading themselves about the greatest convolutions of the ilium, imbibe from it nutritive matter during the passage of the chyme, and that it is thence that the latter contains less moisture in the ilium : he ascribes the same

* De Glandul sec. Str. par. pp. 68, 69.

function likewise to the great gut, and, as the clavate gut is the same organ, it would necessarily also be attributable to this. Thus much is certain, that the chyme is further elaborated and extracted in the great gut of such larvæ before it is rejected from the body by the colon.

A function limited to the conveyance of the chyme cannot be attributed to the very long ilium of the carnivorous insects, namely, the *Dytici* and *Peltodea*, particularly as it is not only longer here than the duodenum, but even several times its length, for example in *Necrophorus*. In these, evidently, as in the higher animals, the ilium must throughout its whole course separate chyle; at least, a thin finely divided chyme is found throughout it. I am of the same opinion of the likewise very long ilium of the *Lepidoptera*, for the small egg-shaped stomach is too insignificant to separate all the chyle requisite for their support, although, as experience teaches us, the *Lepidoptera* are very temperate in the taking of food, and exhibit no trace of their previously voracious appetite as larvæ. All these insects with a long ilium have no distinct thick intestine, whereas in those with a short ilium, for example, the *Capricorns* and *Lamellicornia*, we find it described by Ramdohr as the clavate intestine. In the cockchafer and the other *Lamellicornia*, in their perfect state, instead of the broad sack-shaped thick intestine, we find an oval longitudinal thick gut, which is internally furnished with projecting longitudinal folds, which, as well as in the larvæ, subjects the chyme to a second elaboration, and also extracts it, for which purpose it appears to require the longitudinal folds. This second extraction can also, if it, which we may not doubt, likewise takes place in those insects which have a long ilium, occur only in the ilium. Indeed, such insects, namely, the *Dytici*, *Peltodea*, and *Lepidoptera*, have a longer or shorter cæcum, which, in *Dyticus*, is nearly half the length of the intestinal canal, and wherein the chyme may possibly be subjected to a second digestion. In favour of this opinion the multitude of glands upon its inner surface speak, as well as the viscous nature of all the nutriment contained within it. But we do not always find it filled with chyme, occasionally only in *Dyticus*; it sometimes only contains air, whence is explained Leon Dufour's opinion of its supplying the place of a swimming bladder. In the *Lepidoptera*, the brownish red fluid accumulates in it during the pupa state, which is rejected upon the exclusion of the perfect insect, and which, according to chemical analysis, consists chiefly of uric acid, and very much corresponds with the excretion of the biliary vessels. Treviranus, therefore, compares this cæcum of the *Lepidoptera* to the urinary bladder, and it would we were to institute an analogy with the birds, be analogous to the *bursa Fabricii* of those animals. Thus much is certain, that this cæcum cannot be of so much importance to digestion as, for example, the cæcum of the *Rodentia,* or the clavate and thick intestine of other insects which are analogous organs.

The true rejecting portion of the intestinal canal is therefore the colon. By its considerable size, in the majority of cases, it is adapted to the reception of much matter, and peculiarly adapted, by its strong muscular structure, to the compression of it into lumps of excrement. To promote this object, it has in many cases hard horny ridges and prominences, which assist it in its function. The shape of the excrement depends both upon the size of the colon and its folds. It is so various in the caterpillars of the *Lepidoptera,* that frequently, with a little attention, distinct genera and species may be distinguished by it, a skill which is not unimportant to those who have the care of plantations. In general, vegetable-feeding insects produce more excrement than the carnivorous ones. This is distinctly shown in the caterpillars and grasshoppers, the short but broad colon of which exclude at intervals of a few minutes considerable balls of excrement, which are shaped precisely according to its form. In general, the digestion of these insects is so rapid, that the just filled intestinal canal will have extracted all the chyle in the course of one hour, and the caterpillar recommence eating. Indeed, the food passes through the entire intestine merely to make room for constantly succeeding food, and a voracious caterpillar, therefore, will be continually evacuating excrement. In the perfect insect, the colon is wider than the rest of the intestine, but towards the anus it again contracts, and it consequently evacuates the excrement in smaller, at least thinner, portions, or in a more fluid, thick, pappy consistency; haustellate insects, such as the *Lepidoptera* and flies, reject it quite liquid. The colour of the excrement also depends upon the difference of food; for instance, that of the cockchafer is green, like the leaf of the plant upon which it feeds; that of the water beetle of a yellow white, like the flesh he has eaten; that of the flea red, like the blood it has imbibed; yet the colour always changes a little; it becomes, namely, darker, brownish or blackish, as in the flies, which lap so many different kinds of nutriment. No peculiar offensive or stinking smell is observed in the excrement of insects, and, indeed, their rapid digestion does not admit of so complete a decomposition as in the higher animals, particularly as the entire digestion of insects is almost limited to the imbibition of the juices contained in their food.

§ 225.

Lastly, we must here treat of some peculiar secretions which are the produce of digestion, or at least in their fundamental parts, but which exercise no influence upon it: among these we consider the secretion of the spinning vessels and other secerning organs, namely, those of the poison glands.

The spinning vessels (§ 112), which are found only in larvæ, are long twisted canals, which empty themselves into the spinning vessel found in the under lip, or in some rare instances, for example, in the larva of *Myrmecoleon*, present themselves in the shape of a pyriform bag, which, in the perfect insect, appears to be transformed into the colon: they lie at the anal extremity, and contain a viscous fluid, which, in the younger larvæ, is quite transparent, but, in more mature ones, it is more opaque and thicker. From this fluid the larva spins delicate filaments, which speedily harden in the air, and are then no longer soluble in water. The entire spinning vessel also, when dried in the air, likewise hardens to a firm fragile mass. Chemical analysis discovers the components of this fluid to consist of a substance like lime, a waxy portion, and a little coloured oil which smells like anise. Acids poured upon it harden it; in young caterpillars it precipitates a flocky substance (albumen); but in very concentrated acid it dissolves, as well as in a solution of pure potass: from the former it was precipitated by the addition of water, and from the latter by that of acid in a flocky shape. Hence it appears, that, besides animal albumen, a resinous and an oily substance form components of the spinning fluid, in favour of which the adhesiveness of the fresh material, its rapid drying, and fragility in a mass, speak greatly. It is, consequently, purely an excretion, and is made for the purpose of removing from the body the oily and resinous vegetable portions which are received into the blood by digestion, and again separated from it by the spinning vessels. In the spiders, which feed upon animal substances, and, therefore, doubtlessly, in the larvæ of the *Phryganeæ* and in the *Antlion*, &c., which also devour animal matter, it also contains ammonia* and a material allied to the horny

* Gmelin's Chemie, vol. ii. Pt. 2, p. 1475.

substance, the presence of which is to be deduced from the variety of their food.

True poison glands are less generally distributed: we have described them above (§ 140) among the appendages of the female sexual organs. They are found only in the *Hymenoptera*, viz. in the *Pompili*, *Spheges*, wasps and bees. The secretion of these organs is a sharp corrosive fluid, which is the principal cause of the violent pain that is experienced from the puncture of these insects. The form of the sting, which has also been described above (§ 145), enables them to insert this poison into the wound at the time of the puncture, as the sting is not simple, but consists of several setæ, which form a narrow canal. We find, likewise, in the *Lepidoptera*, appendages which, in structure and place of opening, appear to be analogous to these poison glands. This analogy is supported by the intelligence of some residents at the Cape of Good Hope, who inform us that there is a lepidopterous insect known there by the name of the bee-moth, which defends itself in stinging when captured, and the puncture is so painful, that a large swelling speedily arises which quickly produces inflammation *. The chemical composition of this poisonous fluid cannot be given without analysis: it perhaps contains a free acid allied to the formic acid, or is, probably, the very same thing, which supposition is supported by the similarity of the pain to that of a wound from an ant. These creatures, namely, have no sting, but yet they possess the poison organs, and project from their anus by raising their abdomen this sharp fluid against their enemies. Its acuteness is shown by the violent pain caused by being sprinkled with it. They also defend themselves by biting, but their bite is harmless. That these organs are analogous forms to the urinary organs of the *Carabodea* and *Dytici*, is on the one side supported by their similar situation at the extremity of the body, yet with this important difference, that these open above the intestinal

* Isis. 1831, p. 1917. From a letter received by Professor Reich from the Cape of Good Hope. It is the opinion of the entomologists cited there, that the projecting sting is the male organ, but it is contradicted by a Brazilian *Cossus* in the Royal Entomological Collection at Berlin, and which is a female: it has a long and very pointed sting, which is recurved, but I was not at liberty to inspect it more closely. According to analogy, this sting can be nothing else than an ovipositor formed by the projection of the horny ridges found in the vagina of all insects. It appears most to correspond with the sting of the *Hymenoptera*, yet it appeared to me that the exterior sheaths were wanting, if I may trust a very superficial glimpse which was all I could have of it.

canal, the former, however, beneath it, into the evacuating duct of the sexual organs; on the other side, by their similar form, they also forming serpentine or ramose canals, which terminate in a larger reservoir, or bladder. In both cases they are double, but the poison organs empty themselves into a bladder with a single duct, whereas the urinary bladders remain separated and have two distinct orifices.

We also discover frequently in insects peculiar secretions, which are found limited to certain families. They betray themselves especially by the smell which insects possessing them either constantly produce, or only upon certain occasions. Thus the large *Carabodea* smell like fresh Russia leather, which must be ascribed to a secretion that is emitted through one of the articulating membranes. This supposition is supported by the milky secretion which is poured forth in abundance through the articulating membrane between the head and prothorax and mesothorax, by recently captured *Dytici*, and which has an offensive stench like that of putrid urine. In *Meloë*, a different oily fluid is secreted in the articulating membranes of the legs. In neither of the two former instances could I discover a distinct secreting organ, and Brandt was equally unsuccessful in *Meloë* *. The sharp secretion of the *Cantharides* is universally known, for which also no distinct secreting organ is to be found, but which seems to be deposited principally in the hard horny parts. Here the excretion exhibits itself as a peculiar substance, which chemists designate by the name of cantharis camphor †, and which alone possesses the property of blistering. It is also found in other genera and species of this family, for instance, in *Mylabris*, which is the true *Cantharis* of the ancients. Other volatile, ethereal, and peculiar secretions are observed in *Callichroma moschatum*, the spurious Spanish fly, which insect betrays itself at a considerable distance even, by its agreeable and peculiar smell; in the stinking burying beetle (*Necrophorus*), dung beetles (*Scarabeus*), and in some *Chrysomelæ* and *Coccinellæ*. The last especially, upon being touched, emit a yellow fluid through the segments of the abdomen, which smells strongly of opium. Perhaps it is from this that they have been applied in the toothach. The *Hemiptera* are distinguished among the other orders, and especially the bugs, by a very peculiar insufferable stench, which is, however, only to be detected

* Arzneithiere, vol. ii. Pt. 4, p. 104.

† Gmelin's Chemie, vol. ii. Pt. 1, p. 427.

upon touching or pressing the creature, and is probably produced by a peculiar secretion, which serves them as a defence against their enemies.

Among the *Hymenoptera* also many bees are distinguished by a peculiar very agreeable smell, which may in many instances however originate from the flowers they visit.

One genus of this large family, the domestic bee, produces a secretion of a distinct nature, which is not found in any other insect. This secretion, which distinguishes itself less by its smell than by its peculiar quality, is the wax of which the bees construct their cells. The secreting organ is found in the space between the ventral plates of the five intermediate abdominal segments, and exhibits itself as a delicate, soft, structureless membrane which passes from the superior half of each ventral segment, and, describing an arch, inserts itself in the preceding; hence it is the true articulating membrane itself, which has here transformed itself into a perfect secreting organ. But such a function of the articulating membrane is not without analogy in other insects, for in the *Dytici* the membrane between the head and thorax, in *Meloë* that between the femur and tibia, and in *Coccinella* that between the several ventral plates, is a true secretory organ. The form of the secreting surface presents itself as a long octagon, which is divided into two halves by a central horny ridge. This octagon lies at the anterior surface of each of the central five ventral plates, and stands in connexion with the posterior side of the preceding plate, by means of a process. Thus each bee has five secreting pockets in its abdomen. In these pockets the wax is prepared in the form of very thin, white, and very fragile plates, which are firmly attached to the secreting surface, and thence removed when the bee wishes to construct a cell. For this purpose it breaks the wax plates into small pieces, and by means of its saliva it prepares with it a soft pappy substance, which is stuck together in small pieces, and afterwards smoothed by the mouth with the assistance of the saliva *. The saliva, therefore, from possessing the property of dissolving the wax, must be of an alkaline nature, which is proved also by its organs becoming red when laid in vinegar. In the other families of the *Hymenoptera*, on the contrary, namely, in the ants, a superfluity of acid is found in the body, which

* See G. R. Treviranus, in the Zeitscrift für Physiologie, vol. iii. p. 62., upon these wax-preparing organs, and the mode in which the bees work it.

betrays itself not merely by its smell but more by a peculiar but not unpleasant taste. That this acid is found especially in the abdomen is well known, but we are unacquainted with the organ that secretes it; it is probable that the poison organs and the acid are both merely a very sharp urine.

Among the *Lepidoptera* peculiar secreting organs have been found in some larvæ, for instance, in the larva of *Harpya vinula*, which has a little bag at the ventral plate of the first abdominal segment, that, when filled, is of about the size of a pea, and the aperture to which is a transverse incision at the same spot. The fluid contained in it is a powerful acid, which produces pain and inflammation upon a delicate skin*. In the caterpillar of *Pieris Machaon* there is a similar furcate secreting organ in the neck, which is projected upon its being roughly handled. The getting greasy, as it is called in *Lepidoptera*, also indicates a great provision of secreted juices. In *Harpya vinula* it is frequently the case, and we might thence suppose it to be consequent upon the secretions of the caterpillar. The liquid, however, seems to be no oil, but rather an acid. Lastly, among the *Diptera* we find individual instances of a presence of peculiar secretions, for example, in *Cœnomya ferruginea*, Meig. (*Sicus ferrug.*, *S. bilicor*, and *S. errans*, Fab.); some of the flies which belong to the division of those with a spiny scutellum (*Dipt. notacantha*), which Meigen called whey flies, from their penetrating smell, resembling that of green whey cheese. This smell, which proceeds from the whole body, and which cannot be ascribed to any local excretion, remains even a long time after death, whereas the majority of such odours then speedily evaporate.

§ 226.

II. FUNCTION OF THE AIR TUBES, RESPIRATION.

The chief object of respiration is to adapt the circulating fluid destined for assimilation with the organic mass to that purpose, by the addition of another substance, viz., atmospheric air or oxygen. To attain this we find in the majority of instances distinct respiratory organs, namely, a more or less distributed respiratory surface, which must be purely considered as either an internally or externally produced continuation of the epidermis, and in which the fluid circulates, and

* Rengger's Physiolog. Untersuch., p. 427.

which thus stands in constant connexion with the air, whereas, when this continuation of the epidermis forms an internal cavity, the oxidised respiratory medium is received in it. These cavities, which are everywhere distributed throughout the bodies of insects, we have described above, according to their most general forms, as air tubes or tracheæ; they constitute the respiratory organ, which is consequently neither external nor partial, but is distributed throughout the entire compass of the cavity of the body in uniform perfection. The structure of the respiratory organ will, therefore, be fully known when we shall have proved that these air tubes and no other portion of the body actually constitute it. Commencing with this proof, the subsequent divisions of this chapter will be occupied with the mechanism of respiration, and its effects upon the corporeal functions.

§ 227.

With respect to the proofs that the tracheæ are the actual respiratory organs of insects, the most superficial anatomical inspection of an insect shows us that air is found in these tubes, and that we nowhere find internal apertures to these tracheæ, but constantly external ones. Besides, air is seen to pass through the external orifices, or spiracles, when living insects are cast into water, as air bladders rise from them to the surface of the water. But Treviranus's * experiment is the strongest proof; he placed the large green locust (*Locusta viridissima*) beneath a turned up glass filled with water, and then saw an air bubble rise from the spiracle between the meso- and meta-thorax, which regularly decreased with the respiratory motion of the creature, and again increased with its distension. Hausmann also observed an ascent and descent of the water in a glass tube closed above, the superior space of which contained air and a green locust, and this took place synchronally with the inspiration and expiration of the insect †. Other facts which prove the function of the air tubes as respiratory organs are, for instance, the speedy death of all insects whose spiracles are closed with oil or gum, so that no fresh air can enter the tracheæ, besides the ascending to the surface of all such water insects which have no branchiæ, and lastly, the projection to the surface of the air-tubes whilst the remainder of the creature is immersed in the water. In addition to these direct observations upon the respiratory function of

* Biologie, vol. iv. p. 158.

† De Animal. exsang. respirat., p. 8.

tracheæ we have other indirect proofs derived from their structure. These are their anatomical conformity with the tracheæ of the higher animals, their distension into bags and bladders, which correspond with the cells of the lungs and its bags; and, lastly, the deficiency of a peculiar respiratory organ, which would be the more necessary in insects, from their being covered with a hard integument, which could not exercise that function. All these facts confirm the tracheæ to be the true and sole respiratory organs of insects, and that air containing oxygen is received into them through the spiracles, air tubes, or branchiæ.

§ 228.

If we now return to the mechanism of respiration, we shall find that it presents itself throughout the animal world as a rhythmical motion of the body, whereby the medium containing the oxygen is brought into incessant contact with the respiratory organs. This motion in insects is consequently for the purpose of introducing atmospheric air within the tracheæ, which object is attained by the opening of the spiracles which close the apertures of the tracheæ. If the abdomen of the insect distends at the same time as the spiracles open, the air must necessarily pass into the tubes which are now opened, and when the abdomen contracts, the just inspired air will consequently be forced out again. Thus all respiratory motion presents itself as a rhythmical compression and expansion of the cavities of the body, and especially of the abdomen. The muscles which produce this motion are the same as those described above as connecting the several parts of the skeleton together, namely, the straight dorsal and ventral muscles of the abdomen. The thorax appears to participate less in the contraction of the cavities of the body, at least no contraction or dilatation of it is to be detected in insects quietly breathing; and also the intimate and firm connexion of the several parts of it together prevents such an alteration of its compass in repose. But whether the cavities of the tracheæ are also contracted upon the considerable compression of the abdomen, is uncertain. Nitzsch * has in many instances observed that there was no alteration during respiration, whereas he detected in the large air bladders of the *Diptera* and of the *Hymenoptera* a distinct compression upon the contraction of the abdomen, but which evidently appeared to proceed from the latter, and not from a contraction of the air bladder itself †. Hence,

* Comment. de Respirat. Animal. p. 38. † Ibid. p. 39.

therefore, the rigid spiral filament which encircles all tracheæ is especially adapted to its constant distension, precisely as is the case with the cartilaginous tracheæ of the superior animals. Consequently, by means of the elasticity of this filament, the trachea spontaneously distends upon the distension of the abdomen, the compression of which had decreased its compass; and possibly it is as much distended beyond its natural size, by the introduction of air upon inspiration, as it had been previously contracted by the contraction of the abdomen, at least Comparetti's experiments * upon locusts opened alive appear to indicate as much, but it cannot be kept constantly contracted or distended beyond its usual size owing to this filament.

In general the respiratory motion is very unequal; it is either quicker or slower, according to the state of excitement or repose of the entire system. It appears also to vary considerably in the several orders. Sorg observed † in *Lucanus Cervus* from twenty to twenty-five contractions in a minute, whereas in *Locusta viridissima* ‡ there were from fifty to fifty-five, and in *Deilephila Euphorbiæ* § only twenty. In a cockchafer, whose elytra I had cut half off, I could detect no pulsation at all, even with the greatest attention, and by means of a lens, so long as it remained inactive and as it were asleep; but upon taking it into my hand, the warmth of which aroused it, pulsations were to be seen, at first, it is true, very irregular, both in intensity and the interval that elapsed between them, but it at last breathed regularly when preparing for flight, and there were now about twenty-five contractions in a minute; but the abdomen after each contraction gradually decreased, never subsequently distending so widely as at first, but likewise it compressed itself more and more, so that there was an equal ratio between the decrease of its dilatation and the increase of its contraction. Shortly before taking flight it moved its whole body as it were convulsively, the head was protruded and withdrawn, pro- and mesothorax were also loosened from each other and again brought together, and, lastly, the valve of the cloaca was widely opened, and it appeared to struggle during its violent respiration as if desirous of disencumbering itself of an oppressive load. But all its endeavours

* Obs. Anat. de Aurâ Internâ comp. p. 290, according to Treviranus's Biologie, vol. iv. p. 161.

† Disquisit. Physiol. circa Respirat. Insectorum et Vermium, p. 27.

‡ Ibid. p. 46. § Ibid. p. 66.

were in vain, for its clipped wings made flight impossible. *Libellulæ*, which are held by the wings behind, may be very well examined, and the pulsations of the abdomen are very distinct, but no motion is to be detected in the thorax. The number of these pulsations is greater than in the cockchafer, but not so great as in the green locust. I estimate them at from thirty to thirty-five in a minute. I consider, besides, that the pulsations increase when the voluntary motions, for instance, that of flight, are in exercise, which I conclude from the respiration of a *Libellula* held in the above manner, increasing upon its endeavours to free itself. During this, however, the spiracles of the abdomen did not appear to inspire, and the contractions of the abdomen recommenced only after the motion of the thorax. Treviranus* concluded, from similar observations, and, indeed, justly, that the spiracles of the abdomen respire during repose, whereas those of the thorax are especially in action during flight. He cites as a proof, that the same muscles which contract the cavity of the thorax, our straight dorsal and pectoral muscles as well as the oblique lateral and dorso-lateral muscles, effect the first expansion of the wings by the general contraction of the thorax, and, subsequently, in conjunction with the true alary muscles, produce the motion of flight by the alternating distension and contraction of the thorax. During this motion of the thorax, air must necessarily pour in and out, particularly as the expiration of the abdomen progressively increases, as is proved by my observations upon the cockchafer, and the deeper it becomes, the earlier do the spiracles of the thorax commence breathing, and this supposition is strongly supported by the motion of the head and prothorax. At the very moment, however, that the beetle flies off, it compresses its whole abdomen together, and this is continued during its whole flight, a clear proof that the whole function of respiration now is effected by the spiracles of the thorax. We may also note that the sudden breathing of the abdomen in insects upon their settling after flight, namely, in the flies, bees, and wasps, tends to support it. The longer the creature reposes, the slower and more regular the pulsations of the abdomen become. This opinion also of the respiration through the spiracles of the thorax gives a sufficient explanation of the humming noises produced by most insects during flight, as I shall prove in detail below, for it cannot be conceived that the mere flapping of the wing can produce it, but that it proceeds

* Das organische Leben, t. i. p. 262.

from the air streaming in and out of the thorax during flight. We find also the motion in the wings of insects even at rest during their chirping and crying, for instance, of the great grasshopper, to harmonise with this opinion, for without the air streaming out of the thorax upon the fluttering wings, not a tone could be produced. Therefore, the voice of all insects is no mechanical friction of portions of the skeleton, but in them, as elsewhere, it stands in immediate connexion with the respiratory apparatus and its outlets.

§ 229.

The spiracles themselves participate somewhat in the pulsations of the entire body, at least in the larger ones which lie exposed upon the surface of the body on opening and shutting of them, synchronal with the in- and ex-piration has been observed. We also know, from the preceding description of all the forms of these spiracles, that only those which lie exposed are supplied with a peculiar apparatus for the opening and closing of their lips, whereas those which are concealed beneath portions of the skeleton exhibit either none or only a partially closing margin. Such spiracles consequently do not appear to be able to be closed, but the air seems constantly to pass in and out with each breath. Other writers, on the contrary, maintain a complete closing of the spiracle in some insects by means of extraneous substances which lay in front of it. Reaumur was the first to observe this closing of the spiracles in a pupa by means of a viscous substance, and Sprengel * confirmed it. If now such a substance shall have been observed in insulated cases, which may not be doubted, from the positive assertion of Sprengel, it can occur only as an exception, perhaps, in consequence of the diseased state of the caterpillar; or it was perhaps a peculiar secretion which was separated around the spiracle, and at a moment of danger, for instance, upon being touched, flowed in front of the spiracle, to prevent the application of something prejudicial; subsequently, however, when the caterpillar no longer feared the presence of its enemy, was again absorbed, or mechanically removed; perhaps also the substance may have got there by accident. In all cases, however, free respiration would be impeded by it, and this stoppage could not last long without becoming prejudicial to the insect. It appears, therefore, probable to me, that all pupa in which such

* Comment. de Partib. § 4.

a stoppage of the spiracles has been observed, were either dead or upon the point of death. But that the function of respiration may be long interrupted in pupa, is attested by a number of experiments, and, therefore, it is not at all improbable that the pupa may have exhibited signs of life even when its spiracles were stopped up.

The earliest physiologists, viz. Malpighi and Reaumur, instituted experiments upon the effects of stopping the spiracles with oil or gum, and obtained the result, that if the stoppage were long continued, it would cause the death of the insect. More recently, Moldenhawer *, in proof of his view that the spiracles were not the orifices of the respiratory organs, made many experiments by stopping them with oil, and the result obtained from his investigations was, that not merely stopping the spiracles, but even merely brushing it over with oil, was fatal to the insect system. But this is not the case. G. R. Treviranus †, who repeated many of his experiments, observed death to ensue only upon the stoppage of all its spiracles, and not when the body or portions of it were brushed over with oil; and indeed upon the complete stoppage of all the spiracles, it was some hours before death was produced. This was the case with insects found under water. But the effects of the stoppage were very various: caterpillars lived longest; perfect insects were sooner killed; some, even upon a partial coating of oil, for instance, a wasp, the breast and venter of which was covered with oil of almonds, died in a few minutes. But as it is precisely upon the breast and ventral portions that the orifices of the spiracles are placed, we may presume that they were stopped in this experiment. That it does not prove fatal to cover some only of the spiracles, is proved by an experiment upon a *Meloë*, the ventral spiracles of which were closed. Its preceding activity remained almost unaltered, for the spiracles of the breast, which Treviranus does not indeed know in insects, remained free, and through these the beetle could breathe ‡.

Whereas it has been observed upon the covering of some of the spiracles only, namely, those lying upon the same segments, there ensued a partial laming of that portion of the body thus deprived of

* Beiträge zur Anatomie der Pflanzen, p. 309.

† Biologie, vol. iv. p. 151.

‡ Das organische Leben, p. 257. The majority of observations here made upon the situation of the spiracles in the several orders is erroneous, as the description we have given above will prove.

air, Reaumur and Bonnet * among the earlier naturalists, and Treviranus among the moderns, have made experiments upon this point. According to Bonnet, the oil inserts itself within the spiracle, and by that means still more impedes respiration. Treviranus, who stopped only the posterior spiracles of the caterpillar of *Cossus ligniperda* with oil, observed a trembling, and raising of the last abdominal segment, but which, however, soon disappeared, after which the caterpillar exhibited no further morbid symptom. The same was the case with a green locust, the thoracic spiracles of which were stopped with oil: at first the legs appeared to become weaker and motionless, but it subsequently recovered. My opinion is that this phenomenon of a partial laming can present itself only immediately after the closing of the spiracle, for subsequently air will pass from other spiracles into those tracheæ whose orifices have been closed, particularly as all the tracheæ stand in immediate connexion together, at least in the majority of insects. It is only so long as the organisation is deprived of this auxiliary assistance, that symptoms of lameness can appear. But even without this assistance, it is scarcely advisable to seek in animals which stand only upon a central grade of organisation for the uniform phenomena observable in the more regulated conditions of life of the superior animals. How long a time cannot insects pass beneath water or in spirits of wine without respiring, and yet recover from their stupor! In the latter they indeed speedily die, but I know many instances of beetles having been immersed in spirits of wine for twelve hours, and, upon being removed from it, recover all their functions. But it is much more fatal for insects to inspire air impregnated with the fumes of evaporated spirits of wine; it is true that here they die more slowly, but at the latest in the course of half an hour, and when once thoroughly made torpid, they do not again recover.

§ 230.

The mechanism of respiration in insects which live in water is not in general different from that of those which live constantly in the air. But this observation refers especially to those only which breathe even in this medium through spiracles, whereas the process in those which breathe through gills is somewhat different.

Those water insects which breathe through spiracles must come to

* Contemplations de la Nature, t. ii.

the surface of the water when they wish for fresh air, and bring that portion of their body provided with these apertures in communication with the air above the surface. Among the beetles there are two families especially which live in the water, namely, the *Hydrocantharides* and *Hydrophilus*. The mechanism of respiration differs in both. The *Dytici*, when they wish to breathe, bring the posterior extremity of their body to the surface of the water, and they then separate the last segment of the abdomen from the elytra, and thus admit air beneath the elytra within the space between them and the abdomen; they then close it by pressing the last segment firmly to the abdomen, and return with their fresh supply to the bottom of the water. Here this air is so long inspired by the spiracles, which are situated also within this cavity between the elytra and the abdomen, as it is fit for respiration, after which the insect returns to the surface of the water, again to renew its supply. We thus observe in these insects the same process as we find in those which live in the air. The *Hydrophili* breathe differently. These, as Nitzsch * has observed and described in detail, do not bring the apex of the abdomen, but the head, to the surface of the water, and then project one of their clavate antennæ, the whole clava of which is covered with fine hair, until it comes into contact with the air. But they so twist the clava that its base is exposed to the air and the apex touches the breast, which, as well as the whole underside of the insect, is clothed with short silky pubescence. By this means a communication is made with the external air and that beneath the water covering both the clava of the antennæ and the whole under surface of the insect to which it adheres by means of the coating of down, and by means of this communication fresh air is transmitted to the venter of the insect, and by the same means the expired air is also removed, and the air is likewise transmitted from the ventral surface beneath the elytra, where it is in- and expired by the spiracles there situated. It is to the air thus adhering to the venter that the *Hydrophili* are indebted for their lightness. It is with difficulty that the majority can keep themselves at the bottom of the water by clinging to substances there, and, when once at the surface, only by the help of other bodies, for example, the stem of a plant, down which they creep, can they recover their situation beneath. The great *Hydrophilus piceus* alone, by means of its stronger muscular power,

* Reil's Archiv. für Physiologie, t. x. p. 440.

can work itself beneath the water, and swim about in it, although but slowly, if unassisted, whereas the *Dytici* swim with the greatest facility on all sides.—A third type of water beetles, the *Gyrinus* or whirlwig, also conveys an air bladder with it when it dives, which he can accomplish only with difficulty and the greatest exertion, or by means of other assistance ; he, however, receives the air posteriorly between the abdomen and the elytra, which is the easier to him as he swims freely about in circles upon the surface. The larvæ of the *Dytici* and *Hydrophili* likewise breathe through spiracles which are situated at the anal extremity; they therefore only require to bring the end of the tail to the surface of the water when they wish to respire. They are, therefore, seen with a raised tail and pendent head hanging to the surface by means of their plumose anal leaves. As soon as an enemy approaches they hastily seek the bottom, but in the course of a few seconds resume their former position. The perfect insect, however, can remain longer beneath the water, as it conveys a supply of undecomposed atmospheric air with it.

The majority of the remaining insects which dwell in water breathe through tubes, with the exception of those which breathe by means of gills. The mechanism of this mode of respiration scarcely differs from that of the general mechanism of respiration. By raising the air tube to the surface of the water, the influx of fresh air is admitted to the tracheæ, and this ensues upon each expansion of the cavities of the body, whereas by means of each contraction the previously inspired air is again rejected. But it appears probable to me that expiration is effected not solely by the posterior tubes, but also through an aperture immediately behind the head in the first segment of the body. I have indicated these apertures in the description given above of the respiratory apparatus of the rat-tailed maggot ; they are also found in the majority of the larvæ of the *Diptera* which do not live in water, for instance, in the maggots of the *Muscæ,* and also probably in the larvæ of the gnats, and in these they then develope themselves to the subsequent air tube in the thorax of the pupa. As now these anterior apertures remain constantly in the water, they cannot serve for inspiration, but being present they cannot be superfluous in the organisation of the larva ; besides, nothing appears more probable than that the inspired air is again expired through these anterior apertures.

§ 231.

Respiration by means of gills is found only in such insects as live wholly in the water. The situation, form, and differences of these organs have been given above (§ 126) in sufficient detail: we will merely add here somewhat upon the mechanism of this mode of respiration. By their deficiency of external apertures the gills are chiefly distinguished from the other organs of respiration. The reception of atmospheric air within the tracheæ is thereby naturally rendered more difficult, for its imbibition through the tunic of the gills must proceed more slowly than its mechanical reception through numerous apertures. The gills, consequently, form large broad leaves or long bunches of hair, around which circulates the medium containing the oxygen. A second condition of the reception of this gas by means of gills is the constant motion of these organs, by means of which motion, fresh particles of water, saturated with this gas, are brought into contact with the gills. This motion of the branchiæ varies according to their situation and form.

Lamellate gills, situated at the sides of the abdomen, move like the fins of fishes from front backwards, so that throughout the whole series of these branchial leaves a constant undulating motion is perceived. The first lamellæ bend forwards, whilst the posterior ones strike backwards, and while the former strike backwards, the latter are bending forwards. Thus the motion of all the gills is not contemporaneous, but both progressive and alternating. By this means these larvæ do not swim in thrusts, but regularly, as by means of a portion of the leaves of their gills they are constantly propelled the while another portion reposes, and by this portion they are kept in motion when the preceding is again inactive. By this continued motion of the branchiæ, the larva is constantly changing place, and thereby an incessant influx of fresh air is promoted.

But if the lamellate or hair-shaped gills are placed at the anal extremity of the body, motion is produced by the serpentining of the abdomen, just in the same way as worms without swimming leaves move in water. Thus the larvæ of the *Agrions* swim and breathe at the same time. And, lastly, if the gills lie in the colon itself, as in the larvæ of *Æschna* and *Libellula*, by the opening of the anus and the distension of the colon, water is received in the cavity of this organ, and by its compression again rejected: and by the rejection of the water it is that these larvæ move.

Hair-shaped gills, which are situated upon the thorax, appear but rarely to move independently; in the majority of cases it is by means of the motion of the entire animal, which is effected by the serpentining abdomen, that these gills come in contact with fresh water. It is in this manner that the pupa of *Chironomus* swims, and its whole motion is consequently a respiratory motion, for these pupa take no nutriment. A variation from this is the serpentine motion of the anterior portion of the body when the animal has attached itself by its tail. This motion also, which Nitzsch * observed in the pupa of *Chironomus plumosus*, is a mere respiratory motion. Lastly, if the pupa dwells in an open case, the entire bunch of gills moves either within it or on its exterior: thus the pupa of *Simulia* appears to breathe. Whereas the contact of fresh water with the bunch of gills, which in the larvæ of *Phryganea* are situated within the case, is effected by the motion of the entire insect, in which fresh water is received anteriorly within the cylindrical cavity, and, when expired, is again rejected by the posterior aperture.

§ 232.

The question now arises, how do the insects breathe which dwell within the internal cavities of other animals whither little or no atmospheric air can reach?

To answer this question, we must first illustrate the cases in which insects are found in the interior of other animals. All these cases refer to two chief differences, for either these insects live in cavities to which atmospheric air can easily and does actually reach, and in which case their respiration has nothing problematical and wonderful; or else they live in cavities which are thoroughly closed from the admission of any air. The first case is found in the instance of the larvæ of the *Œstri*. These dwell either in the cavities of the nose or stomach, or beneath the skin, in tumours in horses and the ruminantia. The air can reach all these cavities, which also contain atmospheric air, and indeed those larvæ which live in tumours constantly protrude their anal end, where the two spiracles are placed, out of the tumour, and thus

* Comment. de respirat. Animalium, p. 40.

breathe like all others, or rather like the majority of the larvæ of the *Diptera*. The second instance, however, is found in the Ichneumons, which do not live in the intestine, but in the cavity of the body of other insects, between the intestine and the skin. That these creatures must breathe admits of no doubt; and indeed that they breathe precisely in the same way as the larvæ of the other *Hymenoptera*, namely, through spiracles, is as certain as that they do not at all differ in their organisation from those larvæ. We can, therefore, adopt no other supposition than that such larvæ participate in the respiration of the insect upon which they are parasitic, and that they breathe the air that passes through the tracheæ into the cavity of the body, or that they pierce a trachea, and, remaining in its vicinity, respire the air pouring from it. Such a wound to the respiratory apparatus would not produce death, for it has still sufficient unwounded tracheæ, and it would require only to be a small branch that would admit of the passage of sufficient air for the minute larva of an Ichneumon. Those caterpillars infested by parasites are always evidently ill, and this disease may proceed perhaps from the interruption in various parts of the function of respiration, and this interruption, together with the constant decrease of the fatty substance of the pupa, may deprive it of its remaining strength, and thus slowly kill it. After the death of the pupa, the remainder of its internal organs are consumed by the parasite, or else the numerous parasitic larvæ pierce the skin of the caterpillar, and thus kill it before it can change into the pupa state.

§ 233.

Having now shown the various kinds of mechanism by which atmospheric air is admitted to the internal organs of respiration, we further ask what is the object of this admission of atmospheric air, and what changes does it itself undergo? The reply is given in the result of the various experiments of Sorg, Hausmann, and others, upon the decomposition of air during the breathing of insects, and it is, "All breathing insects deprive the air of a considerable portion of its oxygen, and give off in lieu of it carbonic acid." The quantity of oxygen withdrawn by breathing varies according to the size of the creature, and the intensity of its respiration, and the quantity of carbonic acid given off varies just as much. But thus much appears confirmed, that considerably more oxygen is consumed by the creature than carbonic acid given off. And the more perfectly developed respiring animals are, the less are they enabled to deprive atmospheric air of its whole contents of oxygen: before its complete consumption they appear languid, and, as it were, apoplectic, and they die upon the continuance of this state, or if they have not a fresh supply of air. Whereas many insects, particularly butterflies, as animals upon a lower grade of organisation, so entirely consume the oxygen in the air, that in many experiments that have been made, not the hundredth portion of that gas has been found left in it*. But the loss which the air suffers by the withdrawal of the larger quantity of oxygen, in lieu of which but one half the quantity of carbonic acid is given back to it, appears to be replaced by a second excretion, consisting of azote. One portion of this azote is given off by the lungs or air tubes, and another portion, especially, by the perspiration of the skin. But as this perspiration can be but trifling through the hard integument of insects, if it be not indeed wholly deficient, they consequently must produce less azote but a proportionably greater quantity of carbonic acid.

These are the chief results of the experiments upon the respiration of insects. In proof of them we will give a tabular view of other experiments of Treviranus, without adding more recent ones of our own, occasioned by our less familiarity with such experiments, and from our deficiency in the necessary auxiliaries and instruments. And indeed the results of the experiments of so experienced and competent an observer may well suffice.

* Sorg, pp. 65, 67.

Proportions of Absorption in the same time (100 *minutes*) *and quantity* (100 *grains*).

Name of the Insect.	State of the Thermom. above °.	Quantity of Respired Air.	Excreted Carbonic Acid.	Absorbed Oxygen.	Excreted Azote.
Apis mellifica, neuter -	11,5	27,2	0,82	1,33	0,53
Another with violent motion and in the sun -	22	48,6	2,25	2,77	0,52
Bombus lapidarius A. -	12,5	3,8	0,31	0,43	0,12
——— B. -	15	23,7	1,70		
——— C. -	16	10,0	0,72		
——— terrestris in the sun	14—23	11,0	1,74		
——— muscorum - -	17	46,2	0,64	0,82	0,18
Eristalis nemorum (*Meig.*)	16—16,5	7,4	0,50	0,80	0,30
Pontia Brassicæ (Caterpillar) - -	14—13	2,8	0,16	0,28	0,12
——— Rapæ A. after starving 28 hours -	15	8,3	0,72	2,26	1,54
——— B. on dying	13,5—17	2,0	0,20	0,37	
Vanessa Atalanta A. after 3 days starving - -	13—28	27,0	2,65 (?)	2,85	
——— B. the same and weakened by the preceding experiment -	15	105,0	1,50	2,35	
Libellula depressa A. -	17—16,5	6,2	0,37	0,74	0,37
——— B. -	16,5—14	7,5	0,33	0,93	0,60
Cetonia aurata (larva) -	17	6,1	0,04	0,06	0,02
——— A. - -	16,5	2,9	0,21		
——— B. after 2 days starving - -	13,5—14,5	1,5	0,06	0,07	
Melolontha horticola -	13—15	2,0	0,07	0,17	0,10
Feronia nigra - -	11—15	4,8	0,23	0,56	0,33

If we still draw further results from the above experiments, we shall find in these also a confirmation of the law deduced from the respiratory pulsations, namely, that in the sun and upon the general excitement of the body the respiration is more violent and intensive than in repose or in the shade. A working bee in the former situation inspired almost double the quantity of air, consumed once as much more oxygen, and gave off three times the quantity of carbonic acid, whereas the quantity of rejected azote remained the same. The same result was produced by several experiments made by Sorg. Hunger and the perfect satiation of the appetite likewise exercise great influence upon the function of respiration, and indeed hunger, as in general, acts also enervatingly upon respiration. Hungry insects breathe more slowly, but also longer, than well-fed ones inclosed in the same quantity of air. The latter, however, produce, proportionately, considerably more carbonic acid. A *Cetonia*, which was starved for three days, inspired less by half as much air and rejected only one quarter as much carbonic acid as a well-fed, healthy individual of the same species. The results are similar in butterflies experimented upon under the same circumstances.

That the developing egg respires precisely in the same manner, and under the same conditions, as the subsequent perfect insect, has been proved above by experiments in our description of the development of eggs.

§ 234.

Upon a careful investigation of respiration by means of gills, the same results are produced; the gills also imbibe oxygen, and give off carbonic acid. But the question suggests itself whether in insects which breathe by gills, these gills, as in the other animals with universally distributed blood-vessels, imbibe merely oxygen and expire carbonic acid, or whether they inspire perfect atmospheric air and expire the remainder, containing carbonic acid and azote, having separated the oxygen from it. We must first inquire, whence do the gills derive their oxygen?—Do they decompose the water, consisting of oxygen and hydrogen?—Or do they merely decompose the atmospheric air contained within the water? All experiments convince us that the air only which is contained in the water is changed, and not the water itself. Therefore, all animals die in distilled water deprived of air, and, what is still more, insects die even in well water, which contains more carbonic acid and in which less air is intermixed than in the water of rivers or ponds. This prejudicial effect of well water extends even to those insects which breathe through air tubes and spiracles, and which for this purpose ascend to the surface of the water: these also die quicker or slower in well water. But this does not answer the question whether insects imbibe oxygen or air through the gills. I think I must conclude that they extract the latter, from the following considerations.

In the first place, because the larvæ which breathe through gills exhibit the same internal apparatus as those which breathe through spiracles, and indeed generally possess larger internal air tubes than the rest. Did the gills merely imbibe oxygen, smaller narrower vessels would suffice.

Secondly, if pure oxygen were found in the tracheæ of insects that breathe through gills, they would be able to live a longer space of time even in such media as contain no oxygen, for instance, until the oxygen contained within their tracheæ was consumed. But this is not the case. Those larvæ which breathe through gills are deprived of life as quickly in spirits of wine as those which respire in the ordinary way.

Thirdly, did insects with gills inspire pure oxygen, so would all other insects, as the structure of their respiratory organs is the same, be enabled without inconvenience to breathe pure oxygen. But this is also not the case. Insects in pure oxygen breathe at first more violently than irregularly, and die in the course of a few hours, before near all the oxygen is consumed *.

It hence appears necessary to adopt the conclusion, that even in insects breathing through gills there is a direct transmission of atmospheric air through the branchiæ into the tracheæ.

§ 235.

If we next ask the object of all respiration, and the effect it exercises upon the preservation and promotion of life, we shall find it to consist especially in the alteration of the blood. Observations upon the difference of the venous and arterial blood of the higher animals proves that oxygen intermixed with arterial blood colours it more brightly, and thus promotes its easier assimilation, although not by the mere colouring, yet by the other changes it produces in it, the testimony of which is its brighter colour. A similar alteration will necessarily take place in the juices circulating in the bodies of insects, but in proof of which we are the less enabled to give a striking instance, from, in the first place, the blood of these animals being wholly colourless, and, from the universal distribution of their respiratory organs, whence, consequently, this alteration of the blood is constantly everywhere taking place. In insects, therefore, arterial blood can alone be found, and the motion of the juices which has been detected in insects of different orders can consist merely in its general distribution, and not (as in animals with perfectly distinct arteries and veins) have likewise for

* Compare the Observations of Sorg, as above, pp. 19, 44, 98.

object a motion to and from the organs of respiration. This will be fully proved in the following division of this chapter.

But from the arterial blood all, and especially the animal, organs, derive that portion which is peculiarly theirs, and which is transformed in them. Hence respiration is the first and chief cause of the florid health as well as of the equal and uniform nourishment of all the organs of the animal. The muscles and nerves particularly appear to derive advantage from respiration, in consequence of the change thereby occasioned in the blood. Thence is it also that in animals with preponderant and highly developed organs of respiration muscular and nervous activity prevails. That this is the case in insects, at least with respect to their muscular power, requires no further proof; many experiments and observations, and, indeed, daily experience, convinces us of it. With what a monstrous expense of muscular power do not these little creatures labour! We have merely to reflect upon their rapid and continued flight, upon the migrations of locusts, upôn the solid and compact woods which others destroy with their minute mandibles, upon the powerful pressure which they are enabled to make by their voluntary muscular force, when, for instance, a beetle is taken in the hand, and it endeavours to free itself from its restraint. With respect to their nervous activity, I will refer only to the subtlety and strength of their sense of smell, particularly as this more than any of the other senses stands in close connexion with respiration. But their hearing is also acute, and, above all, their sight. Where is there found such an accumulation of the organs of sight? Where such a relative size in any other class of animals? Where so much caution in the observation of their enemies, and patience in the completion of a once commenced undertaking? but which patience must be attributed to the acute perception of their senses and their great muscular strength.

Hence respiration is, as well as the reception and digestion of food, a chief cause of the undisturbed progress of all the animal functions; both go hand in hand, and the one is useless without the assistance of the other.

§ 236.

Another property which, if not produced by respiration alone, yet stands in an intimate connexion with it, is the peculiar warmth found in many animal bodies, especially in the mammalia and birds. Without entering here upon the several explanations of the causes of this equal temperature in both orders, in illustration of which we refer to the condensed and learned comparisons of G. R. Treviranus *, we will at once proceed to relate the observations that have been made upon the subject of this heat in some insects.

These insects are the bees and the ants. In the bees Swammerdam was the first to observe a peculiar warmth of the hive in winter, during a very low external temperature †. He supposed this warmth was partly to keep a portion of the honey fluid and partly to assist the eggs in hatching and to prevent the bees from freezing. Since Swammerdam similar observations have been made by Maraldi ‡, Reaumur, and Huber. Reaumur observed a thermometer standing at — $6\frac{3}{4}$° external temperature rise in the hive to + $22\frac{1}{2}$°; according to Huber the average temperature of the hive in winter is 86° — 80 F. This warmth increased upon his causing a general motion among the bees by disturbing them, and so much so, that the small glass window in the hive soon became hot, whereas, when the bees were quiet and undisturbed, it felt almost cold; and indeed the wax of the combs melted several times and ran down. From this experiment especially it has been wished to conclude that the warmth in the hive is produced by the motion of the bees, particularly by their occasional general fluttering, which Maraldi considered to be the sole cause of the high temperature of the hive. According to Huber §, however, this occasionally repeated fluttering of the bees is produced by them merely to create a current of air, whereby fresh air is introduced, and that rendered noxious by continued respiration removed. In summer also, and not merely in winter, do they do this, and thereby even at that season produce an equally moderate temperature in the hive, which does not exceed that of the external air. The same has been observed in ant hills, in which the thermometer upon an external temperature of + 10° rose, according to Juch ||, to + 17°. In the wasps and humble bees, also, which likewise live in society, we may with great probability infer a similar phenomenon.

If after such facts it is undeniable that insects under certain circumstances can produce a higher but equal temperature, nothing further

* Biologie, t. v. p. 64, &c. Das organische Leben, t. i. p. 413, &c.

† Biblia Naturæ, p. 161.

‡ Mém. de l' Acad. des Sc. de Paris, 1714, Ed. d' Amst., p. 420.

§ Nouvelles Observ. sur les Abeilles, t. ii. p. 338, &c.

|| Ideen zu einer Zoochemie, vol. i. p. 92.

may be thence concluded than that this warmth is produced only in their social assemblage. Mere mechanical motion is, however, not sufficient, for this produces in summer a lower temperature; the single insect, on the contrary, produces no warmth, but is exposed to the varieties of the external temperature, and dies when this sinks below zero. Hence it merely remains possible to suppose that warmth is developed by respiration.

We have learnt from a preceding paragraph that respiration increases upon motion, and especially on flight, and that consequently there must be a greater quantity of oxygen absorbed by the body. But the condensation which the oxygen necessarily undergoes upon intermixture with the blood, as well as the whole process of combustion, must evolve heat, and this heat upon expiration must pass from the body of the insect to the surrounding medium. If, therefore, many breathing insects are collected together in a small space, heat must be produced even during their quiet slow respiration, which the thermometer evinces; but if the swarm be put in motion, and if the bees flutter with their wings, they breathe, consequently, more strongly and more intensely, and, therefore, a greater quantity of earth is necessarily evolved. Hence even every individual breathing insect would develope some heat, which, however, from its rapid assimilation with the external temperature, is not perceived. But in small spaces, and where many individuals are inclosed together, this evolution of heat would certainly be detected in other insects *. But the reason why the temperature of the hive in summer is even less, or, at least, equal, upon the same motion, to that of the external atmosphere, is to be explained by the current of air produced by the motion by means of which fresh air is introduced and the warmed air removed, as well as that each draught, even upon the introduction of warm air, produces coolness.

§ 237.

III. FUNCTION OF THE DORSAL VESSEL. CIRCULATION OF THE BLOOD †.

THE most general physiological importance of the circulation of the juices has been stated in the introduction to this chapter, and indicated

* Compare Hausmann de Anim. Ex. Respirat., pp. 68, &c.

† It is quite impossible that we should here repeat all the different opinions of earlier anatomists and physiologists upon the function of the dorsal vessel: we hope it will suffice to assure our readers that all the most important treatises upon this subject have been resorted to, and their most useful facts inserted.

as a connecting link between digestion and respiration. The juices prepared by the intestinal canal require the addition of oxygen from the air before they can be assimilated with the corporeal mass, and for this purpose they pass through the vessels to the respiratory organ. Hence it appears that insects, from the universal distribution of their respiratory organ, require no conducting of the juices, and it was this consideration which, prior to a motion of the blood being observed in them, that was sought to explain their deficiency of blood-vessels, and the consequent deficiency of a circulation was thus illustrated as imperative. We nevertheless find in insects a regular motion of the juices, as was first discovered by the observations of Carus *, and subsequently confirmed by Wagner †. From the experiments of both these naturalists, the following general result of the mode of this motion of the juices has been found.

§ 238.

The juices prepared by digestion pass through the tunics of the intestine into the free cavity of the abdomen among all the organs there situated. It here presents itself as a clear and somewhat greenish fluid, in which oval or round globules swim, which are likewise transparent, and from $\frac{1}{002}$ to $\frac{1}{260}$ of a line in diameter. This fluid is received by the dorsal vessel, or rather by its posterior portion, which we have described as the heart, and which consists of a series of consecutive chambers furnished with apertures and valves (§ 117); through these apertures during its distension, and then by means of the contraction of the same organ, through which also the lateral apertures are closed by means of the valves lying in front of them, it is transmitted from one chamber to the other, and then from the last into the aorta ‡. The number of the contractions and expansions of the heart within a certain time varies according to the stage of development and the state of the temperature. The several chambers also do not simultaneously contract, but, commencing posteriorly, they proceed successively, so that the last and first frequently expand together, whilst the central

* Entdeckung eines Einfachen vom Herzen aus beschleunigten Blutlaufes in den Larven netzflüglicher Insekten. Leipz. 1827. 4to.

† Isis, 1832, p. 320.

‡ We must here remark, that this structure of the heart, ascertained to exist by the observations of Straus, was received and taught by even the earlier physiologists. See Bonnet's Contemplation de la Nature, t. i.

ones are still contracted. Thence proceeds the apparent undulating motion which is perceived in the heart through the integument of the body. From the anterior free aperture of the aorta the blood is driven by this motion into the lateral space of the body contiguous to the aorta, and it thence passes into all the vacant spaces of this cavity into the antennæ, feet, and wings, and thence, being continually driven on, it pursues its course at the sides of the body, until it has again reached the ventral cavity, where it then becomes mixed with the fluid there found, and which has been subsequently formed by the constant activity of the intestine, and upon the next expansion of the individual chambers it passes again upon its preceding course.

§ 239.

The motion of the heart itself was observed by the earliest anatomists. Malpighi even observed the contraction of the dorsal vessel progressing from behind forwards, and Swammerdamm as well as later anatomists have confirmed this observation. But as all considered the dorsal vessel as completely closed, it could lead to no insight into the circulating system of insects, and all the observations upon the manner of this motion of the dorsal vessel arrived at no important result. Herold * alone, who made the dorsal vessel especially the object of his investigations, recognised more distinctly its undulating motion. This undulating motion may be readily understood from the recently explained structure of the heart. Thus all the chambers do not simultaneously contract, but always one after the other, so that during the contraction the posterior one drives its contents into the one before it, and during its expansion again receives blood from the cavity of the body. As this alternating contraction and expansion passes from one chamber to the other, the motion of the entire heart, like the peristaltic motion of the intestinal canal, appears to progress in an undulating line, although the motion is not in the entire heart, but only in an individual chamber; but the motion of these chambers passes so quickly from one to the other, that the first and the last frequently expand at the same time, whilst those lying between still contract. With respect to the number of the contractions and expansions, differences have been observed in them, which partly, as in respiration, proceeded from the temperature, and were partly dependent upon the stage of development.

* Physiologische Untersuchungen über das Rückengefäsz der Insekten. Marb. 1823, 8vo.

According to Herold, the dorsal vessel of a full-grown caterpillar, in a temperature of from 16°—20° Reaum., made from 30 to 40 pulsations in a minute, but sank in a temperature of from 10°—12° down to from 6 to 8 pulsations in the same time. In younger caterpillars, the pulsations of the dorsal vessel, under similar circumstances, were quicker, namely, from 46 to 48 times in a minute, in a temperature of 18°, whereas in greater heat and with a quicker motion, in conjunction with great exertion, the rapidity of the pulsations still further increases, but they then appear so irregular and numerous, that no positive number can be given. According to Suckow *, the heart of the pine caterpillar (*Gastropacha pini*) beats 30 times in a minute, but sinks down during the pupa state to 18 pulses in the same space of time. In the just disclosed caterpillar the pulsation is slow and irregular, but subsequently its rapidity increases so much, that it then makes from 50 to 60 pulses in the minute. Herold says that the pulsations of the butterfly increase the moment it commences to strike with its wings, and purposes flying off, whereas he observed during copulation no alteration of its quickness.

§ 240.

The assertion of a motion of the juices is founded upon observations made upon the following insects.

Among the *Dictyoloptera*, all such larvæ as live in water exhibit it very distinctly. In the larva of *Ephemera*, a motion of the globules of the blood has been observed in all the peripheric parts, which, according to Wagener, extend even to the last joints of the antennæ and of the feet. This motion was slower the more the water evaporated in which the larva was contained, but increased again upon the addition of fresh water. The stream of all the peripheric parts collect into two chief currents, which pass backwards on each side of the body, and send off other currents to the exterior margin of the segments, but which speedily return to the main branch after having passed through the branchiæ there situated †. Vessels inclosing these streams have never been observed, and, indeed, the frequently partial change of course distinctly proved the total deficiency of such organs. Individual currents have also been observed to extend even above and beneath the intestinal canal, and to bend over to the main stem of the opposite side

* Anatomisch-physiol. Unters. über Insekten und Krustenthiere, p. 37.

† Carus in the Nova Acta Phys. Med. vol. xv. Pt. 2, p. 8.

without being guided by a determinate canal, but, on the contrary, the globules of blood evidently passed between the fatty body and other internal parts. In the vicinity of each aperture of the heart portions of the stream of blood bent over to the heart itself, and upon each expansion passed into it, being received by those apertures. The blood poured forth immediately from parts that were cut off, namely, from the end of the tail, curdling into a thick greenish granulated mass.

In the larvæ of the *Agrions* there has been observed the motion of the dorsal vessel, the lateral returning main currents, a stream running upon the entire margin of the rudiments of the wings on the exterior taking its course inwardly and on the interior returning, from which here and there also globules passed in the contiguous passages between the parenchyma of the wings, a powerful current also passes through all the anal leaves, explained as gills, and flows inwardly upon the under side of the central tracheæ, but on the upper side again returns; and, lastly, a stream of blood is observed which advances in throbs, and which probably flows from the anterior aperture of the aorta, bending on each side to the eye, and thence proceeds beneath and back again posteriorly.

In all perfect insects of this order, namely, in the wings of just-disclosed *Libellula* (*L. depressa*) and *Ephemeræ* (*E. lutea* and *marginata*) Carus likewise saw a distinct motion of the blood.

Among the *Neuroptera*, those larvæ which live in water exhibited the same appearances. Distinct contractions were constantly seen in the heart of the caddis-fly larva, which is divided into seven or eight partitions and two lateral returning main streams, whence the globules of blood passed into the apertures between the several chambers. Several perfect insects also of this order, namely, *Hemerobius chrysops*, *Semblis bilineata*, and *Semblis viridis*, exhibited in their wings, and the latter also in their antennæ, a motion of the juices.

In those larvæ which live in water, of many of the *Diptera*, namely, of the gnats, Wagener observed a distinct pulsation in the dorsal vessel, in which its contraction was visible in several of the chambers of the posterior end. But even those very transparent larvæ he observed, on contrary, no motion of the globules of the blood. I myself, notwithstanding having made several experiments, it is true with not very perfect instruments, have been unable to detect such globules of blood. In one instance, and also in a second similar one, namely, in the larva of *Notonecta glauca,* Carus considers that the globules of blood are too small to be seen through the microscope, and that it is from this cause that the motion of the juices is not to be detected in the body.

Among the *Hemiptera,* Wagener observed through the transparent sides of the body of the young larva of *Nepa cinerea* distinct streams of moving globules passing from the front backwards; he could also observe the pulsating dorsal vessel contracting in its chambers. In the common bed bug (*Cimex lectularius*) I have perceived the pulsation of the dorsal vessel, and also an indistinct motion of fluids at the sides of the abdomen.

The remaining observations, chiefly compiled from Carus*, refer chiefly to the circulation of the blood in insects not living in water. Among the beetles, he observed it principally in the transparent elytra and wings of *Lampyris italica* and *splendidula, Melolontha solstitialis* and in a *Dyticus;* then in the prothorax of *Lampyris splendidula.* It here had the appearance of a strong current, which came from the abdomen, and which, towards the end of the pronotum, divided on each side into arms, that, upon each margin, turned backwards. In the *Orthoptera,* on the contrary, he vainly sought it in the wings, but Ehrenberg, according to the communication of A. v. Humboldt, has seen a motion of the juices in a *Mantis* †. The transparent wings of the *Dictyoptera* and *Neuroptera* have likewise here and there exhibited a motion of the juices, as well as the wings of *Libellula depressa, Ephemera lutea, E. marginata, Hemerobius chrysops,* but most distinctly in *Semblis bilineata* and in the antennæ of *Semblis viridis.* In the former, he saw the streaming blood pass upon the anterior margin through the chief ribs, and distribute itself upon the whole margin to the apex; it returned back through the ribs lying nearest to the posterior margin. Through the central connecting transverse ribs, blood also passed from the proceeding to the returning current. In the *Hymenoptera,* no motion of the juices was perceived in the wings, and just as little in the *Diptera* ‡. In the *Lepidoptera,* also, it still remains doubtful; but Carus thinks he may

* Nova Acta Soc. n. c. C. L. vol. xv. Pt. 2, p. 1, &c.

† Bericht über die Natur historischen Reisen der H. H. Ehrenberg und Hemprich. Berlin. 1826. 4to. p. 22.

‡ In *Eristalis tenax,* Meig., and *E. nemorum,* M., I have recently observed blood pour out of the roots of the wings during their motion, when the wing itself was cut off.

adopt a motion of the juices in the germen of the wings in the pupa of some *Lepidoptera*, from the result of several of his experiments.

§ 241.

After such facts, I consider the asserted circulation of the juices as proved. Carus was formerly inclined * to limit the circulation to those insects still in their stages of development, and therefore concluded that it disappeared upon their transformation into the perfect state. This opinion he subsequently gave up †, upon being convinced of the contrary by his own experiments; and it also is positively contradictory to the generally adopted physiological significance of the circulation, for what in this respect is the case in young animals, must also be found in old ones. Indeed it is true that in many insects an alteration takes place in the reception of food, and its quantity becomes less, and that thence, consequently, there must be found in them a slower digestion as well as a smaller quantity of separated lymph, but it must not be forgotten, that, precisely at this last period, the compass of the body is smaller, whereas its internal organs are larger, and that these have already attained their perfect development, and require but a small addition to be retained in action; and that, lastly, the whole internal cavity of the body presents less free space in which the stream of blood can be distributed. These various causes appear to me to explain the decrease of the circulation; and indeed in the higher animals the pulse is lower in age than in youth; wherefore, then, should not the same relations be found in insects? But that a circulation is found in these creatures in their perfect state, is proved by direct observation; must these, then, be considered as exceptions to the rule, and that which is the rule in all other animals, form the exception in insects? I see no foundation for such a conclusion.

§ 242.

With respect to the physiological importance of the circulation in insects, I conceive it consists especially in preserving a general motion of the fluids, by means of which all the portions of it are subjected to an equal deposition of oxygen. If the lymph passed through the intestinal canal into the cavity of the abdomen, and remained there stationary, those parts of it which encompassed the tracheæ would

* Entdeckung, &c., p. 21. † Nova Acta Phys. Med. vol. xv. Pt. 2, p. 14.

alone be oxidised; and, indeed, the fluid would not pass equally into the distant members, but that portion which once found itself in the cavity of such a member would there remain without being equally supplanted by fresh juices. But by this progressive motion of the whole body of juices this partial stagnation is prevented, and each organ furnished equally with fresh juice fitted for assimilation. Both the large streams of blood which run along and between the large lateral stems of the tracheæ, are constantly receiving fresh oxygen from the tracheæ, and carry with them the fresh lymph secreted by the intestine, and then give off the freshly-oxidised blood to the heart, which, by its rhythmical pulsation, conveys it on, and rejecting it by the free orifice of the aorta, drives it to all the parts of the body. The returning main streams, consequently, are comparable to the arteries of the lungs, or rather, as in the *Mollusca*, to those large veins which, collecting the blood from all parts of the body, return it through the lungs or bronchiæ to the heart. The passage of the oxidised blood into the heart is occasioned by its expansion and contraction, which takes place synchronally with the respiratory motion of the whole body, and particularly of the abdomen, and these individual motions of the heart are partially produced by its muscular tunic, and partially by the muscles of the wings which bind it to the dorsal plates. The muscular tunic of the heart contracts itself and makes the systole. The muscles of the wings, by their contraction, again expand the heart, and produce the diastole: when the blood streams in through the apertures and by the former, it is driven into the aorta. Hence throughout the whole body a constant oxidisation of the blood is taking place, as, even in the most remote members, tracheæ are distributed, and there oxidise the juices they found. But these juices also do not rest, but participate in the general motion. True venous blood is consequently deficient in insects, and if both the lateral streams have been called veins, this name is only so far tenable as there may be detected in it a returning motion of the blood to the heart.

§ 243.

But how can a motion of the blood be imagined without vessels? This question absolutely appears of great importance, particularly as Carus thought it necessary that there should be vessels in certain parts of the body. This opinion, however, will necessarily be limited to the vessels which are found in the ribs of the wings, and which we have mentioned above. I detected such vessels in many insects which I then examined, namely, in *Dyticus marginalis*, *Copris lunaris*, *Philanthus pictus*, &c., but I yet doubt, from more recent investigations that I have made in the bright and partially transparent pupæ of some capricorns, namely, *Prionus faber* and *coriarius*, the correctness of my above mentioned opinion. In the rudimentary wings of these pupæ I saw with unassisted eyes perfect tubes as silvery-white glittering filaments containing air. These tubes in the upper wing or elytron gave off no branches, but ran undivided in a direct line from the base to the apex. But at the extreme base they collected into two main stems, the one of which takes its course at the anterior margin, and the other upon the sutural margin, both originating at the thorax as a simple stem. The anterior one has two and the posterior one four straight radiating branches, which run parallely. The tubes of the inferior or true wing were divided, but likewise also only towards the apex. They also originated from two similarly disposed main stems, the anterior one of which likewise sent off two and the posterior one four branches. I could distinctly see this by means of a simple lens. Upon its inspection with the microscope, these tubes were observed filled with air, which was interrupted at certain parts, so that the tubes appeared to contain disconnected air-bladders. I could not even yet detect by means of the microscope the structure of the tubes, which was only visible upon removing the external tunic of the elytron, and the tube then lay distinctly in the parenchyma before me; an extremely fine filament was then seen, which wound itself spirally around the circumference of the tube, and left a tolerably wide space between it. On each side of these tubes there was a bright stripe, as if a channel lay free in the parenchyma contiguous to the trachea. I now repeated my investigation in other insects which had been immersed for some time in spirits of wine, but I found neither in the vessels of the elytra, nor in those of the wings, a spiral twisting, and just as little in dried specimens. Thence I might conclude that the spiral filament becomes invisible by immersion in alcohol as well as by drying in the air, at least under the microscopic power that was at my command, but that it nevertheless existed in all the vessels that take their course through the ribs of the wing; that consequently all these vessels must absolutely be considered as tracheæ, and that blood-vessels are not to be found even in the ribs of the wings.

Jurine's * and Chabrier's † observations upon the structure of the wings harmonise herewith; whereas, according to Carus, there is a threefold difference in the structure of the wings with respect to the vessels contained within their ribs. Some, as the elytra of the beetles, have blood and air-vessels; others contain only blood-vessels; the third, lastly, as the wings of the *Hymenoptera* and *Diptera*, exhibit air-vessels exclusively. But according to my opinion and observation, these differences do not exist, but all the ribs contain merely tracheæ or air-vessels, whereas within the rib around the trachea there remains a vacant space in which the juices can freely circulate, and it was in this free space that Carus saw, in all those instances where he perceived a motion of the blood in the wing, the globules pass and return.

Hence also is it that the wings derive their true significance. Oken even indicated that the wings of insects were no true members, but as mere continuations of the skin in which vessels were distributed, they were of analogous importance to the gills, and he thence called them air-gills (*luftkiemen*) ‡. But if now, as I believe it is, proved that the blood actually flows through them, their function as gills is placed beyond a doubt. The partial interruptions of the ribs, Jurine's bullæ, are the places where the blood flows immediately beneath the thin membrane, and can there even imbibe oxygen from the air, which is, besides, presented to it everywhere by the tracheæ around which it circulates. Chabrier's observation, also, that a space filled with moisture is found in the under wings of the beetles §, is evidence that blood flows in the wings, and such a stream can only pass through the ribs contiguous to the tracheæ contained within it.

If the supposed presence of blood-vessels in certain parts of the body is thus contradicted, it may likewise be inferred of the whole body that it has no blood-vessel excepting the large dorsal vessel. Indeed Joh. Müller considers that he has detected vessels passing from the heart to the ovary; but these connecting filaments, as we have shown above, are no vessels. The proposition which I have just stated is therefore proved correct to its full extent. Yet this deficiency of blood-vessels in the bodies of insects is by no means so extraordinary, nor is it without parallel. In the membranes also of the developing

* Nouv. Méth. de Classer les Hymenop. Geneve, 1807. 4to. p. 48.

† Essai sur le Vol des Insectes. Par. 1822. 4to. p. 42.

‡ Natur. Philosophie, 2nd Ed. p. 418. No. 3337.

§ Essai sur le Vol, &c., p. 19.

embryo, the blood originally flows without vessels; and only after the stream has acquired some degree of regularity, do the vessels form themselves around it. The same appears to be the case in the motion of the juices in the lower animals. In these also the circulating fluid forms for itself a passage through the parenchyma of the body; it grooves as it were a course for itself, in which it afterwards constantly continues. This course is in insects attracted especially to the large tracheæ, because the vital air, that substance to which all blood must attain, is transmitted through them. Were the thick tunics of a vessel to be formed around it, the deposition of oxygen could not so easily take place; and indeed in insects it would have greater difficulties to contend with than in any other class, for in them the tracheæ, even to their extreme ends, retain their hard spiral filament, whereas in the vesicles and cells of the lungs and gills it disappears, whence the oxygen can more easily pass through the delicate membrane of the respiratory apparatus, and arrive at the likewise delicate tunic of the blood-vessels; but in insects it is more strongly retained, and would be even more so if the blood-vessel also had a thick membrane. It thence appears to me that the deficiency of blood-vessels is necessary to the undisturbed corporeal functions of insects; their organisation merely required a central organ whereby the motion of the juices is promoted, and by means of which it is regulated and guided; and this organ is their dorsal vessel. The course through it being originally traced, and the first impulse to the motion of the blood being given by the spontaneous motion of the dorsal vessel, the free stream of blood necessarily follows this direction until it again returns within the sphere of the activity of this organ, and is then again forcibly attracted to it, and, as before, involuntarily driven into its preceding course.

THIRD CHAPTER.

THE METAMORPHOSIS.*

§ 244.

In the preceding chapters we have explained how the insect originates, propagates, and subsists, without having noticed the several stages of life it has to pass through, from the first origin of its being until the time it is actively engaged for the preservation of its resemblance. We have indeed here and there drawn attention to the differences which exist with respect to the mode of taking food and its assimilation with the body between the undeveloped and the perfect insect, but we have not yet explained the several successive periods of development, nor shown their physiological character. This will be the subject of the present chapter. We must now look around us for the causes which determine the form of insects in general. We must endeavour to ascertain why insects take this form and no other, and exhibit a body thus composed of rings and limbs, and what necessary changes a thus formed body must be subjected to, in order to maintain its fundamental figure even through the several developments which every organic, or, at least, animal being, is obliged to pass through. But as an introduction to this investigation, we must prelude with some general observations, which refer to the differences of all animal forms, that we may be in a situation to discover from the differences of these forms, the shape of insects and the object of this shape from their opposition to the rest, and then only, when the cause of the articulated body of insects is discovered, can we proceed with the consideration of the several transformations peculiar to it.

§ 245.

The animal kingdom, like all organic matter, the essential character of which is expressed in the idea of becoming or having become, traverses a certain series of grades of development, upon which it

* In this chapter the §§ 245—248 and 251 have been entirely rewritten by the author, and the former §§ 248 and 249 have been changed into the present §§ 249 and 250.—Tr.

ascends from its first simple beginnings to its highest perfection. Nature attains these developments by antitheses. The immediate consequence of such an antithesis, and which is visible in the homogeneous mass of the body, is the antithesis between the interior and exterior, whereby the internal cavity of the body which prepares the nutrimental matter stands in opposition to its external surface, which conditionates its form; the further perfection of this first antithesis, developes the various organs which stand in connexion with those two organic systems. Thus from the originally simple digesting cavity of the body, by degrees the intestinal canal and its various appendages promoting digestion, viz. the glands, are formed; and from the originally uniform integument of the body, on the contrary, all those organs are produced which promote and effect motion. The correctness of these assertions is deduced from the history of the embryo forming in the egg. Thus there appears in the several grades of development of the animal kingdom, as it were a rivalry between the internal nutrimental organs and the external organs of motion, and it therefore may be readily imagined, in the varied direction Nature has pointed out for its creatures to pursue, that in some animals the perfection of the internal organs, and in others that of the external ones, has been especially promoted. We call all those animals in which the first is visible, namely, a prevailing development of the intestines, ventral animals (*Gastrozoa*), but those in which the external organs attain the greatest perfection, limb animals (*Arthrozoa*).

But the highest perfection of the animal kingdom is by no means attained by these two grades of development, for both as partial developments must still appear unperfected. There only is the highest perfection attained where the external as well as the internal organs are equally perfected, and both have acquired their highest grade of development. That this highest development appointed by nature for the animal kingdom may be attained, there must be a third chief group in the animal kingdom, the members of which make themselves apparent by this homogeneous perfection of the external and internal organs. We have long known this third group by the name of vertebrate animals (*Osteozoa* or *animalia vertebrata*).

The individuals of the animal kingdom which belong to these several chief groups, it is easy to discover from the above character of each group, and which the following Table exhibits:—

I. Group—GASTROZOA. The following classes belong here:

1. *Infusoria polygastrica.* Ehrenb. 2. *Polypina sive Corallina.* 3. *Medusina.* 4. *Echinodermata.* 5. *Mollusca.* Cuv.

II. Group—ARTHROZOA. Here belong the classes:

6. *Endozoa. Annulata.* 7. *Rotatoria. Crustacea.* 8. *Myriapoda. Arachnodea.* 9. *Insecta.*

III. Group—OSTEOZOA:

10. *Pisces.* 11. *Amphibia.* 12. *Aves.* 13. *Mammalia.*

§ 246.

The forms of the thus discovered three chief groups of the animal kingdom are adapted precisely to their internal organisation. The first group possess a figure conformable to its organisation, namely, that of a bag or sack, that it may receive in this sack its various organs. In the highest animals, also, the same organs which in animals of the first series are especially developed, also lie in large cavities and bags, that are formed almost exclusively of soft parts. The second group, which is constructed upon the predominant development of the organs of motion, exhibits an elongate form, generally divided into segments and limbs. Herein also they correspond in form with the same organs of the higher animals, which characterise the second series in the development of the animal kingdom, namely, the members, which, as well as them, are elongate, and consist of joints and consecutive divisions. The third group, consisting of the conjunct contents of both the others, has a form partaking of that of both; their bodies, consequently, appear as central bags and cavities, whence the periphrastic subdivided members proceed. They thus, therefore, repeat the forms of all the other animals; indeed, their form is, as it were, a compilation of all other animal forms.

§ 247.

Insects, consequently, by reason of the predominant development of their organs of motion, belong to the elongate animals, divided into segments and divisions. By means only of such a structure is free motion possible. One limb pushes itself forward, affixes itself, and draws the other after it; the alternating, affixing, and quitting is repeated then by every successive limb, and thus the general motion of the body is produced. In some worms, therefore, we can admit but of two limbs, namely, an anterior one, in which the mouth lies, and which, by the suction of the mouth, affixes itself, and a posterior one, which possesses the sucking cavity, and which, by the help of this organ, can attach itself. In the *Annulata*, which consist wholly of rings, for instance, the earth worm, small setæ supplant the sucking cup; in the higher *Annulata*, these setæ develope themselves into feet, which remain in the *Crustacea*, *Myriapoda*, *Arachnodea*, and insects; in the last, organs of flight are superadded. Thus insects maintain, in accordance with the law of successive development, the highest grade among all annulated animals or *Arthrozoa*.

§ 248.

It therefore appears that, in the further development of the three chief grades of the animal kingdom, the place of abode and the thence proceeding influence of the external world (the external medium) has a very peculiar effect upon the animal organism. There are, however, but three differences of abode, which are the water, the earth, and the air. But in these three chief groups of the animal kingdom, particularly in the second and in the third, we find three groups subordinate to these chief groups, which are determined by the places of abode. Amongst the *Vertebrata* these groups have long been known as classes; and are called fishes, as water-vertebrata; birds, as air-vertebrata; and mammalia, as earth-vertebrata. To these a fourth class is associated, that of the *Amphibia*, which apparently is not to be arranged with them, but which, however, presents itself as highly necessary. The living in water, air, and earth are, notwithstanding their great resemblance to each other, so strikingly different, that the animal organism cannot pass directly from one grade to the other, but it requires a connecting member, wherein the organisation is adapted to a residence in both elements, From this transition I have called all such classes—classes of transition.

The group of *Arthrozoa* admit of being separated in the same manner, if the division may be deduced from the mode of their development. We obtain thus, therefore, in their four classes:—

1. The Water-Arthrozoa. Comprising the intestinal worms (*Endozoa*) and the *Annulata*.
2. The Class of Transition. Here stand, as the direct links of transition, the wheel animals (*Infusoria rotatoria*,

Ehrenb.) and the crustaceous *Arthrozoa* (*Crustacea*, formerly called *Malacostraca* by me, not the *Malacostraca* of Leach).

3. The EARTH-ARTHROZOA. Here are arranged the *Myriapoda* and the *Arachnodea* (or *Arachnides*).
4. The AIR-ARTHROZOA. Which comprise the hexapod insects (*Insecta*).

Each of these groups has a peculiar organ whereby it is characterised, and as the general character of the *Arthrozoa* is expressed in the presence of organs of motion, we shall necessarily have to seek for the characters of the subordinate groups among those organs. The character of the WORMS or water-*Arthrozoa* is, that in them we first observe the presence of distinct organs of motion, but which yet are of no determinate type, and which, therefore, sometimes present themselves as sucking cups upon the head (*Cestodes*), or upon the head and belly (*Trematodes*), or upon the head and contiguous to the arms (*Hirudinei*), then as setæ (*Naidei, Lumbricini* sive *Chætopodes*), and, lastly, as short pedal warts with hooklets (*Annelides antennati*, Lam.). In the following class they transform themselves partly to swimming organs (the rowing organs) and partly to jointed swimming and coursing feet, both of which forms are simultaneously common to the majority of *Crustacea*. In the earth-*Arthrozoa* the limbs are conformably shaped, feet adapted only to running; in the air-*Arthrozoa*, or INSECTS, we first find wings as the organs of motion for this element, they possess also legs for running and exercising other functions like the earlier ones.

§ 249.

Is the law indicated by the earlier physiologists, and applied by Oken, especially, to the natural system, correct, that the higher groups are repetitions of the lower ones in their development; or must we rather, with Von Bär *, thus explain it, that the development of every class of animals admits of recognising the progressive perfection of the animal body as well by morphological as histological separation, as also by the progressive construction of a particular form from one more general? In either case it will necessarily be applicable to the development of insects. It is evident that both propositions tend to

* C. v. Bär über Entwickelungsgeschichte der Thiere. Königsb. 1828. 4to. vol. i. p. 231.

the same point. No one who speaks of the embryo of man passing through the lower grades of the animal kingdom can have imagined that man at any period was ever of his embryo life an infusorium, polypus, muscle, snail, worm, crab, spider, insect, fish, turtle, snake, lizard, and bird; but the assertion is nothing more than that man as man has once in the progress of his development been upon that grade upon which the several classes beneath him remain stationary in the progressive development of the entire animal kingdom; and Von Bär's proposition expresses precisely the same thing, for in the successive development of the animal kingdom there is found, just as in the development of each individual animal, a progressive morphological and histological separation as well as the gradual formation of a peculiar shape from a more general one. The most general form of the *Arthrozoon*, as which we have found the insect, is a body that is divided into rings and segments; and insects, therefore, must present us in their development both with a progressive formation of a particular shape from this more general one, as also with the morphological and histological gradual perfection of their individual organs. The series of *Gastrozoa*, as I succinctly call the first series, are, on the contrary, only so far repeated by insects in their development as they themselves in their own development have for object the progressive perfection of the nutritive and propagative organs. This repetition, however, does not extend to the external form, for this is the result of a new development not yet visible in the *Gastrozoa*; whereas the vertebrata which unite in themselves both forms, viz. that of the *Gastrozoa* as well as of the *Arthrozoa*, exhibit also formal approximations to the *Gastrozoa* in their development. Only so long as it remains in the egg-case is every insect a *Gastrozoon*, for it then has no other organs than the nutrimental; but upon quitting the egg-shell it becomes an *Arthrozoon*, and exhibits itself in its then appropriate jointed shape.

§ 250.

Hence, therefore, the essential character of the metamorphosis of insects is found in the repetition of the lower grades of the *Arthrozoa* by means of the development of the highest. No single class of animals, we might say, confirms this repetition more distinctly than insects. The maggot, caterpillar, or larva which creeps out of the egg is of the same form as the earth-worm. Some of these maggots are footless and headless, and move like the leech by affixing the first and last segments of their body, in which, indeed, no distinct sucking-cups are visible, but merely wart-shaped stumps of feet, at least upon the last. This form, which we observe in the larvæ of most of the *Diptera*, is consequently the lowest of all. And, indeed, what is still more, not merely in the organs of motion, but also in the mouth, do they resemble each other, the former, like the latter, possessing short hard-pointed puncturing instruments, with which they pierce their food and then imbibe it. The second grade of larvæ, namely, those maggots which are provided with a head, but are without feet, as, the larvæ of the *Hymenoptera*, and of many beetles, repeat another grade of the *Annulata*, in which, as in *Nais*, there is a distinct head, but the feet are wanting. The third grade of the *Annulata*, namely, those which reside in tubes, and are furnished with large bundles of gills, find, among insects, their representatives in those larvæ of the May and caddis-flies, which dwell in cases and breathe through gills. The fourth grade of *Annulata*, as *Nereis, Eumolpe, Aphrodite*, &c., has, besides a distinct head, many feet on the ventral side of the segments, and their analogies are, among insects, the caterpillars of the *Lepidoptera*, and those larvæ of the beetles which are furnished with feet.

In the pupa state, the insect advances into the class of the *Malacostraca*. Just as the pupa state is a mere transition in the life of the individual, so also is the class of *Malacostraca* a true transition group in the development of the *Arthrozoa*, for the *Arthrozoa* contained in it strive to detach themselves from the life in water to elevate themselves to the life in air. Thence arise the innumerable different forms, and, indeed, the greater difference between the individual organs found in them more strongly than elsewhere; with perhaps the exception of the amphibia, which stand in the same relation to the vertebrata: and the advance from the life in water to the life in air is nowhere observed more distinctly than in the order of the *Malacostraca*. The *Crustacea* are true water animals; they all live in this element, and quit it rarely and as an exception. The *Myriapoda* stand upon the confines between the water and earth-dwellers: some incline to the former and others to the latter. The *Arachnodea*, lastly, are true earth-dwellers, particularly the scorpions, but some true spiders seek the air as their medium, for they distend their web upon elevated sunny places, and, floating in it, seem to endeavour to revel in the purer air; and, indeed, a few raise themselves upwards in the air, for instance, *A. obtectrix*, which is raised by the wind upon its self-formed clouds, and swims in the fluid element. The majority are inimical to water: a few only seek it and dwell in it.

A very similar series of developments to those just observed in the *Malacostraca*, do we find in the pupa of insects with a perfect metamorphosis. The lowest, as the pupa of the gnats, some other *Diptera*, and the *Phryganeæ*, breathe like the *Crustacea* through gills, but their number is small compared with the large order of the *Crustacea*, which thence proceeds that they merely briefly indicate this order, and are not intended fully to repeat it. All other pupa breathe through spiracles. Some of them, as the pupæ of the flies, crepuscular moths, and beetles, lie in the earth; they represent the *Myriapoda*, of which many but rarely visit the light of day, but dwell beneath stones and in other shady places. The pupæ of the butterflies and *Noctuæ* seek, on the contrary, the air, particularly those which hang themselves freely in the air, that they may enjoy it upon all sides. Those that are affixed may, lastly, be compared with the spiders that float in their webs.

With respect to their internal organisation, the imperfect simple tubular form of the entire intestinal canal, the predominance of the circulation in all parts, as well as the mere rudiments of the sexual organs, evince the analogy of the larvæ to the *Annulata*. The perfecting of the intestinal canal during the pupa state, particularly the formation of the proventriculus at this period, and, lastly, the more distinctly developed sexual organs, although the latter conditionates no significant external difference, still further prove the analogy of the pupa and the *Malacostraca*.

We have thus shown the repetition of the lower grades in the development of insects with a perfect metamorphosis. But this entire repetition has been expressed by Oken in the following words*: "Every fly creeps as a worm out of the egg; then by changing into the pupa, it becomes a crab, and, lastly, a perfect fly."

§ 251.

We have as yet taken no notice of insects with an imperfect metamorphosis, and, indeed, because they are not subjected to the law of repetition or analogy which is so distinctly expressed in insects with a perfect metamorphosis; for moulting is no metamorphosis, although

* Naturgeschichte für Schulen, p. 577. 9th Class and pp. 581, 583.

the form of the body is somewhat changed; besides, all other *Arthrozoa* are likewise subjected to this moulting. They differ from the remaining *Arthrozoa*, namely, from those of the third group, merely by the presence of new organs of motion peculiar to them, and the presence of these organs constitutes really their physiological and philosophical character. But insects with a perfect metamorphosis likewise present this character and a second one in addition, namely, the repetition of all the earlier forms of the *Arthrozoa* during their period of development. It is a positive fact, confirmed by the history of the development of all, especially of the vertebrata, that the degree of perfection of an organism or organ is the greater the more numerous the grades of development are which it must traverse to attain its full perfection. If we apply this law to insects, it follows incontestably that insects with a perfect metamorphosis must be placed higher in the series of animal bodies than insects with an imperfect metamorphosis.

We may now ask, why was such a difference of insects from each other necessary? Why could not all develope themselves, and propagate in the same manner? To this we may reply—Nature endeavours to make every possible use of the means which she has conceived allowable for the variation of a determinate type, that is to say, all the forms that are elaborated by the normal progress of development, she absolutely creates and produces as independent creatures. This law, which we find everywhere confirmed, will furnish us with a key to the necessity of a difference among insects with respect to their metamorphosis. I refer for this purpose to the four chief classes of the *Arthrozoa*, each of which is characterised by its place of abode and the possession of peculiarly formed organs of motion, and we already saw above that the presence of wings in any of the *Arthrozoa* suffices to raise it to the class of insects. But we also perceive that Nature, if she will derive differences merely from the organs of motion, possesses no further means to found new variations, for she has already exhausted the forms of these organs. Whence, then, should she obtain means for the attainment of her object of producing the greatest possible variety, if she did not resort to the last, which is the repetition of the earlier forms in a higher grade of perfection? She, therefore, avails herself of this, and allows one portion of insects to be distinguished from all the other *Arthrozoa* merely by the presence of wings, whereas the other portion of already winged insects she raises so above the preceding, that she conducts them, before they arrive at their final stage, through the earlier forms of the *Arthrozoa*, which have remained stationary upon a lower grade, and, at a certain period of their lives, furnishes them with merely pedal warts, then with hooked, short feet, then with branchiæ and natatory laminæ, and, later, in their pupa state, with rudimentary wings, and, lastly, with perfectly developed wings. Thus I conceive to be explained the necessity of both the chief groups among insects.

In insects with an imperfect metamorphosis there cannot, consequently, be a passage through the earlier forms and grades of the animal kingdom; even the analogy which I formerly thought I detected between them and the consecutive classes of the *Gastrozoa*, appears to me now, upon a closer investigation, to be a merely playful endeavour to discover resemblances, and which I consequently no longer value. What I formerly, as a proof of such a repetition, deduced from the successive development of the sexual organs, may, with equal justice, be applied to all insects, or to all *Arthrozoa*, and, indeed, to all animals whatsoever, in as far as in all, the perfecting of the genitalia progresses with the gradual development of the creature.

Nevertheless, all insects, notwithstanding this difference from each other, must be recognised as members of the same class, and, indeed, by reason of the uniformity of the figure of the whole body, that is, by its division into three chief parts. This division of the body, which, among all the *Arthrozoa*, is peculiar to insects alone, is their second most important truly physiological character, which proves the equalisation of the contention between the various organs of the body, and in the limitation of each individual organ to a particular and impassable sphere of action, most clearly illustrates the fixed laws of its type of structure, which is always a predominant character of highly developed and perfected groups. The same law exhibits itself in the structure of the mouth, the antennæ, the wings, and, especially, in the number and articulation of the legs, whence their number, restricted to six, has always been considered as the safest character of insects.

§ 252.

Having thus explained the significance of the insect metamorphoses, it still remains for us to define distinctly the several changes which the insect undergoes during these stages. Indeed, in the anatomical description of the organs of digestion and generation, we have already spoken of the changes they experience during the metamorphosis (§ 114 and § 153); but these changes have not yet been brought into connexion with the other transformations of the body; and, besides, we have not yet at all spoken of the great discrepancy of the form of the limbs, nor even of what is still more important, namely, the addition of new ones. In the explanation of these subjects which we are now entering upon, the insects with a perfect metamorphosis will chiefly occupy us, in so far as in them only does a true transformation take place; whereas we shall speak of the insects with an imperfect metamorphosis only where we take notice of the moulting, and upon our investigations into the sprouting of the wings. We shall here, therefore, have an opportunity of circumstantially referring to that law laid down by Von Bär, that there is visible in the development a perfecting as well by the means of morphological and histological separation as by the progressive forming of a particular figure from one more general.

If an *Arthrozoon*, whose form consists of a longitudinally distended and generally hardened case, composed of limbs and rings, is to enlarge by growth, it must strip off its former covering and clothe itself with a new one, as the old one interrupts the universal distension, and, indeed, makes it wholly impossible. It is only in those *Arthrozoa* which dwell in moist places, so that from their place of abode their integument cannot harden in the air, which, therefore, constantly remains equally soft and flexible, the casting of the external integument is rendered unnecessary, and they therefore do not moult, but even in the higher *Annulata*, for instance, in the leech, a moulting is observed, and still higher, for example, in the *Malacostraca*, it is the necessary condition of growth. In insects, also, this change of skin must likewise take place so long as they grow, and it is this change of skin alone which, in insects with an imperfect metamorphosis, presents itself as the external mark of metamorphosis; but it is also proper to insects with a perfect metamorphosis, among which it indicates, as well as among the preceding, a transition from one stage of life to another.

The earlier physiologists differ in opinion from the moderns upon the mode in which this new skin originates beneath the former. Swammerdamm and Bonnet were of the opinion, in accordance with the general idea of their age of the theory of encasement, that all new skins already existed beneath the old one, and that the latter, without any re-production upon the part of the larva, was merely stripped off. Exclusively of the true object of moulting being overlooked in the adoption of this opinion, the mere observation of the larva having considerably increased in size immediately after the divestment, contradicts it; for if the new skin already existed beneath the old one, must it not there exist in considerably smaller compass rather than in larger? That Kirby and Spence could adopt and explain this opinion as the most correct, distinctly fixes their position in physiology, which, not merely here, but almost everywhere, exhibits itself as an antiquated one. Whereas, according to Herold's * admirable observations, there is not the least trace in the young larva of the new skin, but this first originates towards the end of the first period of the caterpillar's life, a few days only before the old one is stripped off. It is then observed that the mucous and muscular layers of the skin separate all round from the epidermis, and then clothe themselves upon the superior surface with a new epidermis. The development of this new external skin occupies two or three days, during which the caterpillar appears sickly and takes but little or no nourishment. Lastly, the old skin divides longitudinally along the back, and the caterpillar frees itself from its now separated skin by means of contortions and violent motions, first emancipating its head and then drawing the body out. The epidermis, all the external visible organs, and even the mandibles and palpi, remain attached to the old skin. Upon the caterpillar having quitted its old case, it appears very languid, its body is soft and easily injured, so that during its change of skin even a slight pressure is sufficient to kill or wound them, but it speedily resumes its former strength, and it then devours with renewed voracity, as if eager to make up for lost time. Contemporaneously with the formation of the new skin, the intestinal canal has also enlarged, thence after its moulting the quantity of food becomes greater, the digestion more perfect, and the formation of the fatty mass is more rapid and in larger quantities. In general, this first moult takes place about the twelfth day of the life of the caterpillar. The second moulting, which occurs after another lapse of from six to eight days, presents the same phenomena, and has the same effects; and the third also, which takes place after another six or eight days. But its voracity constantly increases, so that a larva does not now merely consume three or four times its own weight of food, but it also increases considerably in corporeal mass; as, for instance, the comparative weight of a full-grown caterpillar of the goat moth to that of the young one just crept out of the egg is, according to Lyonet, as 72,000 to 1. A growing flesh-fly takes in twenty-four

* Entwickelungsgeschichte der Schmetterlinge, p. 26, &c.

hours 150 times its own weight; but the common caterpillar of *Euprepia Caja*, which weighed thirty-six grains, and every twelve hours rejected from fifteen to eighteen grains of excrement, increased only one or two grains in weight in the same space of time *. The increase in weight appears to be much greater in carnivorous larvæ, for, according to Redi †, the maggots of the flesh-flies, which at first weighed one grain, so increased, that each, on the following day, weighed seven grains, which gives a proportion of increase, in twenty-four hours, of from 1 to 200.

After the third moulting, when the larva has acquired its full size, the rudiments of the wings begin to form beneath the skin, upon the first and second segments. They at first present themselves as short viscous leaves, the substance of which greatly resembles that of the mucous tunic, and to which many delicate tracheæ pass, which distribute themselves throughout them. These rudiments increase with the growth of the caterpillar, and betray themselves, even externally, by both the segments of the caterpillar, upon which these rudimentary wings are found, appearing swollen and spotted. Their enlargement probably takes place by the assistance of the blood flowing into them. Simultaneously with the perfecting of these rudiments the intestinal canal increases in compass, and, as a consequence of this increase there is a greater accumulation of the fatty mass. A transformation is also taking place in the anterior feet of the caterpillar, for the larger legs of the butterfly begin to form. But, as a similar transformation is going on in the oral organs, the caterpillar loses its desire to eat and power of mastication, it ceases to receive food, and prepares itself for its last moulting, viz., for its change into the pupa. It seeks for this purpose an appropriate place where it can lie, hang, spin, or attach itself, and it accomplishes this, its last business, the same as its earlier ones, with great care and consideration. After its situation and web are prepared it reposes a few days, then strips off its skin, and now presents itself as a pupa, with the visible limbs of the butterfly.

It is striking that insects, notwithstanding such a great, and, we might almost say, unexampled, capacity of production which is exhibited both in their rapid growth and the increase of the body in mass as well as in the development of new parts and the enlargement of the old ones during the pupa state, display but very slight traces of a power of re-

* Kirby and Spence, vol. i. † De Generat. Insectorum, p. 27.

production. Beckmann * and Goeze † have imparted experiments, the results of which are—that the former, in *Agrion virgo*, and the latter in *Semblis bicaudata*, Fab. (*Perla*, Geoff.), once observed a leg, which was smaller than the rest, whence Goeze concludes that this leg must have been lost, and subsequently replaced by a new one. To these former observations we may add some more recent ones of Heineke ‡, which are absolutely of greater importance. On the 25th of July he cut off both the antennæ of a *Blatta Madeiræ*, after which it moulted on the 8th of August, and now acquired two new, but much shorter ones. He repeated the same experiment in the pupa of a *Reduvius*, where he obtained the same result. In perfect insects also, subject to no further moulting, namely, species of the genera *Forficula*, *Gryllus*, *Locusta*, and *Acridium*, he mutilated in the same manner, but even in the space of two months they acquired no new limbs, but cast off the old ones shortly after they were injured. These results entirely harmonise with the reproduction of the spiders; these also renew their lost limbs only so long as they yet moult, whereas after their last moulting they cast off their mutilated ones, but acquire no new ones. We must, therefore, ascribe to insects, at least to those with an imperfect metamorphosis, the power of replacing lost limbs, with these restrictions. It does not appear to be different in insects with a perfect metamorphosis, for mutilated caterpillars are said to obtain new limbs, that is to say, legs, after the next moulting. But it is remarkable that these limbs do not germinate whilst the insect remains in its old case. I think this circumstance is explained by the hardening of the integument, whence it is to be considered as it were dead, and thence I deduce the reason of the known fact, that wounds given to insects cicatrise only upon the next moulting, and consequently never in their perfect state. It must also be attributed in a great measure to the deficiency of blood vessels, for by their assistance cicatrisation and the resupply of flesh is promoted, namely, the constant streaming of the blood to the wounded spot, is the first cause of its subsequent living reconnexion. By means of the blood the lips of the wound are stuck together, and hence is formed the cellular tissue which unites the divided parts. Both blood and cellular tissue are consequently the means which nature makes use of to replace lost or divided animal

* Physinkalisch-œkonomische Bibliothek. vol. viii. p. 20.

† Naturforscher, part xii. p. 221.

‡ Isis, 1801, p. 1359. From the Zoological Journal, vol. iv. p. 422.

parts; and now, as the first stands upon a very low grade in insects, and the second is wholly deficient, consequently a cicatrisation of wounds can never be effected. But if beneath the wounded skin a new one is formed it uninterruptedly covers the wound of the old one, and after moulting the larva appears healed, if the wound be not of a description to affect its life, and thus interrupt all future changes of the skin.

§ 253.

In our representation of the metamorphosis we have omitted one phenomenon which was mentioned in earlier parts of the work (§ 114—127), namely, the simultaneous moulting of the intestinal canal and tracheæ, with that of the external integument. Bonnet * and Swammerdamm †, the first physiologists of their age, especially with respect to the class of insects, maintained this opinion, and from their works it has passed into those of modern physiologists; whereas Herold, in his history of the development of the butterfly, says, that such a change of the tunic of the intestinal canal never happens, and that in the tracheæ it occurs only in the large main stems ‡. In fact, we must confess that if the stripping of the skin is, as we have above remarked, merely caused by its gradual hardening in the air, and the consequent impossibility of the distension of the increasing body, it does not require that we should thence admit of an equally requisite change of the internal tunic of the intestinal canal, nor even of the tracheæ, except in their large main stems, into which much air passes, and that, therefore, Bonnet's assertion reposes either upon a false observation, or was perhaps wholly invented by him for the support of his theory of encasement. But in opposition to this, independent of the credibility to which a man like Bonnet may lay claim, the testimony of Swammerdamm speaks, and who certainly did not lie, or say more than he saw: he remarks, that at the posterior end of the stripped skin, where it is twisted up and folded, he observed the moulted colon, and that after the moulting of the larva of the rhinoceros beetle the internal tunic of all the tracheæ, even to their most delicate extremities, were visible in the stripped integument §. I have distinctly observed the same in the moulting of the *Libellulæ*; in these, not merely the main stems, but

* Contemplations de la Nature, tom. ii. p. 48.

† Biblia Naturæ, pp. 129, 134, 239, &c.

‡ Pp. 34. and 88.

§ Biblia Naturæ, p. 129, b.

also many auxiliary ones, were divested of their tunic, and likewise the internal tunic of the colon remained attached to the peeled case. We have likewise above drawn attention to the uniformity of the external epidermis with the mucous tunic of the internal organs, and by a similar pathological phenomenon, shown their affinity. Thus, the observations of equally credible witnesses and the several theories clash together. It is difficult to discover the truth in the midst of such contradictions. To conclude that in one order such a changing of the skin exists, but not in the other, appears inadmissible, as nature in general pursues in its process of development a certain uniformity. Perhaps, however, we may find an outlet if we adopt that in smaller individuals the internal tunic of the intestinal canal is more easily absorbed, whereas in the larger ones, furnished with a coarser mucous membrane, it is rejected. Many observations speak in favour of such an absorption, namely, the absorption of the mucous membrane of the egg-tube at its lower extremity, where it stands in connexion with the oviduct after it has developed the lowest egg at this spot, and then has passed into the oviduct itself (§ 210). But the perfect explanation and determination of this doubt remains still as the problem of careful, prolonged, and comprehensive experiments and observations.

§ 254.

The number of moultings of the larva until its full growth appears to vary considerably in different families and genera. "It may be assumed in general that they change their skin three times. This is the case in all insects with an incomplete metamorphosis. After the first change the larva has merely increased in size, but during this second period of its existence the rudiments of the wings form beneath the skin; consequently, after the second moulting, these incipient wings present themselves externally as small leaves, which cover the sides of the first abdominal segment; these larvæ are called nymphs *," it being analogous to the pupa state of other insects. When this pupa again moults the insect attains its perfect condition; the at first short, soft, thick wings spread in the course of a few minutes to their future full size, then speedily dry in the air, when the at first distinct circulation of the blood in the ribs gradually disappears, and the metamorphosis of the individual is completed. It raises itself with difficulty

* The passage in inverted commas is a MS. alteration from the original, communicated by the author.—Tr.

in the air by means of the first strikings of its wings, which succeed but imperfectly, and it then seeks a more elevated spot whence to exercise its new function with fuller effect.

Some genera, which from their abode in water prior to this period, make a transition to living in the air, form in a remarkable manner a perfect exception to the law, that with the casting of the pupa case the metamorphosis of the individual is concluded. It is universally known of the *Ephemeræ*, that in about half an hour, and indeed frequently only some minutes, after they have quitted the pupa case, again moult, and then only are able to copulate and procreate. This observation may be repeated without the least trouble in July and the commencement of August, when the *Ephemeræ* in watery situations quit the water towards evening by myriads. The just excluded *Ephemera* flutters immediately, although with difficulty, out of the water, and in the course of a quarter or half an hour, but in the smaller species in a shorter space of time, it seeks an elevated object, for instance the stem of a tree, the post of a bridge, houses that are close at hand, and even individuals standing upon the bank, and here clings firmly with extended legs. Speedily afterwards the dorsal case splits in its middle, upon which the insect with violent motion first frees its head and anterior legs from the old skin, which is succeeded by the other legs as soon as the anterior ones have affixed themselves, and then at the same time, but gradually, by the wings and abdomen. Prior to this moulting the creature has not acquired its usual markings and dark colour, which we perceive immediately after the new change of skin ; and it is also remarkable, that after this change all the limbs, particularly the longer anterior legs and anal setæ of the male, become both more slender and longer than before. The horny case of the eyes is the only part which does not participate in this moulting. An analogous process is found to take place in the pupa of the *Phryganeæ* and *Semblodes*, which in that state repose without taking food, and are consequently endowed with a perfect metamorphosis, for, according to De Geer *, it quits its place of repose, beneath the water, and creeping up the sides higher than the surface, there casts its pupa case. I am inclined to surmise from my own, indeed not fully comprehensive observations, that the already perfected insect creeps forth, and then reposing for a time, moults a second time. During this repose the wings especially

† Mémoires sur l'Hist. des Insectes, tom. ii.

are formed, which in the just excluded insect possess but half their size, but fully develope themselves after this renewed change of skin.

Among insects with a complete metamorphosis the caterpillars of the butterflies moult, according to Kirby and Spence *, frequently; but thrice, according to Cuvier †. After the last moulting they become pupæ, and after the casting of the pupa case butterflies. The caterpillars of the *Noctuæ*, on the contrary, moult four times, but some of the large ones, which live for two years as caterpillars, much more frequently, for instance, *Euprepia villica*, from five to eight times; *Euprepia dominula*, nine times; and *Euprepia caja*, ten times ‡. The time between two moultings also varies much, which appears to depend partly upon the size of the insect and partly upon its length of life. The larger ones require a longer and the smaller ones a shorter period. In general the interval between two moultings varies from eight to twenty days, excepting that those *Lepidoptera* which change into pupæ late in the summer or autumn, then lie the whole winter as pupæ, and are only fully developed upon the following spring. These pupæ change their larva-skin very early, mostly in the course of a few days, whereas others remain long in it. This is the case in the larvæ of the *Tenthredonodea*; even after the pseudo-caterpillar has spun its cocoon, it still remains for some weeks in its old skin, and only shortly before its time of exclusion does it strip off its dried up larva case. This is at least the case in the genus *Cimbex*, but in the smaller *Tenthredos*, for instance in *Lophyrus*, in which the pupa state is of short duration, the larva skin is earlier cast. Some larvæ, namely, the maggots of many of the flies, *Œstri*, *Syrphodea*, and *Notacantha* change into pupæ in their larva-case. All these larvæ likewise possess the remarkable peculiarity that they do not moult, but retain their old skin from the commencement of their existence. It is in connexion with this peculiarity that we observe the stronger folding of their external tunic, as also their abode in damp situations; some larvæ of the *Syrphodea* alone, namely, the larvæ of *Syrphus*, which prey upon the *Aphides*, make an exception to this dwelling-place, whereas on the other side many larvæ moult which live in moist places, namely, all the larvæ of the *Diptera*, with many joints to their antennæ, for instance, those of the gnats and *Tipulæ*, which distinguish themselves from the preceding by the possession of a distinct head. The

* Introduction, vol. iii. Nouv. Dict. d'Hist. Nat. vol. vi. p. 289; vol. xx. p. 372.

† Leçon's d'Anat. Comp. vol. ii. p. 547.

‡ Kirby and Spence, vol. i. Lyonet, in Lesser Théologie des Insectes, vol. i. p. 167 *).

reason, therefore, why these larvæ do not moult cannot lie exclusively in their damp place of abode; nor that their existence as maggots is but of short duration, as, for example, in the common flesh fly from eight to ten days, but it must be found in other conditions of their organisation which have not yet been discovered. Besides, this phenomenon also proves that the development of insects of different orders, and even of the different families of the same order, can take place in a different manner, and that, therefore, the assertion that the intestine also moults in some orders, whereas in others it does not, is not so wholly gratuitous; but we will nevertheless not decide, having made no observations upon the subject. The determination in another instance is just as difficult, and in which also the observations of several naturalists stand in direct contradiction: this is the case in the maggot of the bee. This, according to Reaumur and Huber's observations *, like all the apode larvæ of the *Hymenoptera*, consequently in by far the majority, does not moult, but merely gradually grow larger. Whereas Swammerdamm says expressly that he has observed the moulting of the larva of the bee †, and that he has likewise found the inner tunic of the intestinal canal in the cæcum behind the stomach of the maggot of the hornet ‡. However the case may be, we prefer adopting the first opinion, as all these larvæ exhibit a very great conformity with those of the *Diptera*, which certainly do not moult. This conformity refers not merely to the larva, but likewise considerably to its mode of life, in as far namely as that the larva of the *Œstri*, as well as the maggots of the pupaphaga, are true internal feeders. But they in so far differ from each other that the hymenopterous larva casts its skin when it becomes a pupa; the larvæ of these *Diptera*, however, change into pupa within their larva skin. In *Stratiomys*, indeed, the shape of the larva remains unaltered, and it was thence that Knoch considered this larva an annulate worm, in which the larva of the *Stratiomys* lived as a parasite ||: in the rest, however, the soft skin of the larva shrinks up into an egg-shaped, hard, annulated case, in which the pupa is concealed, with its free and visible limbs. The other *Diptera*, which moult as larvæ, cast their larva skin before changing into the pupa state; this is the case, for instance, in the larvæ of the gnats, of the *Asilica*, *Xylophagi*, and many others.

* Kirby and Spence, vol. iii. † Biblia Naturæ, p. 163, a. ‡ Ib. p. 133, a.

|| Neue Beiträge zur Insektengeschichte, Pl. I.

§ 255.

The changes which take place within the larva during the several moultings are unimportant. But formerly, where we spoke of the changes which the intestinal canal and the sexual organs undergo during the metamorphosis (§ 114 and 143), and which we have since recently referred to, we noticed that the changes of these organs commence only during the pupa state, and that consequently the caterpillar retains the same form of the intestinal canal and the same figure of the sexual germs, and that both merely increase with its growth, in compass and in the structure of their tunic. But, upon the larva passing into the pupa state, a change of the internal organs takes place, as well as of the external figure. These changes we have indicated at the above place, but those undergone by the larva we explained earlier (§ 60); it, therefore, merely remains for us to make a few observations upon the character of these transformations.

With respect to form, by it the law laid down by Von Bär, of a progression from a general to a particular figure during development, receives full confirmation. The intestine of the larva is simple, broad, generally straight, and without many convolutions; its divisions are not strongly marked, but pass gradually into each other. During the pupa state, however, it transforms itself to a longer, much convoluted tube, separated into several divisions, which now exhibit a distinct difference of texture; and indeed new organs are added of which there was formerly no trace, namely, the proventriculus in the *Carabodea*, the sucking bladder and cæcum in the *Lepidoptera*, the villi in the ilium of the flesh eaters, &c. In the flies, in which indeed the intestine upon the whole shortens, each individual division, however, and particularly the ilium, acquires a more determinate form and a more compact structure; the sucking stomach more distinctly separates itself, its orifice lengthens, as also does the œsophagus. In the sexual organs there is a more distinct difference of structure: parts which previously had a great resemblance to each other, namely, the testes and ovaria, from day to day increase in dissimilitude; and other organs, of which before there was no indication, gradually form themselves from simple processes to long convoluted canals; lastly, the pupa itself exhibits a vast discrepancy of form. The larva was a worm composed of equally large rings; the pupa, on the contrary, possesses the entire form of the subsequent insect, and differs, therefore, with respect to the forms of its rings chiefly by the difference of size found between several, namely, those of the thorax and abdomen. This dissimilarity is founded upon the more determinate figure divaricating more from the general one which the three segments of the thorax have adopted, a dissimilarity found to exist not only between them and the segments of the abdomen but also between them individually.

With respect to the second, the histological and morphological separation, the first we have already superficially touched upon. The tunics of the intestine do not indeed become uniformly more compact and firmer by the metamorphosis, but in general only in those cases in which the perfect insect takes the same food as the larva, namely, in the *Carnivora*. In the *Lepidoptera* the increased development increases the necessity of better and more delicate nutriment, consequently the butterfly does not require so compact an intestinal tunic as the caterpillar. The latter has to elaborate and extract the entire substance of the plant, the former merely feeds upon the most delicate juices of flowers, namely, their honey. The thick fleshy proventriculus, armed with horny teeth and plates, most perfectly exhibits the histological separation. From the thin membranous cardia of the stomach of the larva during the short pupa state this powerful and muscular organ has been produced; from this same thin tunic processes have arisen, and thus its cavity has distended upon all sides. But in conjunction with this the general cavity of the ilium decreases, the muscular fibres contract, and form a compact firmer membrane than that of the stomach of the larva. And lastly, the morphological separation is even more decided; similar rings transform themselves into the most dissimilar divisions of the body, and in these divisions large muscles grow from small beginnings, new organs of motion are also associated during the pupa state, and the old ones become lengthened generally as well as in their several joints, and, indeed, what was formerly a single joint becomes divided into from four to five, namely, the tarsus; or an organ which consisted of three or four joints now exhibits ten, twenty, and sometimes as many as fifty. Eyes even, the most important of all the organs of the senses, originate; and at a place where previously the situation of the head was indicated, merely by the orifice of the mouth, an entire head is formed with all its requisite organs.

§ 256.

The preceding paragraph shows us that the character of the metamorphosis of insects is found to be now restricted to its progress from *a*, in every respect, general form to one more particular and determinate. This character displays itself most distinctly in the perfect insect in the separation of the entire body into three particular divisions, each of which comprises its peculiar organs. It likewise stands in the closest connexion with the general ideas of development, and of the higher perfection of organic natural bodies, in as far as by this structure of the body the individual organs are more distinctly separated from each other, and each has acquired its determinate situation and a more artificial composition. The head is the bearer of the organs of the senses, the thorax of those of motion, and in the abdomen the organs of vegetation are placed. That portion of the body, consequently, which in the series of *Gastrozoa* predominated has become in the insect if not the smallest yet the most simple and least developed, whereas that in which all the organs are situated that characterise the *Arthrozoa*, which are the organs of motion, namely, the thorax, is, with respect to its composition and development, the most perfect. But we have above seen (§ 158) that the organs of motion fall into active and passive. But this separation is first found distinctly expressed in the *Arthrozoa*. We certainly find the active ones or muscles universally among the *Gastrozoa*, and also indications of the passive ones are found in the internal bony parts and partial skeleton ; but a perfect skeleton of hard parts to which the muscles can be attached is first found in the higher *Arthrozoa*, namely, the *Crustacea* and *Insecta*, and which presents itself as an external ossified or horny integument. The most simple form of this external integument is the ring, all particularities and individual divarications have consequently proceeded from the annular form, and must, therefore, admit of being referred back again to it. The first change, however, which the ring in the progress of development suffers is, that it separates into a superior and inferior half; thus are formed the rings or segments of the abdomen, as well as of many larvæ and caterpillars. Whence the lower half thickens in its centre, and from this spot sends processes inwardly, which also occasionally form into a ring, and thus a smaller ring is inclosed within the larger one, but both of which touch at one spot, namely, where a half diameter drawn from the centre touches the circumference. This inner ring, or the processes which indicate it, receive the nervous cord within it, whereas all the other organs are encompassed by the larger external ring. Thus are formed the most perfect segments, namely, those of the thorax.

If we compare this structure of the parts of the skeleton with those found in the vertebrata we discover a not unimportant uniformity in their fundamental composition. That point namely from which the arch of both rings proceeds is analogous to the body of the vertebra; the bow of the smaller ring presents itself as the foramen medullare, and that of the larger ring those moveable processes which hang attached to the vertebræ, and which are called ribs; the superior and generally smaller half ring, lastly, which unites the two arches of the lower half ring to a whole ring, represents the sternum placed between the ends of the ribs. Hence, thus we obtain as the fundamental form of the skeleton of the insect the vertebræ with their radiations, just the same as these bones form the foundation of the trunk and head-bones of the vertebrata. The difference between both is found only that in the vertebrata the radiations of the vertebræ take an opposite direction, whereas in insects they project on one side only. Besides, this view, which appears to contain so much truth as not to require a proof in detail, is by no means new, but has been advanced by several comparative anatomists, namely, Geoffroy St. Hilaire *, Robineau Desvoidy †, and more recently by Carus ‡. We need, therefore, merely refer to the labours of these learned men, particularly to the last, and those who shall consider this comparison an absurdity, we draw their attention to his detailed representation; it here suffices to have found the result in a simple development.

§ 257.

But that the vertebræ here lie upon the surface, whereas in the *Osteozoa* they are encompassed by soft parts, is grounded upon the entire formative type of the *Arthrozoa*, which is no other than that the skeleton in them is always external, whereas in the *Osteozoa* it has become internal. But why this is so ordained by nature we can only answer when we shall have seen why nature has produced *Gastro-*, *Arthro-*, and *Osteozoa*, and to answer this would be stepping beyond those limits within which human investigation is restricted, especially in its inquiry into final causes; consequently a miscalculation of its capacity. But one thing strikes us with astonishment, namely, that in

* Annales des Sciences Physic. Part iv. 1820, p. 96—133., whence translated in Meckel's deutschen Archiv für die Physiologie, tom. vi. p. 59.

† Recherches sur l'Organisation vertebrale des Crustaces, &c. Paris, 1828. 8vo.

‡ Von den Urtheilen des Knochen und Schalengerüstes. Leipz. 1830. Folio, with plates.

the *Arthrozoa* the vertebræ lie upon the ventral side, and in the *Osteozoa* upon the dorsal. This arises from the situation of the nervous cord; if this lie upon the ventral side it then attracts the vertebræ to it, for it is the earlier, they being formed around it. The nervous system in general, as well as every individual nerve, seeks the best protected parts, therefore, in the *Gastrozoa*, as well as in the *Arthrozoa*, its main stem lies at the ventral surface, that it may conceal itself beneath the other organs. If, then, the ganglionic ventral cord of the *Arthrozoa* be analogous to the spinal cord, or as others prefer considering it, to the dorsal ganglionic chain lying contiguous to the vertebræ, which may be doubted since the discovery of a distinct *nervus sympathicus* proceeding directly from the brain; then the encompassing parts of the skeleton will necessarily be analogous to those parts of the skeleton of the vertebrata, which inclose that cord. But we prefer considering the ventral cord of the *Arthrozoa* as the true spinal cord, from its passing within the canal formed by the horny skeleton, and not contiguously, as would necessarily be the case upon the adoption of its identity with the dorsal ganglionic chain. According to this representation, therefore, insects run with their back turned forwards, or rather underwards, and what is called back in them is the true ventral side. This idea has been long since suggested, and was immediately, like everything that diverges from common views, strongly disputed; but the proofs cited in opposition do not appear tenable, as will be evinced by what follows in support of our opinion.

The situation of the intestines perfectly confirms our view. That organ which lies most approximate to the vertebral column of the vertebrata is, with the exception of the vessels which are deficient in insects, the œsophagus and the intestinal canal; even so in insects, it lies immediately over the nervous cord, directly upon the inner horny arch when it is closed, or still between its branches. In the vertebrata next to the intestinal canal proceeding from the back towards the belly we find the lungs and the heart in the thorax, in the ventral cavity the intestine touches the ventral surface, in the pelvis the sexual organs namely, the gravid uterus, lie in front of it. We find exactly the same arrangement in insects: the lungs are omitted, as they are universally distributed; in the thorax proceeding from the back towards the breast we find the heart with its large vessels. In the ventral cavity, whither the heart also extends, it is likewise placed externally, and indeed the return of the aorta to the back is indicated in the two main currents passing from the head and proceeding laterally, inclining downwards. Thus also in insects the motion of the blood first proceeds forwards and upwards, and then backwards and downwards. The sexual organs, lastly, lie in front of the intestinal canal, therefore above, immediately beneath the heart. This situation is shown above in the ovaries; in their rudiments also in the caterpillar it was remarked that they lie above the intestinal canal. The orifice only of the sexual organs differs, as in insects it lies beneath the anus, whereas, according to analogy, it should lie above. Nature appears to have pursued a determinate object in this situation, which agrees with that found in fishes, but which could not be subjected to the twisting of the insect body; but what this object is remains undiscoverable. This only is evident, that the genitalia in insects lie as much in front of the intestinal canal, calculating from the spinal cord, as in the mammalia and other animals. A second objection, besides that of the altered situation of the sexual aperture, which could be made to this twisting of the insect's body, might be deduced from the situation of the mouth, which does not lie laterally with respect to the spinal cord, but upon it, like the former. But the twisting of the anterior half of the head occasions this, and that such a twisting is actually the case is proved by the co-relative situation of the cerebrum and cerebellum, both of which, in fact, do not lie upon one side, but upon the opposite sides of the œsophagus, namely, the cerebrum above, on the true ventral side, the cerebellum beneath, towards the true back. This wholly irregular relation of the parts can only be explained by a twisting of the anterior portion of the head. The organs placed upon that part of the head naturally participate in it, and thus the mouth came beneath, whereas properly it should lie above, were it in harmony with the entire structure of the insect. But how is such a twisting consistent with the simplicity of the case of the head? The reply to this question appears difficult, but in fact it is not so when we consider that the head as well as the body consists of vertebræ. Their number is regulated by that of the cerebral ganglia; in the vertebrata there are three, namely, the cerebellum, the posterior lobe of the cerebrum, and its anterior lobe. This anterior lobe, the ganglion of smell, is deficient in insects, as they have no particular organ of smell, and consequently we find in them only two ganglia, namely, the ganglion of sight and the cerebellum. Thus their skull is divided into two vertebral arches. These are also very distinct in the head of the larva; the posterior one, in which the cerebellum lies, is the largest, and consists of the throat as the base, and of the two large temples which meet at the vortex, as the arch. Between them a triangular piece lies anteriorly and above, the clypeus, which has the eyes at its lower angles, and the mandibles at its base; beneath, the chin lies next to the throat, which thus closes the second arch indicated by the clypeus. Both together form the second vertebra; it enlarges during the metamorphosis, and thereby pushes back the arch of the posterior vertebra. The oral organs are attached to it, and it contains within it, the cerebrum, or the ganglion of the eyes. The clypeus is the body, or vertebra itself, the branches of which, or arch, bend downwards to the chin; the chin itself is the upper plate of the vertebral ring, or part corresponding with the sternum. The mandibles hang attached as limbs to this vertebra. The eyes also are situated upon the anterior vertebra, and which indicate posteriorly its limits, in as much as their horny external surface appear, as it were, introduced in the free space between the two vertebræ, or rather have separated them from each other. Thus, therefore, the optic nerve passes just in the same manner between the two vertebræ, as the nerves of the spinal cord pass between the arches of the vertebræ. The posterior of these vertebral arches, namely, that for the cerebellum has, as well as the thoracic vertebræ, its internal processes, or the second ring, which corresponds with the true vertebral arches. It, therefore, originates as a furcate process from the throat, and embraces the cerebellum with its branches. When these branches unite they form the tentorium, or the small band which divides the occipital aperture into two halves. But we do not find anything analogous in the first vertebra; did it exist, it would necessarily proceed from the clypeus or the forehead.

§ 258.

The opinion, therefore, that the trunk of the insect is formed upon the same type as that of the vertebrate animal is thus corroborated: we have exhibited even the same analogy in the head. The chief difference of the two organisations, however, consists in the back in the insect being turned downwards, but in the vertebrate animal upwards. What Von Bär * cites as a proof in opposition to this assertion, viz.—that the upper side of insects is the distending side, the lower the bending side, and that, therefore, as in the vertebrata, the

* Entwickelungsgeschichte der Thiere, p. 246.

former is more densely covered with hair, and more deeply coloured than the latter—does not at all suffice; for, in the first place, in very many insects, particularly in the beetles, the under side is that which makes the greatest bow, and, therefore, the distending side, and often, as in the bees, is the most densely haired, and besides the darker colouring, as the consequence of a greater effect of light, is no proof in opposition. This is evinced by the universally brighter colour of the upper side of the abdomen in the beetles, in which the elytra oppose the effect of light. What also he cites in opposition from the situation and posture of the extremities is also inapplicable; for the extremities proceed precisely from the same side as they do in the vertebrata, namely, from the dorsal side. In all the vertebrata the extremities are attached to particular bones which stand in connexion with the vertebral column. These bones are, for the anterior extremity, the scapulæ, and for the posterior one the ilium, of the pelvis. We refind these portions of the skeleton also in the *Arthrozoa*, at least in the most perfect among them, namely, the beetles; but they do not lie superficially attached to the vertebræ and its arches, but as external cases they are connected with the ring which is formed by the vertebra and its processes, and necessarily at the spot where they properly belong, namely, between the vertebra and the sternum. This approximation of the shoulder-plate to the vertebral column is very distinct in the anterior extremity of the vertebrata, it descending closely contiguous to the vertebræ; in the posterior extremity, however, where the ribs are wanting, it is even traced, in as far as here the ilium borders immediately upon the vertebral column, and when the sternum here, the os pubis is wanting, it presents itself as an arched process, upon the vertebral series of the pelvis. The same is the case in insects; here also the ribs are compressed, and the scapulæ take their place. We, therefore, obtain in insects both a shoulder-blade and a pelval piece; the first is also the plate, called by us the scapula, the latter our parapleura, the ischium of Straus, which, properly, should be called the ilium. The most distinct proof that these pieces merit their names is the fact that the muscles which move the thighs, namely, its flexor, thence proceed, and that consequently the femur is attached to these pieces. In the anterior legs it is the omia which correspond with them in situation and function Analogous to the dorsal and ventral plates these three plates might therefore, be called the promium, mesomium, and metomium, whereas the dorsal plates should now be called pro-, meso-, and metasternum and the ventral plates, pro-, meso-, and metanotum. But why do the thighs articulate with the vertebræ itself?—why not with the shoulder-blade, as it is present? These questions could be suggested only by a superficial observer, with reference to the posterior femur, for upon the anterior and intermediate pairs the shoulder-blade actually forms a portion of the articulating socket *. The posterior femur also, or rather its ball, which is usually called the hip, joins the parapleura above, and this forms a portion of the articulating socket †. Likewise in the downward bent margin of the parapleura the small articulating socket is formed for the round ball of the top of the femur which revolves in the large hip socket. Lastly, the aperture through which the muscles of motion pass into the thorax is always found between the pleura and the sternum, and is partly encompassed by the former and partly by the latter.

Thus the composition of the insect body and the analogy of its individual plates with the bones found in the vertebrata, is fully proved, and we obtain as the result that

The head consists of two vertebræ, the one of which is twisted in opposition to the other ‡.

The thorax consists of three vertebral rings, each of which is subdivided into the true vertebra, the shoulder-blades and a sternum.

The abdomen consists of nine vertebræ, each of which again consists of the true vertebra and its arch, which are either the analogies of the ribs or frequently merely represent the transverse processes of the vertebra and the ventral sternum, the horny ventral covering. The last of these vertebral rings, namely, the anal and sexual vertebra, is also twisted, so that the vertebra with the anus lies above, and the ventral plates with the sexual apertures lie beneath. These abdominal vertebræ have no internal processes; they retain their original most simple larva form, and generally present themselves as simple but more frequently halved rings. In some cases, for instance, in the locusts, from the lateral parts of the half ring other free moveable half arches project into the cavity of the abdomen, which both in situation

* See Pl. IX. No. 2. f. 2., No. 3. f. 5.; Pl. X. No. 1. f. 6., No. 3. f. 5.

† Pl. IX. No. 3. f. 5.

‡ This composition of the head from two vertebra or rings is confirmed by Ratzeburg's observations upon the development of the larvæ of the *Hymenoptera*. See Darstellung und Beschreibung der Arzneithiere, vol. ii. p. 175, Pl. 23, f. 47—50 and f. 88—91.

and function perfectly agree with the ribs. But I have never been able to find a second series of vertebral arches for the nervous cord.

§ 259.

We must now proceed to the comparison and explanation of the limbs. We have shown above that the wings are no limbs, but gills (§ 243). For the completion of this uniformity, which is already exhibited by their structure from two external membranous layers and the currents of blood distributed between them, we have only to show that these gills lie precisely where when present the gills are always found. If we, therefore, commence with the superior groups, we shall find that in them the branchial apertures lie at the anterior part of the neck, and, consequently, upon the ventral side. In some *amphibia*, namely, the *Batrachians*, they are found exactly at the same spot. The same in the fishes. In these they are protected additionally by means of a bony covering which opens posteriorly and beneath, and therefore towards the venter. In the *Mollusca*, the branchiæ lie more or less upon the back, as it is called, but their back is nothing else than the true belly, from the very same reason, that in them also the main nervous mass takes its course along the so called ventral disc.

We thus obtain this general law for the situation of the branchiæ, viz. that they are placed laterally, but inclining to the venter, and thence descend to the venter. The wings have the same position; they originate between the scapula and sternum, consequently upon the external side of the body, and thence descend to the ventral side. In those insects furnished with gills, they also lie at the same part; they always originate at the side where the main stems of the tracheæ lie, and thence rise upwards, either wholly so or partially inclining backwards, as in the larvæ of the *Ephemera* and *Phryganeæ*. As long as the insect dwells in the water, its rudimental wings are true water gills, but so soon as it has quitted the water, they transform themselves into air gills, for in both cases fluids circulate in their vessels, which, doubtlessly, receive oxygen from the air. The beetles exhibit the most perfect conformity, for in the entire hardening of their body the wings also have become horny, and now supplant the place of gill covers. The *Orthoptera* approximate to this structure by their pergamentaceous superior wings, but many *Hemiptera* approach still closer, for in them half the wing is horny. Thence we must remove the wings from the category of limbs, they being merely gills which are occasionally moved in the air, just as the gills are incessantly moved in the water; the insect, therefore, uses them for flight, as the former are used by larvæ for swimming. The endeavour of some naturalists to see arms in the wings, and to indicate in their ribs the arm-bones with their joints and inflexions, cannot therefore be justified. The wings present me with no other resemblance to limbs than that they move and assist the progression of the creature. If this be the sole character of the arm or of the leg, I will then admit that they are either arms or legs, but, otherwise, certainly not.

§ 260

But there is less doubt of the legs being analogous to the extremities; indeed, they have always been considered as such, and the entire leg as well as its individual joints have been thence named. The first question that suggests itself is—Are the legs forms truly analogous to the arms and legs of the vertebrata? To this we may safely reply in the affirmative, for these limbs are similarly situated, and often consist of just as many, and sometimes, indeed, of more divisions. The similarity of situation is shown above, where we have treated of the scapulæ of the vertebra representing the true scapulæ; we have there seen that the legs hang attached to a distinct plate between the vertebra and the sternum, which corresponds with the scapula or the ilium of the pelvis, and that it is from this plate that the majority of muscles come, positive facts which prove an important analogy.

With respect to the division of the limbs, we always find in insects at least five but never more than nine joints; of these, the first and third, with the smallest second, form a joint articulating upwards; the fourth with the third one articulating downwards; the fifth with the fourth one again articulating outwards; the following joints, lastly, sit where they present themselves upon the fifth, and take a straight direction, and also participate in its motion, yet the entire foot can bend downwards and again distend itself. A perfect conformity with the anterior limbs of the superior animals has been supposed to be found in these articulations. It has been endeavoured to explain the first joint, the coxa of entomologists, as the humerus; the second smallest, as the separated olecranon, the analogue of the patella; and the third, the femur of entomologists, as the antibrachium; the fourth joint, the tibia of entomologists, would then be the carpus; the fifth, the metacarpus; and the subsequent ones, the joints of the toes or phalanges. This explanation becomes absolutely necessary, if the legs of insects be considered the analogues of the anterior limbs; but I prefer considering them as the posterior limbs, and, indeed, because those are the least perfect, not only in structure, but also in function. Where, therefore, true limbs first present themselves, there must they be considered as the inferior ones or legs. Both, however, the arm and the leg differ from each other in the angles of their joints, being opposed so that the angle which in the anterior extremities open outwards, on the posterior ones open posteriorly. But these differences are not found in the extremities of insects; the anterior ones are merely distinguished from the posterior ones by their situation, for their corresponding angles all open upon one side. Hence, therefore, the hip is not the thigh, but the hip, and the trochanter and femur form conjunctively the thigh. The hip is the head of the femur, the trochanter its neck, and the femur its tubular body. This division of the femur into three parts is occasioned by the feet being in insects so placed, that they proceed as it were from the lower end, and direct themselves upwards, in which direction they possess considerable power of motion, which was only to be attained by this mode of articulation. If in solitary cases more mobility is required, the trochanter must be divided into several pieces, and this is exemplified in the genus *Pimpla* (§ 83. 2.). If, however, it be the elbow or olecranon, in this instance we must adopt the existence of two successive patellæ, for which there is no analogy; but if a division of the thigh into three parts may be imagined, it is still more possible to conceive its subdivision into four. If now the coxa, trochanter, and femur be the subdivided superior thigh (*femur*), the tibia must necessarily be the lower thigh (tibia). The angles of both joints fully harmonise with this view, in as far as they always open either posteriorly or inferiorly. The first large joint of the tarsus then indicates the metatarsus, as the basal bones are wanting, and the following are then the phalanges. They vary considerably in number; sometimes they are entirely wanting, but never more than four exist.

If after this explanation, which must still appear forced, from the deficiency of the basal bones of the foot, we look around us for an analogy in the higher animals, we find the most perfect conformity in the structure of the foot in birds. In these, also, the basal bones of the foot are deficient, and in them, also, there is a variation in the number (from one to four) of their phalanges. This variation is found in every individual bird, in as far as each of its four toes, commencing inwardly, increase one joint, so that the innermost, generally the posterior one, has one joint, and the three anterior ones, in regular rotation, two, three, and four joints. In insects, on the contrary, this variation is distributed throughout the whole order, so that their one toe of each foot exhibits either one, two, three, or four joints: it is more unusual for some toes to have three and others four joints, as is the case among the beetles, for instance, in the *Heteromera*.

It is hoped that no one, after this comparative view, will take objection to the explanation of the leg joints; he will but find a conformity of insects with birds, to which, in the course of our treatise, we have frequently referred, and he must therefore be necessarily convinced of the correctness of what we have advanced. Birds are in every respect concentrated insects, and insects birds deprived of their internal skeleton.

FOURTH CHAPTER.

OF MUSCULAR MOTION.

§ 261.

The collective motions of animals are produced by a distinct system of organs, which we call muscles. With respect to the structure and arrangement of these organs in insects, we have already stated all that was requisite in the third chapter of the preceding division; we consequently consider as known both the structure of the entire apparatus of motion as also of its individual parts, and proceed at once to the consideration of their functions.

We obtain as the first and chief difference in motions their subdivision into voluntary and spontaneous.

Under the spontaneous motions we consider all those which are not subject to the influence of the will, and which take place in the insect, from the commencement of its life to its death, precisely in the same manner, and which can never be wholly or for any long period interrupted, so long as life is to proceed uninterruptedly. We know, from what has preceded, that all these organs are encompassed by a peculiar muscular layer, which, by means of compression and distension, produce a certain change in the compass of the vegetative organs, which partly contracts them and partly allows them to relapse to their former compass, and that it is only in consequence of this motion that the functions of every individual part and organ can proceed uninterruptedly. These motions are especially visible in the several parts of the nutritive system, where they present themselves as the peristaltic motion of the intestinal canal, as the respiratory motion of the tracheæ, and, lastly, as the pulsations of the heart. All these motions have been described sufficiently in detail in a former chapter, where we have spoken of the functions of the nutrimental system, and where we discerned in them the true cause of the entire process of nutrition, which commences with the reception of the food. The motions of the sexual organs are less apparent, as they become visible only at certain periods. Yet in the male sex there appears to be, from the moment of puberty, an undisturbed production of semen. This semen, by means of a motion not dissimilar to the peristaltic motion of the intestine, arrives in the vesica seminalis, whence it passes during copulation into the female organs. After this act the activity of the female organs commences, which exhibits itself as a peristaltic motion, both in the egg-tube and in the oviduct, and where it terminates in the production of the collective egg germs.

Upon surveying the common expression of all these motions, we recognise nothing further in them than a spontaneous re-action on the part of the organism to external irritation at least, external in reference to the organ which is moved. This irritation consists in the food, for the intestinal canal, the atmospheric air for the tracheæ, the blood for the heart, the semen secreted by the testes for the male organs, and for the female organs the male semen also which is conveyed into them.

§ 262.

The stimulus, however, which determines the action of the voluntary muscles is the will only of the creature; the insect has but to will, and in the same moment its legs are in motion, and it flaps its wings and hastens away. The common property of both, therefore, consists in their requiring a medium of irritation, the differences we find in the phenomena are that this excitement for the involuntary muscles is physical and corporeal, and that for the voluntary is spiritual. Both descriptions of muscles, however, may be affected in the same manner by one and the same excitement, for electricity effects both a contraction of the heart and the same phenomena in the muscles of the limbs.

The first thing we perceive in the activity of any determinate muscle is a contraction of itself. By means of this contraction its compass enlarges, its texture feels more compact and firmer, and the entire muscle is in a state of excitement. How this excitement is produced we know not, but thus much is ascertained, that the nerves exercise great influence upon the motions of the muscles. But the nature of this influence we must leave undetermined whether, as some physiologists suppose, generation produces the necessary power for acting upon the muscles, or whether, with others, it be to be considered as merely the conductor of the excitement from its point of production to the muscle. We are most fully convinced of the importance of the influence which the nerves exercise upon the motion of the muscles when galvanic electricity is applied to a nerve and a muscle standing in connexion with it, or upon its application to the former alone. Alexander von Humboldt, whose great genius first announced itself in a surprising manner in the illustration of this difficult and then insufficiently-laboured field of physiology, has supplied us with some interesting observations, even in reference to insects *. He saw animated contractions in the limbs when the nerves passing to them were touched by the poles of a voltaic pile, re-actions which continued for a space of twenty minutes, and which admitted of being prolonged three times that space upon the nerves being artificially prepared with alkalis and oxidised muriatic acid. He also observed in the thigh of a *Blatta orientalis*, touched with gold and zinc, from two to three successive shocks; indeed "the thigh raised itself up, and held itself some seconds trembling in the air." He further remarks: "Upon galvanising the spinal marrow of a *Blatta orientalis* with silver and well-burnt carbon, I observed its posterior portion move to and fro and press with its feet." Even in the body of a *Vespa crabro*, the head of which had been cut off fourteen hours before, the same admirable observer saw the limbs tremble upon the application of the metallic stimulus.

This trembling of the limbs after the effect of galvanic electricity speaks also in favour of an oscillation of the muscular fibres in insects as well as in the superior animals. This oscillation was formerly denied

* Ueber die gereizte Muskel-und Nervenfaseir. Berlin, 1797. 8vo. vol. 1, p. 273.

in insects, and its deficiency explained from the imperfection of their nervous system. But the muscular and nervous system of insects is as perfect as that of the *Cephalopoda,* and there can be no objection to admit it in the former, since it has been proved to exist in the latter *. We undertand in this oscillation an undulating motion of the fibres, which is seen together with the contraction, and which, for instance, exhibits itself in partially pressed muscles, as a trembling motion which frequently seizes the entire limb. The incessant vibrating motion in many parts of the body of many insects, for instance, the motion of the antennæ in the *Ichneumonodea,* the trembling of the wings in repose, the palpitation of the extremities of the feet in *Chironomus,* &c., appear to be less the result of voluntary muscular motion than of the oscillation peculiar to all perfect muscular substance.

§ 263.

This muscular activity is therefore the foundation of all the motions exercised by insects. These motions may be referred to four principal kinds, namely, walking, jumping, swimming, and flying. But few insects are restricted to the first and most simple of these motions, the majority possess the power of flight in addition; some can only walk and leap, as the flea; some can walk, leap, and fly, as the grasshopper; many can walk, fly, and swim; whereas there are none which possess the power of swimming and flying in conjunction. Many larvæ can only walk and swim, others creep and swim; no perfect insect, however, possesses the last mode of motion exclusively.

If we now investigate the first, most simple, and most universally distributed of these modes of progression, walking, this also may be subdivided into several kinds, from the structure of the motive apparatus. The first, and most simple, which is the progression of maggots, without the help of feet, and is properly merely an advance upon the ventral surface, is a sort of slow creeping. The maggot thus progresses by means of the longitudinal contraction of its body, whereby the distended and, as it were, swollen head is pushed onwards, this then affixes itself by means of the lower and strongly projecting ventral surface of the first abdominal segment, which appears to act something like a sucking cup, and then draws the body as far as possible after it. The posterior extremity, which in general is furnished with distinctly

* K. A. Rudolphi Grundrisz der Physiologie, vol. ii. part i. p. 290, 294.

projecting pedal warts, then likewise attaches itself, and thus the body pushes itself forward by gradual contraction of all the segments, which begins behind. The alternating attachment of the anterior and posterior ends is repeated as long as the maggot is in motion. We find this mode of progression in all the apodal larvæ of the *Diptera*, and they accomplish it better upon uneven, rough surfaces; upon a smooth surface their progress is imperfect, and then frequently the short pedal warts refuse their office. Some of the larvæ of the *Diptera*, whose pedal warts, as well as occasionally the entire body, are covered with short horny spines or bristles, can perform this creeping motion more quickly and securely, but the mechanism is just the same. As an instance of the first kind of creeping we may cite the larva of the blue-flesh fly (*Musca vomitoria*, Pl. I. f. 25.); and, as the representative of the second, the rat-tailed fly, the larva of *Eristalis tenax* (Pl. I. f. 32.).

The motion of larvæ with thoracic feet and one or two pairs of anal prolegs (the geometer caterpillars, Pl. I. f. 35.) next follows. In them the step-like advance is more distinctly performed by means of the attachment of the first and last abdominal segments. The whole of the middle of the body bows itself into an acute arch, so that thereby the anterior and posterior feet are brought closely together; the posterior feet then remain affixed, but the anterior ones are so far pushed forward with the extended body until it lies parallel to the surface; they then also affix themselves, and draw the posterior ones after them by the arching of the body.

The motion of the caterpillars furnished with thoracic, ventral, and anal legs is indeed the same, but it so far differs that all the segments possessing legs participate in the attachment. This attachment is now no longer from behind forwards, but, after the pairs of thoracic feet have advanced and affixed themselves, the ventral feet follow in succession, until the last pair, or the anal prolegs, move forward whilst the ventral feet still further advance. Thus the whole body is producing a constant undulating motion as the raising and attachment of the consecutive series advance in regular progression.

Lastly, the walk of six-legged larvæ very much resembles that of the perfect insect. In both, one of the anterior legs, generally the right one, makes a step which is followed almost simultaneously by the left anterior leg and right intermediate one. Whilst now the right anterior leg is making another step the left intermediate and right posterior ones make the same movement, and thus support it; whereas the left posterior leg makes a simultaneous movement with the left anterior and right intermediate. This contemporaneous motion of the several legs does not generally take place so exactly synchronally, but rapidly in succession, so that all the legs of each side are occupied in a constantly progressive advance. The anterior and posterior legs appear to take the greatest share in this advance, and the intermediate ones seem only to support them. Thus, the anterior and posterior legs of one side and the intermediate of the opposite side appear to progress together. But this successive motion is distinctly visible only in insects walking slowly, but, when running, the interval of time is so short between the movements of each individually that the contemporaneous motion of different legs is scarcely perceptible, and we can only discern an alternating advance and remaining behind of the two legs of one pair as well as the rapidly successive advancing motion of all the legs of one side.

In this motion of the entire leg every joint, each in its particular manner, participates, so that the hips revolve upon their axis, the femur approaches to it, and the angle between the femur and tibia becomes more acute when the leg bends, whereas all lie more in a line when the leg is extended. The anterior legs, however, bend in an opposite direction to the rest, for they are extended when they advance; the others, on the contrary, upon the same movement are bent, whereas, if the posterior ones extend themselves, the anterior pair must necessarily bend. Hence arises the differences in the insertion of the muscles in the hips. The chief object in the anterior pair, namely, is the advancing motion and clinging, but in the posterior pair it is a pushing forward, which is attained by means of extension. Thence the anterior and posterior legs have more extensors than flexors (at least in *Melolontha*, see § 179); whereas the intermediate participate chiefly in the advancing motion of the anterior legs of the opposite side, and have consequently more flexors than extensors: an advance forwards is especially prescribed to them, we therefore find their flexile apparatus more developed than the extensional.

§ 264.

Leaping, also, is in general effected by means of the legs; but, as exceptions, we find peculiar organs and apparatus adapted for the purpose.

When the legs leap it is again the posterior ones which produce the chief motion, and they are then therefore altogether larger, and also some of their joints are more fully developed. This development chiefly affects the thigh; it is not only longer than in the anterior legs but also much thicker, particularly at its lower end when it is very long, or in the middle when it but little exceeds the rest in length. In the first case it is obclavate, and in the last it is either ovate or conical. When, therefore, a leap is to be made, the posterior leg bends at its knee joint as much as possible; usually the femur and tibia then touch each other. The tarsus is also so much bent back that its superior surface touches the tibia, but the entire femur is so depressed that its axis is parallel to the surface upon which the insect rests. In this position, with its anterior legs somewhat withdrawn, the insect stops for some seconds, as it were to collect itself, when it distends all and chiefly the posterior legs with considerable force and rapidity, and by means of which it throws itself from the surface. We therefore perceive that it is chiefly the extensors which produce the leap; they are consequently throughout the whole posterior leg, and particularly the thigh, the strongest and largest, whence it is also that the greater convexity of the thigh is always above, and not beneath.

The line described by the insect in its leap, if, for instance, when winged it should not expand its wings, and by their action supporting the leap continue it by flight, is that of all projectiles, namely, parabolic, which is explained by the gradually increasing gravity of the body, and in consequence its decreasing power of flight. But the extent of the leap depends partly upon the force with which it is made and partly upon the size of the body, but particularly upon the latter, so that we may consider as a law that the larger the body of the leaping insect the less is the extent of its leap, and the flatter is the parabolic line. Both, however, depend upon the flexure and correlative position of the femur and tibia, so that the smaller the bend the shorter and flatter is the leap. Thus every insect regulates both the direction and height of its leap by the position of its feet and the force of their extension.

The power of leaping in insects, from the lightness of their bodies, and the relative strength and size of their muscles in general, is considerable, and doubtlessly greater than in any other animals. No mammal can leap proportionately so high and far as the flea, which of all insects possesses this power most strongly developed, for in one leap it will spring a height exceeding two hundred times the length of its body. The following genera of minute *Coleoptera*, *Hymenoptera*, and *Hemiptera* class themselves with it in this power of leaping, and we place them in the order of the progressive decrease of the function; for instance, *Haltica, Orchestes, Eupelmus, Chalcis,* and other *Pteromalidæ, Jassus, Aphrophora, Chermes, Livia,* &c. The larger *Cicada*, grasshoppers, and locusts do not leap so well. We also find a few minute *Diptera* possessing this power; for instance, many species of the genera *Ceratopagon* and *Tachydromia,* in the first the males especially, but in general their activity is but small, which is probably occasioned by their softer integuments, whence the contraction of the muscles is much less, but which also may be partly ascribed to the less perfect development of the muscles themselves.

The two families of insects in which we detect peculiar organs for leaping are the *Elaters* and the spring-tails (*Podura, Smynthurus,* &c.)

In *Elater*, the articulation of the pro- and meso-thorax gives them the power of leaping, but it can only be accomplished when the insect lies upon its back, whence, should it by any accident be placed in this position, it could not readily recover itself, owing to its short legs and flat back; nature has therefore supplied it with assistance in the mode of the articulation of the two thoracic segments. For this purpose the mesonotum and mesosternum are prolonged into a projecting tubular process, which is fitted to a cavity in the pronotum and prosternum; upon this process we find in the middle of the anterior margin of the mesonotum a hook-shaped joint, bent upwards, adapted to a cavity in the posterior margin of the pronotum. At the base, close to this hook, there are two smooth flat articulations, which likewise fit two flat cavities in the pronotum. The mesosternum has, on the contrary, exactly in its centre, a deep funnel-shaped groove, into which a conical process of the prosternum fits; upon the anterior margin, close to this large groove, there are two smaller cavities for the reception of two flat processes, which lie at the base, close to the conical process of the prosternum. Their connexion is effected by a tubular membrane, which passes from one segment to the other. If now the insect lie upon its back, by means of the muscles which connect the two dorsal plates together it raises its body upwards, so that the pronotum, moving upon the processes of the mesonotum, bends back upon the dorsal surface of the body. It now suddenly contracts with all its force the connecting muscles of the two thoracic segments, as well as the others which run down from the mesonotum to the prosternum, and it thereby strikes violently with the somewhat raised margin of the pronotum, and the base of the elytra against the ground, which throws it upwards, yet, as this blow does not proceed from the centre of the body, but its anterior portion, this part receives the greater impetus, in consequence of which the body turns over in the air, and it consequently falls with its ventral surface to the ground. It retains itself in this position by the sudden clinging of its legs, and so prevents the effects the concussion would otherwise have of throwing it up again. The dagger-shaped process of the prosternum, which fits into the funnel-shaped groove of the mesosternum, has no other purpose in this motion than to regulate and preserve the direction of the prothorax during the contraction, without participating in the least in the blow.

In the spring-tails a furcate process originates at the ventral plate of the penultimate and ante-penultimate abdominal segments, which in repose lies extended towards the head along the belly, and reaches to about the posterior legs. By the insect striking this process rapidly and with force against the surface it is enabled frequently to make an extensive leap. During this leap the fork is directed posteriorly, but as soon as it again touches the ground it again bends forward. In *Smynthurus*, Lat., De Geer found, besides, a conical process at the sternum, whence the creature projected two long flexible filaments when it wished to affix itself *. Probably these filaments also participate in producing the leap, which is much greater in them than in *Podura*.

§ 265.

In swimming, insects are assisted either by their legs or other organs, which, in conjunction with other functions, exercise also that of fins. Among these organs may be classed the branchial leaves of the larvæ which live in water, of which we have before noticed their incessant motion backwards and forwards, whereby the larva moves and breathes. This is however the case only in those larvæ which have lateral branchial leaves; a portion of the rest, for instance the larvæ of the *Agrions*, move by the serpentine motion of their abdomen, and the leaves at their caudal extremity, which act as a rudder. Thus also do the larvæ and pupæ of the gnats move. Others, again, swim like the leech, by a serpentining of the abdomen; which motion sometimes describes an undulating line, and sometimes, as in the red larva of

* Mémoires, tom. vii. p. 20, Pl. III. f. 7, 8.

Chironomus plumosus, it is produced by means of a lateral convolution of the anterior portion of the body, whereby its posterior end strikes forwards.

But all perfect insects, as well as the larvæ of those with an imperfect metamorphosis, which live in water, swim by means of their legs. Among the *Coleoptera* it is the family of *Hydrocantharides* which possess this faculty, for example, *Hydrophilus, Elophorus*, and the whirlwigs (*Gyrinus*); other insects which live in water, as many *Curculios, Helodes Phellandrii, Donacia Zosteræ, Elmis, Potamophilus, Parnus*, cannot swim, but creep about, clinging to different objects. In the other orders we find but a single family of the *Hemiptera* whose limbs are adapted to swim, namely, the genera *Notonecta, Sigara, Naucoris*, and also in an imperfect degree the genus *Nepa*. They all are, like the majority of insects, from the quantity of air contained in their bodies, as well as from the lightness of their constituents, of less specific gravity than water, and consequently float upon the surface without any exertion of their own, when they contract their limbs. The respiration of atmospheric air, to which all these genera are restricted, is thereby facilitated to them. It is thence also that many water-beetles cannot quit the surface when they have remained for some time in the air; the air then exercises so great an attraction upon them that their swimming power is not able to counteract it, and they consequently remain in this condition until they succeed in overcoming it. This may be observed in any *Gyrinus*; it first whirls itself about upon the surface before it can dive. Other beetles have so little specific gravity, that even with all their endeavours they cannot get beneath the water when any accident has removed them from their places of concealment to the surface. This is the case in many of the smaller *Hydrophili*, for instance, in *Hydrophilus orbicularis* and the *Elophori*. These, therefore, never swim, but creep about, clinging to objects beneath the water; if they quit their hold they immediately rise to the surface, and struggle here until they meet with a reed, that serves them as a ladder to descend by. Even the powerful *Hydrophilus piceus* swims very awkwardly, and has great difficulty to continue beneath the water.

The great *Dytici* are the best swimmers, namely, *Dyticus dispar*, or *Rœselii*. The whole form of its body is flat compared with its size, much narrowed anteriorly, and laterally has a sharp edge, which gradually increases in bulk to where its posterior legs are placed, and then again narrowing by degrees, contributes very considerably to facilitate its swimming. The legs also, particularly the posterior ones, are flat, compressed, and either upon one or upon both edges thickly furnished with long setæ or bristles. The first joint of the tarsus has a very free motion, and can so place itself that either the sharp edge or broad flat surface of the entire foot is brought forward and opposed to the pressure of the water. In the first case the motion finds little resistance, and easily cuts through the water, and in the last the pressure of the water acts as a resisting medium against the broad flat surface of the foot, which is increased to about double its width by means of the long fringes, and thus the beetle is enabled to advance. In addition to the repulsion which the rowing of the insect occasions we may also add the pressure exercised by the water itself, occasioned by the specific gravity of the insect. Were the beetle placed horizontally in the water it would thereby be raised upwards, but its posture is not horizontal, its axis forming an acute angle with the surface, and indeed the head is the deepest situated. By means of this position its swimming is much facilitated, as the pressure of the water from beneath, acting against an oblique surface, pushes both sidewards and upwards. The rowing of the beetle therefore has only to overcome that portion of the pressure which urges upwards, and then, without further exertion on its part, the beetle swims forward. If, therefore, it applies more power than is requisite for its swimming direct, it necessarily descends obliquely, and we consequently always observe it to dive in this direction, and never perpendicularly. But its own muscular activity is, however, the chief cause of its motion in water. This muscular motion is exercised principally by the posterior legs, which bend forwards as far as possible, when the narrow edge is directed anteriorly. In their distending motion all the joints bend, but particularly those of the foot, so that their broad surface is opposed to the pressure of the water; at the same time, but probably merely mechanically, by this pressure the stiff marginal fringe is expanded, so that by lying closely contiguous it forms as it were the face of the oar which the insect uses in its posterior legs. The violent extension of the leg to where it meets its opponent of the opposite side, behind the body, then propels it, and a repeated rowing continues the commenced motion.

The genera *Notonecta, Naucoris,* and *Sigara* swim in the same manner, but with this essential difference, that in them the ventral surface is directed upwards, and the keel-shaped back is directed downwards.

§ 266.

Flight, the last of the voluntary motions to be considered by us, is the most difficult to explain of all, as not only the muscles which are attached to the organs of flight, but all those found within the thorax, participate in producing it, and therefore it is not merely the wings during flight but the entire thorax, by means of the motion according to its several plates, which are detected as contributing to effect it. We can consequently distinguish two chief motions which are visible during the flight of an insect, namely, the individual motion of the wings themselves, and the contemporaneous motion of the thorax. The above described respiratory motion of the thorax during flight is identical with the latter, so that the same motion which effects the in- and expiration of the air from the thorax produces also the flapping of the wings.

The motion peculiar to the wings consists in their expansion and bending backwards; the expansion is produced by the extensors and the bending back by the flexors. From § 178 we know that the extensors are by far the largest of these muscles, and that they vary in compass according to the varying size of the anterior and posterior wings. By the contraction of an extensor, therefore, the wing is expanded, and by the continuance of this contraction it is retained in this position. In those orders with four membranous wings or coriaceous anterior wings we find no difference in the position of the wings during expansion. The anterior ones lie in front of the posterior ones, and in one plane with them, sometimes separate and sometimes connected with them by means of a peculiar apparatus. In the beetles, however, in which the anterior wings are transformed to hard elytra, their position is quite different. Sometimes these elytra are not at all expanded during flight, and this is the case in the genus *Cetonia* and in the earwig. In other instances the elytra are expanded it is true, but in a very different direction, namely, perpendicularly upwards; whereas the wings are extended horizontally, as we observe in *Necrophorus*, in the genus *Hister*, and in many *Staphylini*. In many other beetles, lastly, they lie in the same direction with the wings, yet not in general upon the same plane, but a little higher. In all these cases, therefore, the elytra do not participate in the blow of the wing, but they retain the same position and situation during the whole flight.

The remaining muscles of the thorax, but particularly those of the two segments upon which the wings are placed, and which above

(§ 176) we have called the dorsal-, lateral dorsal-, lateral- and furcate dorsal-muscles, are those which act in common for producing the respiratory and volatile motions, and therefore must be examined here more closely as to their effects. One of them, the straight dorsal muscle, which is expanded between the meso- and meta-phragma, acts parallely to the axis of the body; it arches by its contraction those plates within which it lies, and thereby produces the inflexion of the wing. In insects with connate thoracic segments it is assisted in this function by the oblique, lateral dorsal muscles, which likewise sit quite alone upon the dorsal plate and its processes, particularly the metaphragma. By means of it, therefore, the blow downwards of the wing is produced, and as it also arches the entire thorax, and likewise also distends it, it promotes the inspiration of air. In opposition to them the lateral and furcate dorsal muscles act. By their contraction they approximate the dorsal plate to the sternum, draw it down to the latter, and thereby effect the raising of the wing. They also contract the cavity of the thorax, and thereby promote the expiration of the air. By the alternating contraction of these muscles, opposed in their effects, the flapping of the wing of insects is produced. It is therefore the result of a distension and contraction of the thorax, in which naturally its lateral radiations, the wings, must immediately participate; this is another reason for considering the wings as mere continuations of the membrane of the thorax, which, only in consequence of their change of function occasioned by internal respiration, have received their peculiar extensor and flexor muscles.

If after this very general survey of the mode of flight in insects we look around us for some peculiar divarications of individual orders, we shall find it expressed, especially in the position of the entire body, as well as of its individual limbs. With respect, in the first place, to taking flight, we shall even find some differences in the manner in which this is executed. Those that likewise possess the power of leaping, namely, the *Grylli* and *Cicada*, do it most readily. They raise themselves by a leap from the ground so soon as they may be urged to take flight, then expand their wings already floating in the air, and proceed in the direction already given by the leap. Yet are these insects not good and continuous fliers, with the exception of the migratory locust, but the majority return again to the ground at a very short distance from their place of starting. With the same ease do all other flying insects take wing which bear their wings always expanded, for instance, many flies, butterflies, *Hymenoptera*, and many *Libellulæ*. In the latter, also, they remain in the same position during repose that they are found in during flight; the insect, therefore, does not require to expand and direct them. Thence arises the facility with which these creatures raise themselves into the air; thence, also, as well as from their lightness of structure and small size, the facility of their motion in the air, and the long continuance of their flight. Beetles, and especially the largest ones, have the greatest difficulties to overcome in taking flight. We observe in them distinctly the great exertion not only of the muscles of flight, but all the other organs of the body also labour to support their flight; and the cockchafer in particular, which, doubtlessly, every one of our readers has observed in this occupation, gives us a distinct idea of the great labour these little creatures are obliged to apply to the execution of one of their most ordinary occupations. We see it at first, as it were conscious of its increasing labour, slowly raise itself, expand its antennæ, and, in the endeavour to free itself of a burdensome and hindering load, adapt itself to its purposed course by violent respiratory motions of its abdomen. It has hardly cast this burden from it, when it forthwith commences with considerably increased activity its pedestrian journey, seeking for some elevated spot whence it may commence its aërial expedition; and if it do not speedily find one, its anxiety to fly urges it to endeavour from the plain surface, but this impatience is frequently punished by the failure of its exertions. But, having reached an elevated spot, it raises its elytra during the violent backward and forward bending of its head, then suddenly expands them as well as the wings, and at the same moment makes its first elevating blow, after having, at the same time, compressed the whole abdominal cavity by means of the flexible dorsal integument, and thus driven all the air out of it. Thus, during flight, respiration takes place only in the thorax, and the abdomen resumes that function only when the creature alights after its completed course. But then its first motions are very violent and powerful.

The position of the body during flight in the air in this and other beetles is not the usual, viz. the horizontal, but inclined obliquely towards the horizon, in which inclination the head takes the more elevated, and the anal extremity the lower place. The cause of this oblique position I think may be found in the preponderance of the abdomen, particularly during puberty, owing to the turgidity of the internal genitalia, over the smaller and lighter thorax and head; at least in those insects in which no such preponderance of the abdomen can occur, partly from its smallness, as in the flies, and partly on account of its thinness and lightness, as in the *Libellulæ,* we observe no such obliquity during flight: whereas in other insects in which the abdomen itself is heavier, for instance, in the *Bombi* and wasps, we observe a similar posture, yet its greater weight does not incline the thorax from its horizontal position, but the abdomen alone, which is affixed at one small spot, hangs down. In other insects, again, in which the very long and also heavy abdomen forms by far the most considerable part, it is placed in such a position as not to incline the thorax during flight considerably from its horizontal position. Among these is found the genus *Fœnus;* which raises, during flight, the abdomen with, in the larger species, its very long ovipositor, perpendicularly upwards, or even sometimes bends it forwards, so that the chief pressure is directed towards the centre of the body. But there requires less strength to advance the thus pressing abdomen, than if, stretched directly out, it drew the entire body downwards, and daily experience can teach us how much more easy it is to balance a long stick upon the flat hand or the tip of a finger, than to carry it with an extended arm. Most external organs adapt themselves to the same law, for the legs are in general contracted to the body, and but very rarely stretched out posteriorly. But the antennæ appear always to maintain their extended position during flight, but which position is transformed in the *Cerambycidæ,* furnished with long antennæ, into a gentle curvature inclining outwards and backwards. In this position they contribute much to maintain an equilibrium with the abdomen, that it may not sink still lower.

This inclining posture of the whole body is, however, of no consequence to the execution of flight, but the likewise oblique attachment of the wings to the thorax is especially so. This oblique attachment is distinctly seen if a line be drawn through the direction of their affixion, and this is conceived to lie in the plane of the axis of the thorax when both are found to cut closely behind the thorax, and even sometimes upon its posterior limits *. The wings consequently during flight do not move perpendicularly to the body, but on an oblique plane; and are also acted obliquely upon by the pressure of the air, so that upon rising they appear bent upon the posterior margin, and upon sinking they also appear raised. This difference of posture is occasioned

* See Plates IX.—XIV.

by the irregularity of the nervures, for upon the anterior margin stiff, firm and inflexible nervures are found, but upon the posterior margin there are none, and in its vicinity there are only soft, thin and flexible ones. Also the oblique position of the wing to the direct plane of its motion effects the entire progression in the air ; so that by the pressure of the air going obliquely against the surfaces of the wing, it acts like any other power upon an oblique plane which admits of being divided into two so called parallelograms of force, one of which is lost, but the other acts perpendicularly, yet somewhat less effectually than the original force. An equal force, which, like that of the stroke of the wing, presses downwards, presses also upwards in the stroke, which, likewise, may be divided into two forces, one of which is lost. We thereby acquire, therefore, two moving forces, both of which, it is true, stand perpendicularly to the wings, but yet cut each other in their direction, as the posture of the wing is different in its rising and sinking. These two moving forces consequently form, when we add to them their parallels, a third parallelogram of forces, and the diagonal of this parallelogram, drawn through the angles where both forces meet in the horizontal plane fixed by the centre of gravity, describes the line of flight.

Had not nature concurred in all these adaptations, had, for instance, the surfaces of the wings stood at right angles to the plane of motion of the wings, progression in the air could not have taken place, but the insect must necessarily have stopped short in the air upon the very first stroke of its wings, as the pressure from above and beneath would have been opposed in a linear direction, and, in consequence of the rapidity of the motion of the wings, would have neutralised each other. But this is actually the case in some volatile motions, namely, in hovering, or the stopping at one spot in the air. The insect can give voluntarily such a posture to the wings, that the propelling forces oppose each other in a linear direction, and the consequence of which is, that it remains hovering at one spot in the air. But it requires much exertion, whence it is that the strokes of the wings follow each other more rapidly, and the buzz during it is shriller and louder. We particularly observe this capacity of hovering in the *Diptera,* which, in consequence of the narrowness of the base of their wings, possess the power of moving the wings on all sides, and among them again we observe it most perfect in the *Bombylii, Anthracodea,* and *Syrphodea,* likewise in many true genera of flies, viz. *Miltogramma.* This order also is distinguished from the rest with respect to their flying apparatus, by being deficient in posterior wings, instead of which they possess balancers. We have before (§ 168) expressed our opinion of their supplying the place of posterior wings; modern experiments have confirmed this opinion in as far as they anatomically agree with the wings, namely, in consisting of a simple but somewhat more compact neurated membrane, which, as well as the membrane of the wing, is a continuation of the epidermis, and forms a closed, and, in these, a smaller pedunculated bag. Into this peduncle a tolerably thick trachea passes, but which, however, is not more than half as thick as the foot-stalk, and which, as soon as it reaches the knob, ramifies within it in many branches. With respect to the function of this poiser during flight, Schelver * has already proved that they are essential to it. He cut off the balancers of several *Diptera;* they indeed still flew, but only short distances. I have convinced myself of the correctness of his assertions by many experiments: every fly which was deprived of these organs had lost the art of flight; they indeed flew a distance of from one to two feet, but then rolled over, and fell to the ground. If then they were urged, they made a fresh endeavour to fly, but which again failed in the same way, as well as in all subsequent ones. To convince myself if any other mutilation of the body would affect the capacity of flight, I now likewise cut off the scales, but the result did not justify my expectations. *Eristalis tenax* flew with the same rapidity and skill after as before the operation, the same as if it had suffered no loss. Schelver, indeed †, gives a different result to the same experiment, but he errs; I have frequently repeated my experiment, and always with the same consequence. The results to the capacity of flight from the loss of the legs are also not correct, for a *Tipula*, from which I removed every leg but one, flew as well as before the experiment, but the loss of all the legs appears to injure that operation.

§ 267.

Having thus explained the different motions of insects, we still have to make a few general observations upon the force and duration of muscular motion. Both attain a degree in insects which remain to be

* Beobacktungen über den Flugund das Jesumme einiger Zweiflugligen Insekten. Wiedemann's Archiv. vol. ii. Pt. 2, p. 212.

† Ib. No. 4.

discovered in other animals, and is probably nowhere surpassed. I think I discover the cause of this, for such small and insignificant creatures, remarkable phenomenon in the preponderance of their respiration; for wherever we meet with the function of respiration, and especially of the respiration of atmospheric air, preponderating, we find in conjunction the faculty of powerful and continuous muscular activity. Thus in this view also there is an affinity between insects and birds, as both classes exhibit the high importance of respiration to the entire organisation, and, as a consequence, the most powerful muscular activity.

The muscular power exhibits itself likewise in each of the four several modes of motion. The rapidity with which certain insects progress on foot is admirable, and presents itself in a very distinguished degree in the last family of the beetles, namely, the *Carabodea*. Their allies also, the *Staphylini*, display very rapid motions both in running and in flight, but especially in the former. Even among the most minute insects do we find rapid runners, for instance, among the flies, in which the genus *Tachydromia* of the family *Empidodea* derive their name from it. But it is not solely in the rapidity of their motions that we recognise the muscular power of insects, but also in their faculty of coursing about upon perpendicular walls and vibrating surfaces. This faculty they especially owe to their sharp claws, and to the clinging organs placed at the extremity of their foot. Many of these, namely, the *pulvilli* of the bees, wasps, and flies, are true sucking cups, which at first lay themselves flatly upon the object, and then by their concavity and rarefaction of the air beneath them clutch closely to it. But yet considerable muscular power is requisite for an animal to continue hanging with its whole body suspended by its own limbs by voluntary muscular force.

Still more admirable is the rapidity with which many insects that prepare for themselves cavities and subterranean dwellings are able to execute them. This rapidity also presumes great muscular power, and especially a great duration of the force. How rapidly, for instance, does not the larva of the ant-lion dig its pit, which can receive within its cavity at least a dozen insects of its own size! How speedily do not the fossorial wasps dig a hole for the reception of their eggs after they have first placed in it a caterpillar as large as themselves, and frequently weighing at least half as much again; and yet the common *Ammophila sabulosa* carries off its prey with the greatest facility! Who has not observed an ant-hill, and admired the industry with which these little creatures labour! Whom has the fact escaped that two or three pismires, or, according to the size of their prey, five or six of them, convey away a large caterpillar, which has by accident come within the limits of their fortifications, and bear it, notwithstanding its violent resistance, to their purposed spot! In such undertakings they frequently work in opposition to each other, and, under such circumstances, the colossus remains for a time immoveable, retained by equal powers acting in opposition to each other. Lastly, the burying-beetle, how quickly does it not bury its corpse! From four to six of them are sufficient to bury a moth several inches deep in the course of a quarter of an hour, and even a single beetle would execute this certainly monstrous labour in the course of an hour. Let us only reflect upon the capability of even a dozen men burying a whale in one hour; and yet the proportions with respect to size are more favourable to the execution of the project in this last case than in the former.

But the force and duration of muscular motion exhibits itself most conspicuously during flight. We admire the continuous flight of the migratory bird and the rapidity of the swallow, and yet the most common insects exhibit the same phenomena. The well-known dung-beetle flies in warm summer evenings with a rapidity which yields in nothing to the swallow, although it is not one-tenth part its size. The *Œstri*, *Tabani*, and flies which pursue cattle and horses with a voracious thirst for blood, excite by the humming noise of their flight the poor objects of their rapacity to escape by resorting to their quickness, but they do not thereby secure themselves from their persecutors, who, quicker than them, at last discover a suitable place of their body for the exercise of their parasitic occupation. We may frequently convince ourselves of their rapidity when riding upon a horse about to be attacked by an *Œstrus*, upon spurring it to its full speed, for it constantly remains in the vicinity of the animal, at about two or three inches distance from its body, and even at last, when convinced of the impossibility of executing its purpose, it flies away still faster than the rider, preceding him with incredible rapidity upon his own path. The most remarkable instance of this kind is possibly that related by an English traveller *, who was travelling with a steam-carriage that was

* In the Philosophical Magazine.

propelled at the rate of twenty miles an hour. This carriage was accompanied a considerable distance by a humble-bee (*Bombus subinterruptus*, Kirby), not merely with the same rapidity, but even with greater, as it not unfrequently flew to and fro about the carriage, or described zig-zag lines in its flight, in addition to which the wind was against them. Leeuwenhoek relates an instance in which a swallow in a long avenue pursued a *Libellula* of the genus *Agrion* for the space of an hour without catching it *; the little creature continued at least six feet below its pursuer, and at last escaped it. These few instances will convince us of the muscular power of insects. A detailed description of their different modes of flight would lead us too far; we consequently refer to Kirby and Spence's Introduction to Entomology: in the 23rd letter in the second volume will be found an interesting collection of such instances.

We have as yet cited no convincing instances of the duration of muscular motion, but they are in fact of rarer occurrence than those which exhibit the power and rapidity of flight. Certain phenonena, however, namely, the migrations which certain insects occasionally undertake, prove that even in this view the power of insects is not insignificant. As a wandering insect, the migratory locust is most celebrated. We do not here speak of the devastations that this terrible creature frequently produces, but merely of its flight. This is indeed but slow and heavy, for the locust flies but a short space above the ground, unless opposing objects intervene and cause it to rise higher, yet still of not shorter duration. In their migrations, which, in 1774, devastated Siebenburgen and Hungary, and which even advanced as far as Vienna, swarms were observed several hundred fathoms thick, one of which occupied four hours in passing a high tower, and thus long at least must every individual have flown. The intelligence of an American newspaper is still more striking †, which relates that the ship Georgia, upon its voyage from Lisbon to Havannah, upon the 21st of November, was in the vicinity of the Canary Islands, but yet 200 English miles from land. A calm came on, which was succeeded by a light wind from the north-east. Now for the space of a whole hour locusts fell upon the ship and the surrounding sea, which covered its entire surface, yet they were not at all fatigued, but jumped and endeavoured to escape their pursuers. If we even conclude that these

* Kirby and Spence, Introd. vol. ii.

† Ib. vol. i.

locusts were conveyed even a considerable distance from land by high winds, yet must a great portion of their journey be ascribed to their own continuous muscular power, for otherwise they would have fallen much earlier into the sea, but as the abated wind no longer supported their flight like the violent one, their strength decreased and they fell down. Other instances are found of the continued voyages of *Libellulæ* to considerable distances. We have before mentioned the rapidity of their flight in a case observed by Leuwenhoek. Indeed these little creatures do not more excite our astonishment by the lightness and rapidity with which they fly, than by the duration of their motion. They incessantly swarm and hover about meadows, brooks and ponds, their favourite places of resort, without ever reposing any length of time; and as if they wished to excite still more the rage of their pursuer by their playful motions, they hover in front of him the moment he thinks to capture them, and yet do not allow him to attain his object. Several instances are on record of their migrating in vast multitudes. Kirby and Spence in their classical work * have cited several, and I myself have twice been an eye-witness of such migrations. They proceeded rather low, in innumerable multitudes, in an undulating body over the heads of their astonished spectators, without the least apparent cause of their collection or migration offering. On the evening of the day they dispersed, and on the following day, all the streets of the town over which the swarm passed were animated by the returning members of this numerous society.

We will here conclude our description of the motions of insects. Much that was highly interesting and much that might be still said upon these subjects from the natural history of these creatures, we have necessarily left unnoticed, as our object was but to state the chief results and most general phenomena. The very interesting work of Kirby and Spence contains such a multitude of these details, related in a charming style, that, had we wished to have been more copious, we could but have repeated their animated description. We must consequently refer our readers for what relates to the external relations of insects entirely to the work of those learned and well-informed gentlemen.

* Introduction, vol. ii. p. 12.

FIFTH CHAPTER.

OF THE SOUNDS AND NOISES EMITTED BY CERTAIN INSECTS.

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§ 268.

The investigation into the sounds emitted by insects during their motions does not inappropriately follow the description of these several motions, for the causes of these sounds appear to exist in these motions themselves. It was formerly supposed that the majority of these sounds were produced by the motion of the wings alone, without taking the least consideration of the apertures that are found upon the body of the insect, and through which, upon every respiration, air streams in and out. The mechanical friction of the wings together, or of the latter against the thighs, were considered as the causes of the loud cries of many grasshoppers and locusts, and also the vibration of the air caused by the strokes of the wings was considered as all that produced the hum in the flight of bees, wasps, and flies. If even the friction of portions of the integument together, for instance, of the pronotum upon the face of the mesonotum in many beetles is apparently the sole cause of the noises emitted by them, yet in the majority of other instances a mere mechanical friction is not sufficient to produce so strong and shrill a tone, for it is doubtlessly frequently the air streaming out of the stigma, and thereby putting vibratory bodies in motion, that produces these sounds: and just as easily as this is considered to be the cause of the noises emitted by the *Cicada*, may it also be proved to be that of the humming of the bees, wasps and flies. An experiment of this description is the theme of the present chapter: we therefore pursue the path, in our investigation of this subject, which nature seems to have traced, and shall commence with the sounds produced by mere mechanical friction, which will be followed by the hum heard during flight, and we shall conclude with such noises as are produced by peculiar organs.

§ 269.

By the friction of parts of the integument together, all those sounds are produced which we observe in beetles of the different families. The best known family in this respect, and which also produce the loudest sounds of this description, are the capricorn beetles. Almost all the species of this very extensive group emit, upon being touched, a tolerably loud, chirping, uniform sound, varying only in its intensity, and which is produced by the friction of the posterior margin of the pronotum upon the prolonged anterior portion of the mesonotum which projects somewhat into the cavity of the prothorax. Both the surfaces are very smooth, but not otherwise distinguished, so that the mere mechanical friction of the one against the other must be regarded as the sole cause of the sound produced. Indeed the same sound may be produced after the death of the creature, by rubbing the two parts together. Whether this sound have any determinate purpose, for instance, attraction, cannot be decided with certainty, but thus much is the case, that both sexes equally produce it, and, particularly, only in such situations as affect their free and voluntary motion. I have never found that any *Cerambyx* made it, unless disturbed or touched, and precisely when those restraints were most violent the sound was then loudest; for instance, when impaled by a pin, and he endeavoured with all his limbs to free himself from his thraldom. The same is the case in all other insects which produce sounds by the same means. We also detect similar sounds in the dung-beetles, viz. in *Geotrupes stercorarius, vernalis, Copris lunaris,* and others of the family of *Lamellicorns*, as in *Trox sabulosus*. The only difference is, that these beetles produce it by rubbing the abdomen against the elytra. Of this we may easily convince ourselves by taking such a beetle between our fingers, and turning its belly upwards; we then distinctly see the up and down motion of the abdomen. The sound is also prevented if a pin be introduced between the abdomen and the elytra, so that the former cannot touch the latter. The burying beetle (*Necrophorus vespillo*), the lily beetle (*Lema merdigera,* and another species of this genus), even a swimming beetle (*Hygrobia Hermanni,*) and many others, produce similar sounds in the same manner. Indeed, according to Latreille*, the *Pimelias* emit similar sounds by rubbing

* Hist. Nat. tom. x. p. 264.

either their legs together or against the body. Bugs also (viz. *Cimex* [*Reduvius*] *subapterus*, De Geer *) and the *Mutillæ* (*M. Europœa*) produce such sounds upon being touched †, the former by the motion of its head, probably, therefore, by rubbing the occiput against the margin of the prothorax.

Hence, consequently, all these sounds are doubtlessly expressions of pain or displeasure, precisely as many of the higher animals only under similar circumstances make their voices heard, but have otherwise no use for them.

§ 270.

The second kind of sounds which insects produce are those which we hear during their flight, and especially by the *Hymenoptera* and *Diptera*, but also by the beetles, *Orthoptera*, and bugs. That these sounds are not produced solely by the flapping of the wings, we may easily convince ourselves, for if the wings be cut off, the fly produces its former sound, although somewhat weaker. Hence, therefore, the question occurs, Which is truly the organ of sound? The reply will readily suggest itself when we shall have first more closely investigated the conditions under which the noise originates. If any fly, for instance, the very common *Eristalis tenax*, be held by the legs, and the wings left free, it will endeavour by the violent motion of its wings to emancipate itself, and emits a loud buzzing sound. If the wings be half cut off, the vibration of the wings continues, and the sound becomes shriller; but if they be quite cut off, we observe their roots still in motion, and the sound becomes a little shriller, but also weaker than before. Thus, therefore, the presence of the wings has no influence upon the production of the sound, and at most but a trifling one in causing a change of tone. But there are other organs besides the wings upon the thorax which might be the causes of the sound, namely, the scales behind the wings, the poisers, and the spiracles which lie between the meso- and metathorax. If the scales be removed, the sound is not at all affected; it remains unchanged as long as the wings can vibrate. If the poisers, lastly, be cut off, this produces no difference of sound, and a fly deprived of all the external organs which tend to assist the flight, can, so long as the mere stumps of the wings remain to vibrate, produce a distinct but somewhat weaker and higher sound. The spiracle alone remains, therefore, to be considered as the cause and

* Mémoires, tom. iii. p. 190. † Kirby and Spence, vol. i.

instrument of the sound. To convince myself of this, I closed both the spiracles with gum, and then urged the fly to vibrate its wings, but it was scarcely to be induced to do so, yet when it occasionally tried it, no sound was produced; only after an interval, when the spiracle was freed from its stoppage by means of violent volatile motions, was the sound renewed. There is no doubt, therefore, that the air streaming from the spiracle is the cause of the sound, and that a body which by this draught of air is brought into vibration, must necessarily stand in connexion with the spiracle. I therefore cut out one of the spiracles, opened it carefully, separating the angles of the incision, and soon found what I sought, namely, the vibrating body, and not one only, but very many. That lip of the spiracle, namely, which lies posteriorly, and also somewhat inwardly, and which is lengthened upon its inner side, that is turned towards the commencement of the trachea, is formed into a small flat half-moon-shaped plate; upon this plate there are nine parallel very delicate horny leaves, the superior free sharp edges of which are bent somewhat downwards, so that the anterior one inclines a little over the rest. They are also higher towards the trachea, and towards the margin of the spiracle lower, and the central one is the largest, from which on each side they gradually become smaller and lower. Upon the air, which is driven with force out of the trachea, touching these laminæ, they are made to vibrate and sound precisely in the same manner as the vibrating of the glottis of the larynx. Thus, consequently, there is no insignificant analogy between the spiracles and the larynx, particularly of birds. To convince myself that it was merely the posterior spiracles of the thorax which emitted sounds, I likewise inspected the anterior ones, but found in them not the least trace of the just-described laminæ at the inner side of the posterior lip*.

We can now comprehend the reason of the change of tone on the loss of the wings. The vibrations of the contracting muscles can no longer be so intense in consequence of the loss of the organs made to vibrate, and in consequence of the weaker contractility, the air cannot be expired with the same degree of force. The tone is therefore weaker than when the wings were present; also, as Chabrier supposes, some air may escape through the open trachea of the wings which are cut off.

* Chabrier, in his Essai sur le Vol des Insectes, p. 45, &c., likewise explains the hum of insects as produced by the air streaming out of the thorax during flight: he also speaks of laminæ which lie at the aperture of the spiracle; but I cannot recognise from his description whether he saw these or others.

Whether the structure and situation of these vibrating bodies be the same in all buzzing insects, I cannot for the present decide. Another work, devoted exclusively to this subject, will impart all the details that I may discover; but for the present, thus much is determined. Delicate laminæ are found at the entrance of the posterior spiracles of the thorax, which are set in vibration by the streaming in and out of air, and which are the cause of the humming noises produced by bees and flies during their flight. In the buzzing-beetles, for instance, the cockchafer, I could not discover such laminæ near the aperture of the thoracic spiracles, and in these, therefore, the outward streaming air must be the sole cause of the tone; physics teach us also that a stream of air made to pass through any aperture with violence will produce a sound. In fact, the tone of the humming-beetles is weaker, proportionately, than that of the much smaller *Diptera*, and we may thence trace the cause of it to the deficiency of the vibratory laminæ.

§ 271.

The sounds that are produced by peculiar organs solely adapted to the purpose are found only in two orders, namely, in the *Orthoptera* and in the *Hemiptera*; in both cases they are in general peculiar to the male sex alone, and the females are then dumb. The male *Orthoptera*, in which we observe such organs of sound, bear them always at the base of the superior wings. Among these the genus *Acheta* and *Locusta* possess them. In both it is a round, flat, shining, very thin plate, seated at the base of the wing, immediately behind the large main nervures, which appear to produce the tone. The following is doubtlessly its mechanism. By means of the violent volatile motions which agitate the whole body, but during which the wings are not expanded, the air is driven out of the spiracles, and especially out of the central ones of the thorax, and thus bounds against the inflected external margin of the superior wing, which is pressed closely to the thorax. It must necessarily, therefore, to find an exit, rise beneath the wing, in order to escape from it beneath the posterior margin. Pursuing this path, it precisely strikes upon the just described elastic field of the superior wing, which vibrates through the pressure of the air, and consequently emits the sound. To corroborate this view I have cut off the wings of several locusts, but they never subsequently made any noise. It is here, therefore, the wings or the vibration of the elastic base of the wings, which produces the sound upon the motion of the wings. The shrill tones of the grasshoppers, locusts, and field crickets are therefore tolerably alike, varying merely in intensity. The tone of the cricket is probably the weakest, and that of the grasshopper perhaps the strongest. According to Kirby and Spence * the mole cricket is said to produce a dull tone resembling that of the goat-sucker, but I never heard it; and in the insect itself I have not been able to find anything analogous to a vocal organ.

In the remaining *Orthoptera* which possess a voice, namely, in the genus *Gryllus*, Fab. (*Acrydium*, Lat.), it is equally found in both sexes. The organs which produce it lie at the base of the abdomen, upon its first segment, one on each side, immediately behind the first abdominal spiracle. Each presents itself as a half moon-shaped cavity, closed at its base by a very delicate membrane, which is sometimes wholly free (*Gryllus stridulus*), and at others half covered by a triangular plate, projecting from the anterior margin. Close to the anterior margin of this fine membrane there is a small, brown, horny spot, upon which internally a delicate muscle is inserted, that runs over to a projection of the external horny plate which lies over and in front of the margins of the spiracle. By means of this small muscle it is made to vibrate, and consequently sound, when the whole body is agitated by the volatile motions. The sound thus produced is increased by a large air bladder, resembling a distended trachea, lying beneath the fine membrane, which re-echoes the sound like a sounding-board. But the tone thus produced is, however, weak, but it is loudest in the thence named *Gryllus stridulus*, and possesses no other differences than in intensity and weakness. Formerly it was thought that the friction of the posterior thighs against the wings was the sole cause of the chirping of these creatures, an opinion founded upon the contemporaneous motion of the wings and hind legs. Indeed, such a friction of the hinder femur against the inflected margin of the superior wing appears to participate in the mechanism of the sound, for even after the death of the creature I could produce a similar but much weaker sound by rubbing those parts together. Thus the allied genus *Acrydium*, F., (*Tettix*, Lat.) appears to produce the weak tone which it emits, for it has no vocal organ like *Gryllus*. The African genus *Pneumora*, Lat., also is said to produce a sharp chirping noise by the friction of the femur against the abdomen, or small ridges seated upon it. De Geer even detected the vocal organ of *Gryllus*, and considered it as such,

* Introd. vol. ii.

but he did not clearly comprehend its true mechanism * during chirping. Joh. Müller has latterly described it as an auditory organ †.

It is in the family of the *Cicada*, namely, the larger ones (*Tettigonia*, Fabr., *Cicada*, Lat.) that the voice attains its highest degree. In these creatures also we find the voice possessed exclusively by the males, and it is produced by an organ that has the greatest resemblance to that of the *Grylli*. In these it is also an elastic membrane, which is longitudinally folded and stretched over an oval horny ring seated immediately behind the first large spiracle of the abdomen, which, by a peculiar muscular apparatus, is made to vibrate. To each of these elastic membranes a strong conical muscle runs, which, with its broad basal surface, is attached to a plate-shaped horny tendon, the short pedicle of which is in connexion with the drum, and which originates at a central, furcate, horny process of the ventral plate of the second abdominal segment, the analogue of the furcate process of the breastplates. This muscle, together with the membrane, constitutes the vocal organ. If the abdomen, by the respiratory motion, be expanded or contracted, this muscle likewise stretches, whereby the membrane is made to vibrate, and consequently resound. The sound is increased, as in the *Grylli*, by means of a large air bladder, which lies at the lateral portion of the abdomen, and which closely covers the muscle as well as the membrane. In this cavity the sound rebounds, and thus proceeds more strongly from the insect. As external organs, there are, in addition to this vocal organ, some other parts which serve as a cover to it, but which are not of importance to the production of the voice, namely, two half circular horny plates, which spring from the margin of the horny integument in front of the drum, and more or less cover it; also beneath the drum in the centre of the ventral plate of the segment behind the coxæ of the posterior legs there are two small, oval, transparent fenestrations filled by a tense membrane, but which likewise appear to stand in no direct causal connexion with the voice. In the female also these little fenestrations are found, although less perfect, as well as the external valves which cover the drum; but there is not the least trace of this itself, nor of the muscle which moves it. The air-bladder the female likewise possesses, but it is smaller than in the male ‡.

* Mémoires, vol. iii. p. 471, Pl. XXIII. f. 2 and 3.

† Zur vergl. Physiol. der Gesichtssinne, p. 438.

‡ Compare, upon this vocal organ, the Treatise of Carus in the Analekten zur Naturwissenschaft und Heilkunde. Dresden, 1829. 8vo. p. 151.

At the close of this description of the several organs whereby insects produce peculiar sounds, we still have to speak of the sound and the mechanism that produces it in a *Lepidopterous* insect, the well-known death's head moth (*Acherontia atropos*, O.), which it emits upon being touched or disturbed. Reaumur and Rossi were both acquainted with the plaintive cry of this moth, and expressed their opinion that it proceeded from the friction of the tongue against the palpi. More recently, the experiments which Passerini has made to ascertain the organ which produces this sound have proved that it must lie somewhere in the head. He found a cavity in the head which has connexion with the false canal of the tongue (or rather, it should be said, with the central canal formed by the application of the two halves of the proboscis together), and about the entrance to which muscles lie which rise and sink alternately, and by these motions drive the air out of it and re-admit it. I do not, however, distinctly see how the mere streaming in and out of air could produce so loud a noise, if at the entrance there be not some body made to vibrate by its passage. Such must therefore be shown to exist, to explain fully the mechanism whereby the death's head moth produces its plaintive cry. I have not yet possessed a living individual of this otherwise not uncommon moth, I can therefore say nothing from my own experience; according to Duponchel *, whom we have to thank for the communication of Passerini's observations, there is a delicate membrane stretched between the eyes and the base of the proboscis, which certainly might be the cause of the sound if we adopt that the above cavity immediately adjoins it, and that it is made to vibrate by the air passing to and fro. Duponchel found this membrane also in *Sphinx Convolvuli*, which, however, produces no such sound; but then the internal cavity may be wanting whereby the faculty of causing the membrane to vibrate, as in the death's head, is lost, and it is consequently dumb. Passerini purposes making his observations public, which will then doubtlessly spread more light over this interesting subject. Thus much, however is certain, that the death's head moth makes a peculiar plaintive cry, which is produced by a particular organ seated in the head.

* See Annales des Sciences Naturelles, tom. xiii. p. 332 (Mar. 1828), and Heusinger Zethshrift für die Org. Phys. vol. ii. part iv. p. 442.

SIXTH CHAPTER.

OF SENSATION AND THE SENSES.

§ 272.

The functions of the nervous system are certainly among the most problematical of all the animal organs. Even in the higher animals, in which observation is more easy, and it has to contend with fewer difficulties, much still remains in impenetrable obscurity, notwithstanding the light that has been given in modern times to this portion of physiology ; it will therefore strike us as less singular if the most general phenomena of the functions of the nervous system of the lower animals have not been satisfactorily explained. We move here in a field where simple experience frequently quits us, and a wider space is given to the fancy for its hypotheses and inventions. Yet we will keep ourselves as far as possible from this frequently misguiding conductress, and only endeavour to explain what our own experience and that of others enables us to do satisfactorily.

It accordingly appears confirmed that the nervous system, and chiefly the first chief ganglion or the brain, is the truly animating element which sets all the other organs in activity, and retains them in it. From the nervous system the muscle derives the irritability which puts it in action; by means of the nerves the intestinal canal is excited to digestion, and by the impulse of the same organs the sexual parts exercise the function appointed to them. Lastly, the nerve is the recipient and conductor of all immediate perceptions of external objects, and consequently the seat of sensation in general. Experience corroborates all these assertions. With respect to the effect of the nerves upon the muscles, we know from Rengger's * experiments, that after the nervous cord has been cut through at any part, the portion of the body which lies beyond that spot can exhibit no more motion. Rengger repeated this experiment in different kinds of caterpillars, some of which he cut through at a higher and others at a lower part of the

* Physiologische Untersuchungen, &c. p. 41.

ventral cord, and the same result always ensued. The legs which lay behind the scission no longer executed their function, but appeared as dead. The segments of the body also became flaccid and motionless, and only at isolated spots catchings of the muscles were to be observed. If the caterpillar were now carefully opened it was seen that the posterior portion of the stomach, namely, that which lay beyond the scission, no longer exercised its peristaltic motion, and that its contents no longer passed into the ilium, and also that the indigestible remains contained in this portion, as well as in the colon, were no longer ejected, but that entire part of the intestine appeared lifeless. The anterior portion acted however as usual; the caterpillar still ate and crept about with its anterior legs as if fully enjoying its preceding state, dragging its insensible lamed posterior portion along with it. If, lastly, the scission which separated the nervous cord were very near the head, so that thereby the lamed portion considerably preponderated over that still capable of motion, the latter was likewise hindered in the full exercise of its function, the caterpillar could then no longer crawl, although it exercised the requisite motions with its anterior legs, yet the preponderating lame posterior portion prevented its moving from the spot. Upon the nervous cord being separated at so high a spot the vital system was considerably affected, and the caterpillar soon ceased to live, but the further backwards the cut was made the longer the caterpillar lived, and the less was the exercise of its functions disturbed.

The irritability of the muscles beyond the point of separation was not yet wholly lost by the cutting, they speedily contracted after considerable pressure, but immediately became flaccid upon the removal of the exciting cause. The motion of the stomach also continued at its superior extremity, even when the nervous cord was cut through between the second and third pairs of legs, as this portion of the stomach received its own nerves from the pharynx; but if this nerve running from the pharynx was separated the peristaltic motion of the anterior portion of the stomach likewise ceased, and the entire function of digestion suddenly stopped.

Hence the brain appears the true seat of the animating forces, which are transmitted from it by means of the nerves to the most remote organs. The more distant therefore from the brain the wound takes place, the less is the disturbance that it occasions to the system, but the closer to the brain the more fatal is the operation.

But, to obtain a positive result, Rengger now made his experiments immediately upon the brain itself. He first laid it bare, and by some further incisions he removed it, and carefully closed the wound. The creature made, even during the operation, several convulsive motions of the whole body, which continued for a space of time after the removal of the brain, but then ceased, upon which the body appeared as in a paralysed state; the caterpillar could no longer eat, could no longer walk, but struggled first forwards and then on one side or the other; the peristaltic motion of the stomach disappeared, and only here and there did a fasciculus of muscles still catch. But, just as in the preceding experiments, the muscles retained their individual irritability, and reacted upon the application of stimulants. Rengger, that he might avoid the hemorrhage and other violent effects which necessarily occur in such operations, wounded and removed the brain with a red hot needle, but still the loss was accompanied by the same phenomena.

§ 273.

Treviranus' observations *, however, do not harmonise with the conclusion deducible from the preceding communications of an important preponderance of the brain over the other ganglia. He saw a *Carabus granulatus* after its head was cut off still run about and seek a way to escape by; even after the removal of its prothorax the creature exercised its former voluntary motions, until, upon the removal of the mesothorax, they died away in irregular catches. The head of *Tabanus bovinus* was cut off, and it was then laid upon its back, when it made every possible endeavour to resume its usual position, and laid hold of a pencil offered it, and thereby crept up. Other insects, which were injured only upon one side, directed their motions towards the unwounded side. Thus an *Orgyia pudibunda*, O., of which the left antenna was cut off, kept running in a circle towards the right side, and continued this motion even when it had lost the entire left side of its head; when, however, the whole head was removed, the creature made violent exertions, running in circles, sometimes on one side, sometimes on the other. The same moth lived three days without its head, and continued to move its wings violently until its death. A different result was however produced when Treviranus removed the antenna of a wasp, for it moved indifferently on both sides. *Æschna forcipata*

* Das Organische Leben, vol. ii. part i. p. 192.

also lived four days without its head, and even evacuated excrement during this period, but it could no longer move its wings, and was sensible only to pressure made at its caudal extremity. Treviranus also cites an experiment of Walckenaer, in which *Cerceris ornata* had its head cut off just as it was entering the cells of *Halictus terebrator*, when it still continued its endeavours, and even turned round towards the hole upon being placed in a contrary direction.

§ 274.

To endeavour to harmonise these discordant results, or rather, to ascertain to which the preference was truly to be given, I myself instituted the series of experiments which follow.

Among the *Coleoptera* it was chiefly the water-beetles, viz. *Dyticus sulcatus* and *cinereus*, which I made use of. I first took the male *D. cinereus*, and cut off its head, but the crop and proventriculus were also thereby removed from the body; from the very instant it totally ceased all voluntary motion, but upon pinching the feet severely with a pair of pliers a strong reaction of the muscular irritability was produced; the posterior legs immediately made three or four swimming motions, but they then remained in their preceding lifeless and gently bent position. This reaction continued, but constantly decreasing in force, for about half an hour, after which the severest pinching was not able to produce it.

I opened the breast of a lively female *Dyticus sulcatus*, between the second and third pairs of legs, so that the nervous cord was laid bare. With a pair of pliers I now laid hold of the nervous cord, and removed it; the left posterior leg was immediately lamed, but the right one and all the four anterior legs still exercised their voluntary motions, and the creature could still tolerably swim when thrown into the water. When placed upon its back, the contractions of the muscles were distinctly seen. These continued for about an hour, the posterior legs then lost all motion, and even their irritability, whilst the anterior ones still possessed it, but yet a decrease of animation was clearly seen, and in about three hours afterwards it was completely dead.

In another male *Dyticus sulcatus* I separated the nervous cord close to the soft connecting membrane between the pro- and meso-thorax; in the course of a few seconds the motion of the four posterior legs ceased, whilst the anterior ones retained their perfect mobility, but signs of irritability still presented themselves. The anterior legs, even after four hours, still exercised their voluntary motions, although with less vivacity, but in the evening the insect was dead.

In a fourth perfectly animated male *Dyticus sulcatus*, by an incision which removed the horny integument of the head, I laid the brain bare. Immediately much yellowish brown green blood streamed forth; it was perfectly clear and viscid, and covered the entire wound, and stood upon the naked part like a drop of water. I thus allowed the insect to go; it retained its complete motion, but moved all its limbs slowly and convulsively as if severely injured. I now removed the brain by means of pliers; the insect immediately became motionless as dead, and did not move a single joint as long as it lay upon its belly. Upon my teasing it, after about a minute it endeavoured to cling with its legs, but this motion appeared to proceed rather from the irritability of the muscles than from its own volition. I now laid it upon its back, and it directly made its usual swimming motions, during which, as when swimming, the anterior pair were drawn closely up to the breast. These motions lasted uninterruptedly as long as the insect lay upon its back; if I laid it upon its belly they ceased, and the insect again moved no limb. I now cast it into the water, when it swam upon the surface with the greatest rapidity, impelled by incessant natatory strokes, striking all its comrades that it met on one side by the violence of its motions, and continued thus uninterruptedly for about half an hour. It did not, however, descend to the bottom, nor did I see any respiratory action in its abdomen. After this, upon the gradual decrease of the force of its strokes, it lay upon the surface with distended legs, but displayed irritability upon the legs being pinched; lastly, towards evening, the experiment having been made about 11 a.m., all life had vanished.

The brain was similarly laid bare in a female *Dyticus sulcatus*, but the incision passed obliquely through the right eye, and wounded its right hemisphere, whereby the insect lost the voluntary motion of the left posterior foot. I now removed the brain entirely, and the insect became instantly lifeless, but in the course of a few seconds the legs recovered their motion, but not to the same extent as in the preceding experiment. Cast into the water, this female did not swim like the former insect, but lay with extended legs, moving with a catch some of its joints; these motions could be perceived, even after an hour, upon effective excitement, but towards evening, as in the preceding experiment, the beetle was perfectly dead.

With grasshoppers I have made the following experiments.

A small *Gryllus* (*Acrydium*, Lat.) I opened in the breast, between the intermediate and posterior thighs, and removed the large ganglion lying there. The insect thereby immediately lost the mobility of the posterior extremities, and was also very much enfeebled, but yet crept about by means of its four anterior legs. Having accidentally soiled its antennæ, it made stroking motions towards them with its left anterior leg to cleanse them, and upon my taking it up by them, it made very active exertions with the anterior legs to free itself. I now made an incision in the same individual through the membrane of the neck, whereby the nervous cord was separated, but the œsophagus not injured. The creature at first still moved its anterior legs, and in them there was a powerful reaction upon pressure, and it trembled for a time afterwards, but otherwise exhibited few signs of life; it lay lifeless upon one side; it did not even lie upon its belly; but yet there were still catchings in the feet when nipped with the tweezers, but not in the large posterior thighs. In ten minutes the motion of the legs considerably decreased, and in half an hour the animal was entirely dead.

A second somewhat larger and also very active *Gryllus* I again cut through the membrane of the neck; the insect, immediately after the incision, made violent movements with its thighs, which cast off one of its posterior legs; the other legs exhibited irritability as often as I pinched them, but, after the lapse of a minute, it lost all voluntary motion, it could no longer walk, and remained quietly lying upon its side when so placed. In half an hour it was dead.

I have besides made experiments in *Diptera*, namely, in some species of *Eristalis*.

I separated the nervous cord of a lively *Eristalis nemorum*, closely in front of the middle legs; those legs immediately lost their motion as well as the right posterior leg, but it still crept about by means of its anterior legs and left posterior one. These motions continued, but its course was not straight, but inclining obliquely to the left. I now made the incision deeper, to be perfectly convinced that I had thoroughly separated the nervous cord. The left posterior leg now lost its motion, but the fly still crept with its anterior pair, but it could no longer fly, as was the case upon the first incision. I now cut off its head; immediately all the motion of its anterior legs ceased, but the proboscis of the separated head still throbbed when I drew it from the cavity of the mouth. These catchings continued for a quarter of an hour, but the body was entirely dead.

In another lively *Eristalis nemorum* I made an incision transversely through the eyes, and seriously injured the brain ; the insect, however, still retained the perfect mobility of all its legs, and crept about, although but slowly; shortly, however, its strength decreased, it reposed quietly, and but slightly moved upon excitement; in an hour it was quite dead, but still displayed slight irritability of the muscles upon violent external excitement.

§ 275.

From these experiments, and those communicated by Rengger, we may deduce the conclusion, that after the separation of the nervous cord at any part, the voluntary motion of the organs seated beyond the point of incision is lost, but that the irritability of the muscles, that is to say, their power of re-action upon external excitement, is retained by these organs as long as life is still present, but that it disappears with it. It thence consequently follows that the nerve passing to the muscle supplies the place of external excitement, and that therefore the will can act upon the muscles only through the medium of the nervous system. These experiments also confirm the assertion so frequently repeated, that the brain is the principal of all the ganglia, and that the causes of all the vital phenomena exist in it, and proceed from it. The instance in which the male *Dyticus* swam about a considerable time after the removal of its brain appears to contradict this conclusion, but I am still very strongly inclined to perceive nothing but irritability in the rowing of the feet. The entire uniformity of the motion speaks strongly in favour of this opinion, as well as the circumstance likewise that the beetle deprived of its brain did not execute these motions so long as it lay upon its belly on a dry surface. We may also deduce from these experiments, that still for a short time after the removal of the brain, not merely signs of life but even proofs of voluntary motion present themselves, which are the stronger the more imperfect the injury to the brain may be. We may here class also the experiments made by Treviranus, but I doubt their entire accuracy. How could a beetle seek ways to escape when all the organs whereby it might perceive such opportunities were removed from it? Walckenaer's observation is more probable, that the *Cerceris* repeated several times its preceding endeavours after the loss of its head; it was merely a continuation of the undertaking resolved upon previously to the mutilation, but which, however, could only continue as long as the remainder of the nervous cord still conveyed the excitement impressed upon it by the will; that, however, after the alteration of the direction of the motion the wasp absolutely resumed its previous position, I very much doubt, it is improbable in every case, and my experiments do not tend to substantiate it. Treviranus' remark also, that the *Orgyia* lived for three days after the loss of its head, excites just suspicion, for in all similar experiments of mine life had perfectly vanished in the course of a few hours. But I am acquainted with other instances in which the *Noctuæ,* after having been killed with red hot needles, and extended upon the setting-board for a week, have not only moved the abdomen upon the application of an excitement, but still also continued to lay eggs. I think the reason of this may be found in the independent irritable life of the sexual organs, which, excited by the continual stimulus of the eggs contained within them, continue laying them, and as long as eggs exist within them display signs of irritability. To this class, consequently, the instance cited by Treviranus may be placed; life no longer truly existed, but merely the reactive power of the sexual organs, and they did react when excited by external stimulants, but I consider the observed motion of the wings as very doubtful; for the needle thrust through the thorax and the other red hot one would doubtlessly have had the same effect as removing the ganglion situated in the thorax; the red heat would doubtlessly have deprived it of its activity, and thereby the motion of the parts with which it supplied nerves would necessarily have been destroyed. We frequently observe in insects thus mutilated a still continued motion, for instance, in the antennæ and the parts of the mouth, when the legs and wings have entirely lost theirs.

§ 276.

The influence which the nervous system exercises upon the several organs of the body may thus therefore be generally stated; we have still to consider more closely the nerves as the recipients of external excitement, in short, as the organs of sensation in particular. It would be difficult to obtain a satisfactory result upon this subject by experiments upon insects, for, although we perceive that they are sensible to external excitement, yet we cannot distinctly prove that they receive these sensations through the nerves. We can maintain nothing further with certainty than that in insects similar organs are found, to those whereby the higher animals, and particularly man, feels, and that therefore, by means of these organs, insects likewise perceive the presence and quality of the external objects which their body touches. But we know, upon the other side, by means of direct observations, that insects do feel, and we may therefore deduce from the preceding opinion, founded upon analogy and these observations, that the nerves of insects are likewise the organs of sensation.

Observations confirmatory of the presence of sensation in insects daily offer ; we have but to look at some creeping insect, and observe how it convinces itself of the presence of an object by touching it with its antennæ, and then carefully avoiding it ; and besides, insects that are reposing are disturbed from their repose by any ungentle touch, and upon a repetition of the disturbance quit the spot ; and lastly, pupa, upon the least touch, and by their rapid and serpentine motions, instantly evince a feeling of displeasure. In many pupæ the sensation of inimical influence is so delicate as scarcely to be credible ; the mere opening of a box in which they may have been placed disturbs them, and, indeed, some of the slightly clothed pupa of the *Coleoptera*, whose natural situation is beneath the earth or in dark situations, instantly move, and with considerable force, if a ray of light be allowed to fall upon them, but they are peculiarly sensitive to bright sunshine.

But we are most distinctly convinced of the sensation of insects upon impaling them for the collection. Even the mere pressure of the pin produces unpleasant sensations, which the insect expresses by the rapid and painful motion of its limbs ; upon its point proceeding still further the expression of disagreeable feeling increases by its more rapid and unnatural contortions, and I have frequently observed, that at the moment when probably the pin passed through the ganglion, and when the insect appeared as it were suddenly lamed by its excessive pain, it extended all its limbs, and even its oral organs, and then ceased for some seconds all motion. This motion continues for some space of time, frequently from a week to a fortnight, as long as the insect is teased, but it does not appear to happen in repose, or if the insect be enclosed in a dark situation, at least I have observed many instances in which, under such circumstances, the insect did not move. Hence, as well as from the subordinate sensibility of the nervous system of the lower animals, we may conclude that insects thus impaled no longer feel any pain, and that their motion is produced merely by their endeavours to free themselves from a disagreeable restraint. In favour of the adoption of this opinion the deficient formation of the blood in insects speaks, in consequence of which no inflammation and suppuration can take place. Inflammation, however, or the immediate touching of the nerve laid bare, by the air or other extraneous bodies, occasions our feeling pain from a wound, and as long as this irritable condition does not occur no pain is felt. This irritable condition, however, can never take place in insects, they having no blood-vessels and cellular membrane, through which the irritable matter may transude, but merely a lymph, circulating freely in the body. This lymph encompasses the extraneous body, the pin, coagulates around it, and thus perfectly protects the nerves from its influence. According to this view the majority of impaled insects die of hunger, and not by mechanical wounding; if, for instance, the thoracic ganglion or the nervous cord be not separated; for so serious an injury to the nervous system the preceding experiments have shown must speedily produce death; but yet I would not be understood as approving of that certainly very unnecessary torture to which poor captured insects are exposed by the young and old, as objects of their pleasure. In support of this opinion we may still mention that many impaled insects still continue the exercise of their most usual corporeal functions; for instance, still eat, still evacuate excrement, creep about with the pin through them, and sometimes even fly, and lastly, the *Lepidoptera* even copulate in this state, and, a still more common occurrence, is their continuing to lay eggs.

§ 277.

Upon passing from these introductory observations upon the functions of the nervous system in general to the senses themselves, we may maintain, in reference to these, that insects are not deficient in any important one found in the superior animals. At the end of the preceding division we described the organs of the several senses, but we yet found only one certain organ of sense, which, with few exceptions, is discoverable in all insects, and this was the eye. We, nevertheless, endeavoured to discover the other organs of the senses, proceeding from determinate observations which prove that insects have perceptions which can only be received by senses of touch, taste, smell, and hearing, and we then found several organs, each individual one of which admitted of being referred to some one of these senses, either from analogous situation or structure to that of the same organ of sense in the higher animals, and partly from the deficiency of a satisfactory proof of a different function of the organ. Thus we recognised in the palpi organs of touch, in the tongue the seat of taste, in the mucous membrane of the tracheæ the sense of smell, and in the antennæ, lastly, we discovered the instruments of hearing. The mode whereby the insect receives perceptions through these organs will certainly not divaricate from that found in the superior animals. Touch, taste, and smell require the direct application of the investigating organs to the investigated object, and so soon as this takes place the insect perceives. We have convinced ourselves by experiment that an insect feels objects all over with its palpi which it wishes to inspect for food or other purposes, but that the tongue tastes, and the mucous tunic of the tracheæ smells, can only be made probable. With respect to the latter, it is contradictory to the views of very learned naturalists, namely, Kirby and Spence * and Treviranus, who both adopt as the organ of the sense of smell a peculiar one standing in connexion with the mucous tunic of the mouth. With respect to its situation above the mouth, it has certainly the analogy of all the other animal classes in favour of it, and their opinion would even on that account merit entire approbation if absolutely the organ of which these authors speak could there be found. But this is not the case, and even Treviranus convinced himself by multitude of experiments of its absolute deficiency, and so suggested the opinion that the mucous tunic of the mouth was likewise the organ of smell, and that therefore the sense of smell was especially to be ascribed to haustellate insects only. Kirby and Spence, however, to whom the striking contrary proof exhibited in the extremely keen smell of the burying beetle was probably present, decide absolutely in favour of a peculiar organ of this sense, lying beneath the clypeus, and which they call the nose, and which borders upon the mucous tunic of the mouth. In the burying beetle they say they have discovered this organ in the form of two circular fleshy cushions, which are covered by a beautiful and finely transversely striped membrane; the same also in *Dyticus marginalis*, in which it is further provided with a pair of warts; as also in *Œschna viatica*. But the investigations of other anatomists do not confirm these discoveries. If such an organ really existed at the spot indicated, Straus would certainly have seen it in the cockchafer; and I believe I may assert, that in several endeavours

* Introduct. to Entom. iv. Letter xlv.

I made expressly for the purpose in *Dyticus marginalis* and *Calosoma sycophanta, Hydrophilus piceus,* and *Scarabæus vernalis* that it must have shown itself if it had been present at the spot mentioned. In freshly opened insects I could discover really nothing of the kind, and in those which had been long immersed in spirits I saw the space in front and between the clypeus and the most approximate organs filled with nothing but coagulated blood. I cannot therefore determine in favour of Kirby and Spence's opinion, but prefer the earlier hypothesis, that the internal surfaces of insects receive smell, and supply the place of an organ especially devoted to that sense.

The majority of modern physiologists and entomologists agree in explaining the antennæ as organs of hearing, as we have already remarked. Kirby and Spence's representation, whose names were inadvertently omitted to be mentioned there as the authorities for our opinion, conveys so much conviction that we may almost consider it as settled, although we must at the same time admit that all the difficulties are not yet solved: we have already indicated above that the real perception of sound may possibly depend upon the trembling produced by the vibration of the air in organs so easily moved as are the antennæ, and we here repeat this opinion as the explanation of the mode by which insects hear. According to Kirby and Spence, Wollaston suggested this opinion, and even supposed that insects could perceive much more delicate tones than our ears are capable of distinguishing, from their very much greater irritability. This irritability, however, in consequence of the much harder integument in which insects are enveloped, can be possessed only by the antennæ, which are so easily moveable, and which, indeed, in many insects are in a constant state of motion; even the slightest vibration of the atmosphere must be sufficient to put into motion an organ of the structure of the antennæ of a gnat, and thereby apprise its possessor of the approximation of some occurring change; this is equally the case with the delicate and easily moveable antennæ of the *Grylli,* and indeed of all insects furnished with long antennæ; the same with the short fan-shaped flaps, as well as with the delicately haired joints forming a knob in the antennæ of other insects; the very structure of all betrays the possibility of very delicate perception. Organs of touch they cannot be, for their surface is too hard and horny, and besides, all insects have for this purpose organs furnished with a very delicate touching surface. Hence the mode whereby insects hear will necessarily differ from the hearing of the superior animals, and in reference to it we may possibly be allowed to surmise that they do not possess the power of distinguishing tones; but in opposition to this, it may be mentioned, that their females would not be able to distinguish the luring tones of the males from any other sounds, and consequently their possession of a means of indicating their presence would not much serve them; and also the signs of recognition among the bees, to which we shall have occasion to return below, is opposed to it. There are also other instances of a mode of communication among insects, by means of peculiar sounds.

§ 278.

The way in which insects see by means of their eyes will be best explained by Joh. Müller's investigations *. With respect to simple eyes, we know, partly from their structure and partly by the direct observations of Reaumur † and Hooke, who closed these simple eyes, and then never detected the creatures moving in the direction of these eyes, and that they only then flew whither their compound eyes could survey their path, that these vertical points are actually eyes. Joh. Müller has made it probable, from the structure of these eyes, that their refraction must be very great, in as far as each ray of light suffers a fourfold refraction, the first of which is produced by the convex cornea, the second by the anterior convex surface of the lens, the third by the posterior convex surface of the lens, and the fourth, lastly, by the convex surface of the glassy body itself. This disposition presumes an indistinct distant sight, as the object is thereby too great to be distinctly seen, but a well defined and distinct short sight. And, indeed, we find in all the *Arthrozoa*, which have merely simple eyes, for instance, in the *Arachnodea*, the power of sight agreeing with this view, for it is only closely that spiders can see accurately, at a distance the object appears to vanish from them. If we apply this to the simple eyes of insects we shall find in them, likewise, that the function of their simple eyes is adapted for a distinct close sight, and particularly for small objects, which are difficult for the large field of vision of the compound eyes to survey. They hence appear to make most use of their simple eyes in narrow spaces, and as these simple eyes, as well as compound eyes, are almost exclusively found in those insects which feed upon the

* Zur Vergleichenden Physiologie des Gesichtssinnes, p. 332, &c.

† Mémoires pour servir à l'Hist. des Insectes, tom. v, part i, p. 363.

juices of flowers or other vegetable substances, they may probably be of especial service to them for the discovery of this pabulum, particularly to those which thrust themselves into the flowers themselves, and there seek the nectaries.

The compound eyes of insects appear constructed for vision at greater distances, and to embrace a wider horizon, and yet by means of these only are they enabled to have a distinct close sight. They are so composed that each individual facet can survey but a small space of the entire field of vision, so that each contributes to the perception of all the objects comprised within that field; but each separate one does not at the same time see all such objects, whence the insect must receive as many forms of objects in its eye as there are individual facets to the eye. This consequence of a common and yet subsidiary vision of these facets springs partly from the immobility of the eyes, and partly it arises from the circumstance that only those rays of light which fall in a right line upon a facet of the eye, which itself forms the segment of a circle, can reach the optic nerve of this facet, whereas all others are withheld by the pigment which partly separates the individual glass lenses* from each other, and partly circularly surrounds the margin of the crystalline lens beneath the cornea. Hence it results that the nearer the object is, the more obliquely do all but the perpendicular rays of light fall upon the facet, and therefore contribute so much the less to the production of the image; the object

* Treviranus, even in his latest work (Gesetze und Erscheinungen des Organischen Lebens, neu dargestellt, vol. ii. Pt. 1, p. 77), denies the presence of this glass lens in the eyes of all insects. Joh. Müller has so far modified his earlier assertion that the *Diptera* in lieu of it exhibit beneath the cornea a transparent crystalline layer, which beneath each facet of the cornea stands in connexion with a filament of the optic nerve, but that in all insects there is either a true crystalline lens or something analogous. According to Treviranus, the lenses serve "to shorten the distance of the concentrated rays from the divisions of the cornea to the extreme ends of the filaments of the optic nerve, there where the light, owing to these divisions, is but slightly refracted, and the refracted rays form a very long arch." But, according to Joh. Müller, their object appears to be rather to concentrate into one point the rays falling in a right line.—But the observation communicated by Treviranus is more important, namely, that the filaments of the optic nerve proceed at first from the clavate optic nerve itself in large stems, whence subsequently radiating branches divaricate, as has been figured by Straus in the cockchafer (Pl. IX. f. 6). In *Œschna forcipata* he even saw the nerves run parallely to the plate which forms the inner circumference of the eye, and thence proceeded the filaments destined to supply the divisions of the cornea.

consequently is most clearly seen closely, and more indistinctly at a distance. If now each facet of the eye can survey but one small portion of the field of vision, yet will the entire eye be able to survey a field the larger in proportion to the size of the segment of the circle it forms and to the convexity of its arch. Therefore, the larger the eye is, and the more convex, the wider will be its horizon. The various structure of the eyes of insects agrees also with this. Males, which are appointed by nature to seek the female, have larger eyes than the latter. Insects which live in and upon their pabulum itself, have small and flat eyes, like all parasites; others, again, which have greater difficulties to contend with in procuring their food, as those insects which live upon prey, like the *Carabodea, Dytici, Libellulæ,* &c., have either large or greatly convex hemispherical eyes. The position of the eyes also corresponds with their size and convexity; flat eyes, which are able to survey but a short space only, are always more approximate and placed more anteriorly than laterally, and are frequently contiguous, as in the male *Syrphi.* Spherical and very convex eyes are placed laterally, and their axis is frequently directly opposite, but they yet harmonise by their greater convexity with their field of vision, as is distinctly observable in the large *Carabi.* But the fields of vision of the two eyes do not affect each other, there still remains a free space between the eyes, which the insect can only survey by turning its head. Sometimes, to compass a still wider field of vision, a complete divarication from the usual form becomes necessary, as in *Gyrinus,* a division of each eye, the one half of which lies upon the vertex, and the other half is placed at the lower surface of the head; the latter is for the discovery of food which the insect finds in the water, and the former to secure it from its enemies which approach out of the water; or, as in some male *Ephemeræ,* in which two large flat eyes lie upon the vertex, and two smaller but more convex ones are found at the margin of the head.

Joh. Müller appends to his beautiful and apparently perfectly successful explanation of the sight of insects, the result of which we have condensed above, some other more general observations, which we cannot forbear briefly introducing here. Thus the relative proportions of the distinctness of the image in various eyes increases, according to him, in proportion to the size of the sphere of which the surface of the eye forms a segment, with the number and smallness of the facets, and with the length of the transparent lens. Whereas the power of sight at a distance or close does not depend upon the structure of the eyes; every compound eye which distinctly discerns objects at a distance, produces also closely a clear image of it. But the larger the individual facets are, and the smaller the spheres formed by them, and the brighter the pigment deposited between the lenses, the more indistinct does the image of the object seen become, and in such a structure a better image is formed of distant objects, but a worse one is seen of approximate objects, for the rays are more diverging in consequence of their proximity, whereas they run more parallely from every point of an object at a distance; in the former case, therefore, it passes through the brighter pigment into the contiguous glass lenses, and renders obscure the image that should be there formed upon the retina.—The apparent size of the object seen corresponds only with its true size when the convexity of the eye is perfectly spherical and concentrical with the convexity of the optic nerve; in every other case the apparent size of the image will not correspond with its true size, and the image must therefore appear distorted. Hence all elliptical or conically arched eyes wil see worse than those forming the segment of a circle.—As the structure of the eye does not differ in water insects and those which avoid the light from that of day insects and those which live upon the land, namely, the pigment is by no means brighter in the former, as Marcel de Serres affirms, consequently their sight must fully correspond with the sight of day insects.

With respect to the difference of structure of the eyes in larvæ to those of the perfect insect, in insects with an imperfect metamorphosis, it consists especially in the relative size of their compound eyes. These are always smaller in larvæ, but continue increasing with every moult, until they at last attain their full size. In the large eyes of the larvæ of the *Cicada* no facets are observed; these, therefore, gradually distinctly develope themselves. The cornea of the eye is changed also with the change of skin, which very well admits of a transformation. Whereas simple eyes are never found in larvæ with an imperfect metamorphosis; they present themselves only as bright spots where they are subsequently to appear.—The majority of larvæ of insects with a perfect metamorphosis have merely simple eyes, and, indeed, exactly where the compound eyes afterwards appear; many entirely want eyes, and a few, as the larvæ of the gnats, have already compound eyes. With respect, therefore, to the development of the eyes during the metamorphosis, it appears to take place especially during the pupa state, and, indeed, by the compound eyes being gradually developed from the simple ones. Pupæ, however, have the entire cornea immediately after stripping off their larva-skin; and in the pupa of *Stratiomys* Joh. Müller found beneath it the glass lens and the layer of pigment yet but slightly coloured. If now this composition of compound eyes from simple ones actually takes place, which cannot very well be doubted, it may serve as a guide to the explanation of the parts of the compound eye, which I would thus explain: the glass lens corresponds with the glassy body, the lens with the thick cornea, and this latter with a superficial thin layer of the entire cornea, which it likewise is, and which is peeled off during the metamorphosis. After the last moult this layer grows to the lens, and they then both appear as identical, but, in relation to the other parts, merely as a thick layer of the cornea. Hence the compound eyes of insects consist of the same parts as the simple eyes.

SEVENTH CHAPTER.

THE LUMINOUSNESS OF INSECTS.

§ 279.

The peculiar light which many insects, but chiefly beetles, display, is a very remarkable phenomenon. We have deferred its consideration to the end of somatic physiology, as it does not appear to stand in direct connexion with either of the four chief functions of the animal body, but may be considered rather as the result of an entirely peculiar vital phenomenon, the cause of which has been by no means thoroughly ascertained. We will defer communicating the results of the experiments made upon this highly interesting subject to the end of this chapter, and first mention those insects in which this peculiar luminousness has been observed.

The majority of them belong to the *Coleoptera*, and indeed to two families which also in other respects present a tolerable affinity. These families are the *Elaters* and the *Lamprodea*. Among the *Elaters* we know as luminous the *E. noctilucus*, *E. ignitus*, *E. lampadion*, *E. retrospiciens*, *E. lucidulus*, *E. lucernula*, *E. speculator*, *E. Janus*, *E. pyrophanus*, *E. luminosus*, *E. lucens*, *E. exstinctus*, *E. cucujus*, *E. lucifer*, and *E. phosphoreus* *. In all of these there are two bright oval, convex spots upon the thorax, which, after death, are of a greenish yellow, and whence light, whilst living, streams forth, and in addition to which there are two other spots upon the abdomen that are luminous, and which, during repose, are concealed beneath the elytra. Indeed, the whole inside of the body is luminous, but it is concealed by the impenetrable integument, and only sometimes upon the very great expansion of the abdomen is it perceptible through the divisions of the segments. All the named species are found in tropical America, and, according to Sloane, repose during day in dark shady places, and only fly during dusk and at night, when they betray themselves by their light; but, according to Sieber, they also fly at noon in the sunshine, but then exhibit no light. Their light is of a bright blue-white colour, and in the larger species, for instance, in *E. noctilucus* †, it is so strong, that, by its aid, small writing may be read at night if the luminous spots be passed regularly over the lines. Some naturalists who have had the opportunity of observing the insect in its native country (Spix) assert that they have found beneath the luminous spots a yellowish glandular mass, to which a multitude of branches of the tracheæ are distributed from the approximate main stems. These are the true luminous bodies whence the light streams forth either brightly or dully, according to the quantity of air the insect admits to them by respiration. It is also said that the insect can prevent the emission of all light by, according to Spix, preventing the admission of any air. Amongst the natives, all these insects are called *Cucujos* or *Cucujii*; they use them as ornaments for their dresses by night, and they are worn by the females especially as ornaments to the head-dress, and the Indians are said to bind them to their feet on a journey, to enable them to discern their road more distinctly. According to Piedro Martire ‡, the inhabitants of Saint Domingo keep the luminous *Elaters* in their rooms

* See Illiger in the Magazin der Geselsch. naturf. Freunde zu Berlin, vol. i. p. 14.

† See Curtis in Zoological Journal, 1827, No. 2, p. 379. Heusinger Zeitschrift, vol. iii. Pt. 1, p. 137.—Thons Archiv. vol. ii. Pt. 2, p. 63.

‡ In Kirby and Spence, vol. ii. p. 462.

at night, which destroy the gnats that would otherwise disturb persons sleeping; but this tale does not merit belief, as the *Elaters* are well known not to be carnivorous, but feed upon nectar and pollen. Yet by the light they distribute they may probably chase away the gnats.

§ 280.

The European *Lampyri* were known as luminous earlier than the *Elaters*. The ancients were acquainted with this faculty*. The Romans called them *cicindelæ*, the Greeks λαμπυρίδες; but it does not appear that they distinguished several species; and, as in southern Europe, the *Lamp. Italica* is the luminous species, it is doubtlessly upon this that they made their observations. Besides this, there are three other species in Europe, *L. noctiluca*, *L. splendidula*, and *L hemiptera*, the second of which is common with us (Germany), the first is found in more northern countries, and the third in southern ones. The last is not deficient in the phosphoric light, as Illiger first thought, and, probably, it is also present in the numerous extra-European species of this genus. The most recent experiments upon their luminousness have been made chiefly upon the *L. noctiluca*, which is common in the south of England and in Sweden, by J. Murray †; upon *L. splendidula* by Macartney ‡ and Macaire §; and upon *L. Italica* by Carus ||. *L. hemiptera* was observed and described in detail by Müller ¶, and he also first discovered its luminousness, although the light was but feeble. Both sexes are luminous, as also are the *Elaters*, but the light is strongest in the female. In the *Lampyri* it does not stream from the thorax, but from the posterior extremity of the abdomen, where also, even after death, there are spots which are brighter than the rest of the integument, and it is these especially which shine. Besides the difference of light in the two sexes, there are others between them even in their external form. In *L. noctiluca*, the largest of the European species, the male, which has wings and elytra, is of a uniform brownish grey, with a reddish grey margin to the pronotum: the apterous female has a similarly shaped back, which is, however, of

* Plinii Hist. Nat. Lib. 18. c. 66. 2.—Aristot. Hist. An. l. 3.

† Experimental Researches, Glasgow, 1826.

‡ Schweigger's Jour. &c. vol. x. p. 409.—Gilbert's Annal. vol. lxi. p. 113.

§ Gilbert's Annal. vol. lxx. p. 265.

|| Analekten zur Naturw. u Heilkunde, p. 169.

¶ Illiger's Magazin. vol. iv. p. 175, &c.

but one colour, and it has a yellow-white, thin-skinned fat abdomen. In both, the luminous spots present themselves as four bright points, two of which are upon the antepenultimate abdominal segment, ad two upon the next one. In the smaller *L. splendidula*, the male, which is also winged, and is of a brown grey, has a bright glassy spot upon the convex margin of the pronotum: the female, which is entirely of a whitish yellow, and is brown only on the centre of the pronotum, has very short oval elytra, which merely cover the margin of the mesonotum, but it has no wings. In both the luminous parts are two transverse bands on the ventral side of the two penultimate abdominal segments, yet in the female the whole abdomen distributes but a weak light. With respect to size, *L. Italica* is between both; it is black, with a red prothorax and legs; two large white spots on the penultimate and antepenultimate abdominal segments display the light. In this species the female does not differ externally from the male; both are winged; yet some entomologists, as Rossi, Illiger, Carus, speak of apterous females, but they have certainly mistaken the larva for the female *. In *L. hemiptera*, the male has truncated elytra and the female none. It is also the smallest of all, being scarcely four lines in length, entirely of an opaque black, but which is lighter in the female, and the ventral plates of the penultimate and antepenultimate abdominal segments are whitish. But these do not emit the light, which is confined to two round spots on the penultimate segment. In *L. splendidula*, I have discovered the larvæ to be luminous. Müller was acquainted with the larva of *L. hemiptera*, but he does not say whether it gives light. The *L. splendidula, noctiluca* and *Italica* conceal themselves during the day, and only appear at night-fall, when, upon warm damp evenings, the male flies about, whereas the female sits tranquilly among the hedges and shrubs, betraying her situation to the male by her much brighter light. *L. hemiptera* creeps about also by day, but generally in damp weather; it also appears earlier in the year, namely, towards the end of April, whereas *L. splendidula* about the end of May and the beginning of June, and *L. noctiluca*, on the contrary, is found chiefly towards the end of the summer.

Their light is of a bluish white, and sometimes also of a greenish

* Touss. de Charpentier, Horæ Entomologicæ, p. 192. Pl. VI. f. 5 and 6. He also separates the larger specimens, as *L. Lusitanica*, and the smaller ones with a black spot upon the pronotum are, according to him, the true *L. Italica*.

or quite bright colour; it is strongest in the female, and shines uniformly, as in *L. noctiluca* and *L. splendidula*, but in *L. Italica* and in others * it varies in intensity in rhythmical vibrations; during the day it is not observed, and can be momentarily suppressed by night at the will of the insect. This they appear to do in moments of danger, at least I have often observed that those which I have caught with my hat during flight immediately ceased shining, and so frequently deceived me by my fancying that I had missed the creature, but I afterwards discovered it in my hat, when it again shone. The light is increased during motion as well as during exciting corporeal action, for instance, during copulation and in great heat, but which must not be much higher than 40° R.; cold, however, speedily destroys the faculty, and even at 10° beneath zero. If the insect be kept some days in the dark it entirely loses its luminousness, but regans it upon being again placed in the sunshine. After its death the light still lasts some hours and even days, and even afterwards can be re-produced by warm water or acids. All poisonous gases, which speedily kill the insect, destroy just as quickly its light; even in pure oxygen the light was indeed at first brighter, but disappeared at the death of the insect. In heated water, on the contrary, the light long continued in a temperature not exceeding 50° R., but immediately disappeared upon the application of greater heat, and also by degrees as the water cooled. Electricity has no influence upon the strength of the light, nor did it produce any luminousness in insects already dead, whereas galvanic electricity occasioned a much brighter light, and even re-produced the luminousness in dead insects which no longer exhibited it. But these effects are not produced in vacuum, nor if the creature be covered with oil. Upon anatomical inspection there was found at the shining spots a whitish, transparent, granulated mass, intersected by tracheæ, and which mass did not appear to be very different from the fatty substance. This mass shines also for a time when removed from the body of the insect, particularly in warm water, but it loses its light upon drying, but regains it for a short time upon being remoistened.

Among other beetles we find the *Scarabeus phosphoreus* named as luminous, and upon which Lüce has communicated some observations †.

* See Carus, at the above cited place, and in the Isis, 1824, vol. ii, p. 245, where it is related, that according to Long, a New Holland species also exhibits this rhythmical luminousness.

† Rozier, Journ. de Phys. vol. xliv. p. 300.

According to him, the insect which is found in the department du Var, in the vicinity of Grosse, in May and June, but which, with respect to its situation in the system, is no farther known, distributes a phosphoric light from its abdomen, that disappears when the beetle contracts it, but which remains with the juices pressed from the creature so long as they continue moist. *Paussus sphœrocerus* also, which is found on the coast of Guinea, and is remarkable for the singular globular form of its antennæ, its discoverer, Afzelius, observed likewise to emit a weak phosphoric light from the globe of the antennæ * ; the same is supposed of *Chiroscelis bifenestrata*, Lam., a beetle belonging to the family of the *Melanosoma*, which is provided with two oval, hairy, reddish spots upon its second ventral segment, and it is from these that the light issues †. From a communication of Latreille ‡ the large yellow spot is luminous upon the elytra of *Buprestis ocellata*, a very beautiful insect, native of China.

§ 281.

Instances of luminous insects not of the class of beetles are great rarities. Kirby and Spence observe that it is to be seen sometimes in the eyes of some nocturnal *Lepidoptera*, for instance, in *Noctua psoi* and *Cossus ligniperda*, and also relates an instance in which the common mole cricket (*Acheta Gryllotalpa*, Fab.) is said to have been luminous; but this faculty can present itself merely as an exception, for no other observations have ever been made upon it. Perhaps they had been in contact with rotten wood, which is also sometimes luminous, or with other rotting substances, and the light with a portion of the substance still adhered to them. The luminousness of the Brazilian lantern-fly appears more credible, from the positive assertion of Mad. Merian §. In this insect, which belongs to the family of the *Cicada* among the *Hemiptera*, the light is said to be produced from the large clavate frontal process, and to be so strong that a single specimen is sufficient to admit of reading very clearly by it in the dark. But this observation is not supported by the testimony of any modern traveller. Count Hoffmannsegg, supported by the communications of Sieber, was the first to attack as groundless this tale of Mad. Merian ||, and subse-

* Trans. Lin. Soc. vol. iv. p. 261. † Ann. du Mus. d'Hist. Nat. No. XVI. xxii. 2.

‡ Kirby and Spence, vol. ii. p. 471.

§ Mar. S. Merian de Generat. et Metam. Insect. Surinamensium, p. 49.

|| Magaz. der Gesellsch. Naturforsch, Freund Izu. Berlin, vol. i, p. 153.

quently the Prince of Neuwied * confirmed this contradiction, having never observed the least trace of a peculiar light in the *Fulgora laternaria*, Fab., which is by no means a rare *Cicada* in the Brazils.

§ 282.

These, therefore, are the collective instances hitherto known of a peculiar light emitted by insects. There are many opinions of the causes which produce this faculty, one of which lays most stress upon the influence of the nervous system, another upon the respiration, and a third upon the circulation. Others, but chiefly chemists, speak of a substance resembling phosphorus secreted by peculiar organs, and whence the light is emitted. Treviranus, however, who has anatomically inspected *Elater noctilucus*, as well as the *Lampyri*, say there is no organ anywhere situated that secretes the luminous substance, not even at the luminous spots, and that this quality proceeds from the fatty substance. This appears, as is confirmed by Macaire's investigations, to consist, in luminous insects, of a great portion of albumen, and to this some ascribe the faculty of being luminous, but it requires the peculiar quality, according to Macaire, of being semi-transparent. We know no instance of albumen itself being luminous, but must conclude that some other substance is incorporated with it, and that either this substance alone, or by its connexion with the albumen, is the cause of the light produced. The best known substance that produces light is phosphorus, which is abundantly present in animal bodies, and we therefore might ascribe the luminousness of insects to the phosphorus intermixed with their fatty substance. Phosphorus alone does not shine, but only gas charged with phosphoric vapour when coming into contact with oxygen, or if this be the saturated gas when this meets with hydrogen or azote, and this kind of mixture is only to be exhibited in luminous insects to explain the faculty peculiar to them. This, therefore, admitted, for a convincing proof of its presence has not yet been produced, it follows, as Treviranus accurately says, and observation has confirmed, that the insect is luminous not merely at its brightly coloured spots, but throughout its interior † wherever the luminous phosphoric combination is found; the brighter coloured or rather colourless spots, for the subjacent fatty substance is the cause of the whitish yellow colour, serve only to give a free passage to the light.

* Reise nach Brasilien, vol. ii, p. 111.

† See Treviranus, Biologie, vol. v. p. 475.

The observations that have been made under a variety of circumstances also tolerably harmonise with the conditions under which phosphorus is luminous, in so far as its light disappears in irrespirable gases, increases by warmth, but is destroyed, also like phosphorus, by cold, immersion in oil, alcohol, acids, saturated solutions of salts and alkalis, as also in vacuo.

If, therefore, phosphorus appears to be the substance which produces the light in insects, it may be asked, as phosphorus is not luminous in itself, what may be the conditions under which phosphorus is luminous? To this the above remarked differences of opinion especially refer. As phosphorus can only become luminous by contact with oxygen, if, therefore, we imagine it combined with the fatty substance, or with its albumen, respiration gives it luminousness; by means of respiration oxygen is deposited in the corporeal substance, and each inspiration therefore makes the beetle shine. Now, as we have before noticed, respiration being strongest during flight, it necessarily follows that the emission of light will also then be most powerful. In opposition to this the wingless state of the female might be urged, yet her short thicker body must contain more of the fatty substance, and must therefore emit a stronger light than that of the male. Next to respiration the circulation of the blood appears to have considerable influence upon the light, for we know that the substance emits the light only when moist. As, now, the blood flows all round upon the fatty substance, this may be considered as the moisture, which helps to support the luminousness. Carus has also observed that upon each pulsation, and consequently upon each fresh wave of blood, the light shines brighter. He refers to this also the brighter shining of the female, as she constantly dwells in dark, damp places. Thirdly, the nervous system may exercise a certain influence upon the production of the light, for as it is the chief agent of all the voluntary actions of the body, it will also necessarily exercise an influence upon the voluntary suppression of the light if the insect stops this influence by checking respiration in the way in which it causes the nerve to act upon the muscle in muscular motion. That it possesses this faculty of checking the respiration we know, but that this cannot be long protracted lies in the very nature of the thing, and thus by both causes the momentary cessation of light which is frequently observed, and which we have mentioned before, may be produced. Upon respiring anew the beetle would necessarily become again luminous.

SECOND SUBSECTION.

PSYCHOLOGICAL PHYSIOLOGY.

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§ 283.

After the consideration of the corporeal functions of insects there still remains a whole series of phenomena which are not the pure results thereof, but are superior intellectual functions, which may be exercised apparently at the will of the insect. Similar phenomena naturalists have observed, not in insects only but likewise in the higher animals, and in them very especially, and have found therein the analogies of the intellectual powers of man, yet with the essential difference that these phenomena in animals must necessarily ensue, whereas man, superior to the compulsion of nature, has the means of resisting this necessity by his volition. Hence the idea of freedom. Were the enjoyment of this freedom, and indeed especially of moral freedom,—for external freedom is merely the result of internal or moral freedom,—given to man by nature with restrictions, his intellectual superiority would then completely vanish, as he would then necessarily exercise all his functions within certain limitations, and never remain within these limits nor ever surpass them. His freedom then would also be merely apparent, and he, as well as all animals, would then be curbed by the chain of certain instincts, the satisfying of which would become a necessity. But man is free, that is to say, he has the faculty of in so far subjecting his natural instincts to other relations, either voluntary on his part, or introduced by social life, as the law of self preservation will admit, and may satisfy them at his own discretion; whereas the animal is not free, it exercises all, both corporeal and intellectual functions, from a determinate necessity, from which it has not the power of emancipating itself. Thence the entire greatness of man consists in his freedom, and in it consists the faculty of his progressive development or perfection, as well as the possibility of his degeneration, and which would place him beneath the animal. The animal is equally perfect in all its individuals; men are distinguished from each other as perfect or imperfect, according to the exercise of their freedom towards good or evil.

§ 284.

The phenomena thus characterised bear in animals the general name of instinctive impulses, and that which urges their exercise we call instinct; in man we call them intellectual phenomena, and their stimulant mind or soul. Instinct in animals, therefore, is the analogue of the soul in man; a soul differing only from the human soul by the necessity with which it does everything, whereas the human soul is independent of necessity, and freely resolves upon its actions. From this necessity, with which the instinctive impulses of animals act, ensues their determinate restriction in every species. The instinct of every animal is enclosed within a circle, which it cannot pass, and all the phenomena within this circle are repeated by every individual in the same manner. In them, therefore, there is no teaching or progressive perfection, but the young just born individual exercises all its instincts just as its mother did, without being in the least taught to do so. This unconscious execution of the first occupations harmonises with the desire of the infant for the mother's breast, and with its innate power of suction, that we cannot forbear considering both as quite analogous phenomena. But it is only during his nonage that man exhibits himself as an animal with innate skill; these disappear so soon as he becomes older and more developed, whereas they remain with the animal during its whole life. The celebrated wisdom of many animals is founded solely upon the faculty by necessity present in them, and what we admire is nothing more than the general law of nature, that for the attainment of their object they always select the best and most serviceable means. Necessity and suitableness are therefore as inseparable phenomena in the instinctive functions of animals as in the physical world are the ideas of life and action; they cannot be parted, one conditionates the other; for a necessary unsuitableness would destroy itself, whilst man, by the insight gained through experience and custom, is led to new endeavours, upon an ascertained unsuitableness, which at last conducts to the suitable accomplishment of his object. But the animal makes no essay, what it undertakes it succeeds in, and indeed with the least trouble, and with the least expense of force, as it seeks the easiest and surest way to its object. Yet this apparent choice is no choice, but iron necessity, which rules the life of all organisms, and which endeavours to dominate in the life of man, wherein it at first indeed acts promotive, but subsequently chiefly obstructive and restrictive.

§ 285.

But we, nevertheless, observe phenomena in many animals, and also in insects, which appear to be the result of a free and rational consideration, and of a certain degree of reflection; indeed experience, recollection, and memory are likewise perceived in them.

The reflection of insects consists in the choice of the best means to attain the object. There is nothing remarkable or astounding in this when we admit that nature for the exercise of every function of the insect has prescribed to it the way, and that we therefore observe all insects invariably follow this prescribed path. But there are facts which cannot be made to harmonise with this prescribed course. For instance, it is well known that when bees in the construction of their combs meet with objects that obstruct their progress in a right line, they avoid them by the change of its direction, before the comb touches the object, therefore by the immediate cessation of the continuation of the work in that direction. Darwin observed a sand-wasp (*Sphex sabulosa*) which wished to carry off a large fly that it had caught, but as it violently fluttered with its wings, and so hindered her own progress, she bit off its wings, and then flew off with it unimpeded. We must in these cases,—as in the organs of the body and their functions there is exhibited a certain faculty of adaptation to a determinate purpose, as, for example, the alternating secretion of one instead of the other, of the intestine instead of the skin, in rheumatic affections, &c.,—admit also of an adaptation of the instinct to new purposes, which expresses itself in the recognition of the necessity of a change of the function yet in action before the obstruction which obligates it absolutely obtrudes. It is evident that this recognition is a purely intellectual activity, which appears to contradict the prescribed necessity in the functions of animals. But this contradiction is only apparent, for nature has also prescribed the choice of the most serviceable means to the end, and this choice presumes a knowledge of difficulties and hindrances. Hence the instinct of the animal is competent to a partial quitting of the prescribed circle as soon as extraneous phenomena intrude into the actions of insects, which likewise lie beyond the circle of their usual functions, and this transit, this voluntary adaptation, still more convinces us that the instinct of animals corresponds to the soul of man, and that reason, which has been considered as the exclusive characteristic of man, is not wholly wanting in them.

The proof that insects acquire a certain experience, and are capable of combinations of what they have experienced, many bees exhibit to us, which lick with their long tongues the honey glands of flowers, and fly industriously around from one to the other. Thus, humble-bees, which cannot reach with their proboscis the nectaries placed at the bottom of the long tubular flower, open it at the side with their mandibles, and now passing their tongue through the aperture, imbibe the honey previously inaccessible to them. According to Ch. K. Sprengel, those flowers which contain nectaries are often decorated with radiating markings, generally red, which serve the insect as a mark of recognition. If such a recognition actually take place, experience which the insects have gained can be the sole instructor. According to Reaumur, the ants that have formed a dwelling in the vicinity of a bee-hive never enter it so long as it continues occupied by the bees, but laboriously collect their nectar from the *aphides* dispersed upon plants; but if a hive, of which the bees have been destroyed, be placed in the situation of the former one, they speedily visit it in large troops, and enjoy the honey undisturbed. Here, therefore, we again detect experience, viz. that the bees immediately destroy all visiters that intrude into their dwelling, as the warning instructress of the cautious reserve of the ants.

To the faculty of collecting experience, a second is superadded, which gives this experience its value, namely, memory. The experience gained must remain in constant recollection if it be to yield a constant advantage, and it is made so by a quality of the soul which we call memory. This quality is also attributable to the instincts of insects. The same as the swallow and the stork yearly return to their former dwellings, so does the bee each spring revisit her former collecting places, and the very same tree whence she gathered honey the preceding year. Among the many hives which may possibly be placed together, each bee accurately recognises her own when she returns from her journeys, and we never observe the neuters flying around other hives for the purpose of discovering theirs. This is not a mere recognition of the same hive from its external marks, but the bee exactly knows the spot where it is to be found, for if another have been put in its place, it will prepare within it, in conjunction with all its returning comrades, a new dwelling, supposing that the preceding one has been lost in the interim *. Kirby and Spence relate another still more striking instance of the memory of these creatures, in which a swarm from an old hive occupied a hole in the roof of a house, but were again removed by its possessor. Every year the envoys of the new swarms of the same hive regularly returned to this hole to convince themselves of its existence and suitableness, certainly a distinct proof of the remembrance of the discovered place among the older members of the hive. There are many instances of the memory of insects, which all, more or less, prove it to be a quality of their instinct. Thus, the *Odyneri*, which have found a hole for the dwelling-place of their young, constantly return back exactly to it when they quit it to fetch the young ones' provisions. If it be closed during their absence, on their return they seek about upon the wall, yet without entering other holes; if they again find it, they remove the obstacles and pursue their previous labours.

But the power of communicating to their comrades what they purpose is peculiar to insects. Much has been talked of the so-called signs of recognition in bees, which is said to consist in recognising their comrades of the same hive by means of peculiar signs. This sign serves to prevent any strange bee from intruding into the same hive without being immediately detected and killed. It however sometimes happens that several hives have the same signs, when their several members rob each other with impunity. In these cases the bees whose hive suffers most alter their signs, and then can immediately detect the enemy. But in what these signs consist is not known. The wasps also apprise their comrades of the place whence they fetch the materials of their nests, whence it happens that some always fetch the same material, for example, rotten wood; others a different material; and others, again, coloured substances.—The ants, also, can inform their own citizens of the presence of a choice morsel, for Kirby and Spence relate an instance where a pot filled with treacle was suspended from a ceiling, and which being discovered by one, she fetched a whole host of her comrades. In places distant from their abode, ants touch each other with their antennæ, so to recognise their friends and enemies, and, after having satisfied themselves, they pursue their journey. A remarkable instance of such a communication is related in Illiger's Magazine ‡, in which a

* Kirby and Spence, Introduction, vol. ii. p. 590.

† Germar's Magazin, vol. iii. p. 425. ‡ Vol. i. p. 488.

traveller observed *Gymnopleurus pilularius* prepare its ball of dung. This ball happened by accident to fall into a hole whence the insect could not remove it by all its exertions. It therefore apparently gave it up, but speedily returned with three comrades, and their united labours succeeded in accomplishing it. This instance is so remarkable, that we might be inclined to doubt its veracity were it solitary, but those above communicated are so analogous, that we cannot help considering it as true. They therefore prove that insects possess the power of communicating their objects to their fellows without the intervention of language, and that the imparting of determined objects must be classed with the qualities of insect instinct. We have thus found four important functions which are considered as the qualities of the human soul to exist even in insects.

§ 286.

If we now survey the several phases of the instinct of insects, we shall find that all refer either to the preservation of the individual or to the conservation of the species, and, consequently, stand in close connexion either with the several functions of insects, to provide themselves with subsistence, or with the suitable depositing of their eggs, the provision of their young, and their undisturbed development, &c. Between these two groups other phenomena present themselves which refer to both, we mean their connexion in large societies, which is peculiar to certain species, and which precisely furnish us with the most animated and comprehensive picture of the several intellectual activities of which insects are capable. We will, therefore, more closely inspect these chief functions of the instinct of insects, and, in the first place, those referring to self-preservation; then those referable to the conservation of the species; and, lastly, the societies and unions which have been observed in certain genera and species.

EIGHTH CHAPTER.

OF THEIR SELF-PRESERVATION.

§ 287.

The means which insects make use of for self-preservation are of two kinds, as they refer to their mode of procuring food and to their means of defence against their enemies. They both evince in so many instances an amount of sagacity, that we feel astonished at the apparent high degree of reflection and consideration announced by it; indeed they would absolutely convince us of a freer activity of the mind, did not the same phenomena of necessity and a want of freedom exhibit itself in as far as that every individual repeats the same processes in the same manner and in perfect concordance even to their minutest details, without having learnt it from its predecessors.

I. Means of Defence.

§ 288.

The means insects have received from nature for their defence may also be viewed under two aspects, namely, first, as a passive means derived from the form and structure of their bodies, and, secondly, as an active means of defence derived from the free exertion of strength on the part of the insect.

Passive means of defence are derived chiefly from the form and colour of the body, by their giving insects such a resemblance to the objects in or upon which they dwell, that upon superficial observation it is not easy to distinguish them from it. To give examples of this, we might remind our readers of the similarity of colour of many beetles to the ground upon which they are found. This is strongly exemplified in the large family of *Curculios,* in which the majority of the species of the genera *Thylacites, Sitona, Trachyphlœus, Cleonis,* &c. are of an earthy grey or yellowish, like the sand or loamy soil where they creep. *Thylacites incanus* is of a brownish yellow, like that of the colour of the earth of the woods covered with fallen pine leaves. *Thylacites* *geminatus*, in many districts a very injurious enemy to young vines, is of the same yellowish brown grey colour as the soil of vineyards. *Cleonis sulcirostris, Cl. glauca, Cl. marmorata*, &c., are greyish, like the dry light earth upon which they crawl. The resemblance is still more striking in those beetles which dwell upon a slippery clay soil, and which from their rough integument are unwillingly soiled with this clay, as, for instance, *Asida grisea*, *Brachycerus algirus, Meleus variolosus, Trox arenarius, Opatrum sabulosum*, and many others. Others, again, like our native tortoise-beetles (*Cassidea*) are generally of the bright green colour of the plant upon which they dwell. But the resemblance of insects in other orders to lifeless things is still more remarkable, namely, in the *Orthoptera*, in which many species of the genus *Mantis* resemble fallen and green leaves, both in form and colour, as *Mantis siccifolia, M. oratoria*, *M. phyllodes*, &c. The locusts also, which dwell chiefly amongst high grass and upon green plants, are usually of a bright grass green; others, as *L. Ephippium* and the *Grylli*, which prefer dry hedges and fields, are, like these, of a grey streaky colour and sculpture. This is also the case with many bugs, which, as they are deprived of all other means of defence, would necessarily become the easy prey of all enemies if they did not, as in the species of the genus *Aradus*, resemble the bark of trees where they dwell, or were they not, like the *Corei*, difficult to discern upon fields and hedges where they are found, from their grey colour. The same means of defence is possessed by many of the moths which, as it is well known, repose tranquilly during the day, and only fly at dusk. Many conceal themselves in the slits of the bark, and, consequently, from their conformity of colour, are easily overlooked. The caterpillars also of many *Lepidoptera* possess in their form and colour means to prevent their being observed, many of them being green, like the leaves upon which they live. Others, namely, the *Geometers*, so closely resemble the young twigs of trees, that even upon a strict inspection they are difficult to be recognised as caterpillars, particularly if they, as they not unusually do, stretch themselves straight out, holding only by their posterior legs, when they perfectly resemble a young leafless twig. I was myself once thus deceived by the caterpillar of *Ph. quercinaria*, Borkh (*Eunomus Erôsaria*, Tr.), mistaking it for a small dry twig, upon wishing to break off a small twig of oak, but I subsequently observed its motion, and then, upon a closer inspection, recognised it as the caterpillar of this moth. The caterpillars also of *Gastrophaga quercifolia*, of *Calocala Fraxini*, O. &c., very much resemble the dry twigs of trees, and the moth of the first also closely resembles a dry fallen leaf, and may thus easily conceal itself when it reposes motionless by day, as is the case with most moths.

As, in all the above instances, form and colour are the means of defence, in others, it is provided by the external integument and peculiar habits. Thus the caterpillars of most of the butterflies and the larvæ of the tortoise-beetles have a skin covered with simple or ramose spines, which clothing gives them a formidable appearance, and thereby partly, and partly by the pain which the spines give to the œsophagus, disqualify them for being the food of birds. Others are protected by their thick hairy clothing both against the prejudicial influences of the elements as well as from the attacks of insectivorous birds. The cuckoo alone, which likewise, from its other habits, is a most remarkable bird, not deterred by this fur from swallowing such caterpillars, and it is thence that its stomach is frequently covered inside with hair, an occurrence that has occasioned much dispute, as some naturalists maintain that this accidental clothing is the constant structure of the stomach. Among the habits which many insects find a protection from their enemies, we include that of many larvæ covering themselves with their own excrement, as is the case with the larva of *Lerma merdigera* and some others. They then resemble little lumps of dirt, and are certainly also regarded as such by many of the enemies of insects.

Other insects secrete peculiar fluids, in which they partly envelope themselves and partly thereby secure themselves from the attacks of their enemies. The *Aphrophora spumaria* is one of these, which envelopes itself in a thick white frothy fluid, that comes out of the anus. This cuckoo-spittle is found during summer upon almost all shrubs, and particularly willows; within it is seated the larva of that *Cicada*, which undisturbedly sucks its nutriment from the plant, constantly the while secreting fresh bubbles. The perfect-winged insect has no longer the frothy covering. We find other coverings in the *Aphidæ* and tortoise-beetles, which envelope themselves with a white woolly or fibrous substance, the origin of which we are not yet acquainted with, but it appears likewise to be produced by a peculiar secretion of the skin. Other insects, as the *Cantharides*, burying-beetles, carrion-beetles, carrion-flies, wasps, &c., emit, upon being touched, such a nauseous stench, that this must prevent every insectivorous bird from using them as food.

Another peculiarity which may be also classed among the passive means of defence is their tenacity of life, and for which they have to thank, in the first place, an organisation adapted to all possible circumstances, and, secondly, their hard exterior integument. The latter acquires in many insects, particularly the beetles, such hardness, that it is with difficulty that their elytra can be pierced. This is especially the case with the large *Curculios*, for instance, the species of the genus *Cleonis*, *Lixus*, *Otiorhynchus*, &c., then in the *Histers*, which have so firm an integument, that, upon any but a stony surface, they may be trod on with impunity, and are more easily pressed into the ground than crushed. This is partly the case also with the *Byrrhi*. This hard clothing is not found exclusively among the beetles; in the otherwise soft *Diptera* there is an instance of the kind, namely, in the louse-fly of the sheep (*Melophagus ovinus*), which cannot be crushed between the fingers; and the smaller parasites, as the louse and the flea, are difficult to crush in this manner. Respecting the tenacity of life with which they, even wounded or mutilated, resist death, we have before cited instances. Impaled insects will live thus for several weeks, and at last appear to die less from the effect of the injury than from hunger. I myself have kept *Blaps mortisaga* for three months without food; and Rudolphi mentions, in his "Physiology," an instance which Schüppel communicated to him, of an insect of the same family which this skilful entomologist received from the South of France, which, although impaled, arrived alive in Berlin, and here even continued still to live for some time. Other cases, in which beetles have been enclosed in wood for years without any food, have been communicated by other writers; and instances of insects remaining torpid in spirits of wine for several hours, and indeed days, and yet be re-aroused from their sleep upon being brought into the air, I have previously mentioned. They still longer retain their life in water. According to Lyonet, the caterpillar of *Cossus ligniperda* will live nearly three weeks beneath water; and according to Curtis, the plant lice will survive for sixteen hours in that element, but die if continued for twenty-four. Kirby and Spence relate, after Reeve, instances in which in warm fountains, the temperature of which was about 205° Fahr., he has found the larvæ of *Tipulæ*; and Good has observed little black beetles, probably

Colymbetes, in the hot sulphur baths of Albano, and which died when, placed in cold water. He himself found a specimen of *Lyctus Juglandis* Fab., in the warm dung of a hotbed, and cast it into hot water to kill it; after it had been some time there it was removed, and appeared dead, but speedily again moved, and entirely recovered. Reaumur and De Geer also relate instances of the larvæ of the gnats being found frozen in ice, and which revived when the ice melted. One of my acquaintances saw a *Dyticus latissimus* enclosed in ice, he took it out, and found it alive; and Alex. v. Humboldt found insects upon the Cordilleras above the limits of snow, which, although not natives of this altitude, yet retained their vivacity at this temperature.

§ 289.

The active means of defence which we find in insects are more numerous and more striking to the eyes. Some appear merely defensive, in as far as insects which use them can only protect themselves by attitude and appearance: among them we class the sudden torpidity aped by many insects in a moment of danger. Thus the minute *Agathidia* roll themselves up, and appear dead; thus the *Byrrhi* and *Anobia* contract their limbs, and pretend death so long as they are in the hands of their enemies. Others stretch out their limbs, as *Geotrupes stercorarius*, and thus imitate dead insects. Among the *Hymenoptera* the ruby-tails (*Chrysodea*) adopt the first plan of deceiving their enemies, by rolling themselves up when caught, and only arouse themselves upon the departure of their enemy. Others, particularly the tortoise beetles and *Curculios*, endeavour to secure themselves upon the approach of an enemy by suddenly falling down from the leaves upon which they were seated, that they may thus conceal themselves among the leaves and blades of grass; if they are found here they simulate death, but not with the obstinacy of the species of the preceding genera. Those active means of defence which may likewise be used as defensive weapons are very numerous, and partly consist in large mandibles and other pinching instruments, and partly in concealed stings. All the carnivorous beetles are furnished with the first kind of arms, namely, the *Carabi*, *Cicindelæ*, *Dytici*, *Staphylini*, &c. In general, however, the bite of these creatures is not injurious, and with the exception of the pain occasioned by the mechanical injury, the bite has no prejudicial consequences. Among the vegetable feeders also there are many, as the *Dynastes*, *Lucanus Cervus*, many capricorn beetles, and others, furnished, some with really large mandibles and others with processes upon the head and prothorax, which, like the mandibles, can meet like tongs, and thus serve as a weapon. This is asserted of the *Hercules* and its large comrades. Pincers of a different kind, as in the earwig, are likewise doubtlessly arms, but in general their possessors are too weak to wound the larger animals or man with them. The generally known means of defence of the bomb-beetle (*Brachynus crepitans*) is of a peculiar description: it consists in its ejecting from its anus against its enemy a vapoury moisture accompanied by a slight sound, and which vapour has great resemblance to the gas of aquafortis. It is not yet distinctly known what organ secretes this fluid; according to some it is the anal glands, which we have considered as kidneys; and according to others, on the contrary, the ejected gas is nothing else than the air accumulated in the colon. This opinion seems to be the most correct, for in the former we cannot distinctly see how the fluid contained in the bladders could so immediately be transformed into gas. Another mode of defence, which we have before mentioned, is allied to this, namely, the ejection of the corrosive juices of the stomach, which we observe in many of the larvæ of the *Lepidoptera*, in almost all *Carabodea*, and in the grasshoppers. It has evidently for object to deter their enemies, for it is only in moments of danger that insects eject it, and therewith soil their enemies, as in the *Grylli*, or project it against them, as in the rest. The sharp stinking urine of the *Dytici*, and the other secretions which we have before mentioned, are cast forth in the moment of danger to check the enemy.

We have before noticed some peculiar organs of secretion in several larvæ, as, for instance, in that of *Pieris Machaon*, which are projected at the approach of danger: they appear, in fact, to be glandular organs which partly secrete odours and partly liquids, for the purpose of chasing the enemy. In *P. Machaon* the furcate organ lies in the neck, between the head and prothorax, and the same in *Doritis Apollo*. In the larvæ of *Harpya vinula* it projects from the tail, in the form of a filament; and in the larvæ of the *Tenthredonodea* they lie between the five anterior pair of ventral feet, and are wart-shaped, transpierced protuberances, which project only during danger, and then emit a peculiar odour. In other larvæ they lie upon the back, as in the caterpillar of *Lip chrysorrhea*. Among the beetles similar organs are found in the genera *Cantharis* and *Malachius*, which in these are seated at the sides of the thoracic and ventral segments, and are likewise projected in times of danger. It is remarkable that these organs in all the preceding instances are of a red colour: it might be thence concluded that the substances which they secrete or contain are very rich in acids. The larva of *Chrysomela Populi* has likewise secreting organs upon its back, in the form of two conical knobs on each segment, whence, at a time of danger, a white, milky, and strongly scented fluid issues, which may also serve chiefly as a means of defence. In the processionary caterpillar, according to a recent discovery of Dr. Nicholai, the whole external surface of the skin secretes a sharp juice, which is distributed over the body in a farinaceous form, and which acts very prejudicially upon all organisms that inspire it; therefore workmen who are occupied in woods where this caterpillar is numerous sicken very rapidly. Bechstein knew that the processionary caterpillar was prejudicial to the touch, but he ascribed their effects to the hair that was removed by it.

Other larvæ, which have not received means of defence in such organs of secretion, nor in the thick hairy coat that envelopes them, construct cases for themselves, into which they retire upon the approach of danger. We find such among the larvæ of the *Coleoptera*, namely, in the larva of *Clythra*, which all dwell in cases formed by themselves, and in which they change into pupæ. Among the *Lepidoptera*, the remarkable genus *Psyche* forms such cases of morsels of wood, and there change into the pupa, and even the naked apterous female still continues to dwell in it. Besides these, the family of the *Phryganea* are furnished with this means of defence; their larvæ live in the water, and form cases of small stones, pieces of wood, shells, &c., which they also close with a distinct lid when they change.

The sting is the chief weapon of offence. The majority of insects furnished with a sting as a means of defence belong to the order of the *Hymenoptera;* it is but recently that a stinging lepidopterous insect has been found, and which we have before mentioned. It is always the female which possesses the sting, or else the neuters; the males never have it. We refer to the anatomical division of this work for its structure, and we can only say of the way in which it is used as a weapon, that the insect upon the approach of danger projects it from the abdomen, and thereby endeavours to wound its enemy with it. It is not so much the mechanical injury that occasions the pain as the poison which is injected into the wound. There are solitary instances of two or three stings being present at the same time, and which also wound in conjunction, namely, among the wasps, and in the genus *Onyderus*. I have hitherto neglected to inspect more closely the structure of this threefold sting, but I surmise that in this case the several setæ of which the simple sting consists are more remote from each other, and therefore project separately from the abdomen.

The stings of the *Diptera* are not weapons of defence, but organs whereby they may imbibe their nutriment. They are therefore only used for this purpose, and not as a means of defence. Among the *Hemiptera*, which likewise possess organs of puncture in the mouth, the latter may not be affirmed, for the *Notonecta* defend themselves with their proboscis, and their puncture, as was before mentioned, is very painful.

II. Instinct of Nutrition.

§ 290.

The food which insects take is more important to their self preservation than all these means of defence. We have before classed their chief kinds, and can here only make a few observations upon the way in which they procure it.

In the majority of insects this takes place without much art or exertion, in as far as the insect in its most helpless state, namely, as a larva, finds itself generally in a place where its food is very abundant. It has to thank its mother's care for this, for she lays the eggs mostly where there is food for the larva, or else provides it with food in its cell, in whichshe has enclosed the egg. But these instances do not properly belong here, but to the following chapter, where we shall speak of the means provided for the conservation of the species, and only such facts, as convince us of the instinct of the insect for its independent supply of food, shall here be mentioned. Among our native beetles the larvæ of the *Cicindelæ* exhibit these instincts. They dwell in sandy places, where they dig a cylindrical hole by means of their feet and mandibles, wherein they sit. They watch from this place of concealment all insects that pass by, and which heedlessly venture to the margin of the hole, when they fall in, and are then devoured by the larva. Miger, who first observed this larva *, has given a detailed account of its economy. The plan adopted by the larva of the genus

* Annales du Museum d'Hist. Nat. v. 14.

Myrmecoleon, in the order of the *Neuroptera*, is very similar to this, which is also found abundantly in sandy places, and here excavates a funnel-shaped cavity, at the bottom of which it lies concealed with its mandibles projecting, and it likewise seizes and sucks all insects which by mischance fall in, and then throws away the empty case by placing it on its head and giving it a jerk. These two larvæ are, however, almost the only ones in which we observe such striking and exceedingly sagacious methods of procuring their food, the majority of the rest of the carnivorous larvæ hunt about like the beetles for prey. The larvæ of the *Carabodea* are found especially in the earth, beneath stones, and in other nooks, where they prey upon the vegetable-devouring larvæ, which seek a place of safety. It does not, however, appear that the law that carnivorous animals shall not destroy other carnivora is strictly obeyed, for indeed the larvæ of one species frequently devour those of another, which Miger states of the voracious larvæ of the *Cicindelæ*. The black larva of *Calosoma sycophanta* devours with appetite the caterpillar of the *Lepidoptera*, especially that of *Liparis dispar;* consequently, where this caterpillar is abundant they are also abundantly found. They are then observed to pursue their food even by day, and knowing that the caterpillars are found especially upon trees, they themselves climb up and there attack them. It is chiefly in the morning about sunrise that they are to be found there; I have also detected the perfect insect in the same pursuit. We cannot, however, maintain that other larvæ possess peculiar instincts for obtaining their food. The vegetable feeders are deposited in the egg state by the mother in the vicinity of plants, where they find their food. This is likewise the case with the perfect insect. The *Lepidoptera* and *Hymenoptera* fly from flower to flower, visiting at pleasure now this and now that; insects which devour vegetable substances dwell in the vicinity of the plants which serve them as food, or if less particular in their choice, they feed wherever it presents itself; a few undertake wider migrations for theirs, as the locust, and devour every vegetable they meet with. But it is not a migratory insect in the same sense as in birds, but it is found almost all over Germany, sometimes singly and sometimes in bodies, but sometimes their numbers are so great that one district is no longer able to support them, and they then undertake their devastating expeditions. Other species of this genus also seem to possess this wandering propensity, at least the South

African migratory locust is specifically different from the European one. Whether the migrations of the *Libellulæ* have the same object cannot be ascertained with certainty, but it is improbable, as they are carnivorous.

NINTH CHAPTER.

OF THE CONSERVATION OF THE SPECIES.

THE SEXUAL INSTINCT.

§ 291.

The impulses which nature has implanted for the conservation of the species are more evident than those for the preservation of the individual. We have before hinted that all the several conditions of insect life appear to have for their chief object the conservation of the species, and we have also ascertained that the life of the individual terminates with its sexual activity, it having thereby fulfilled the object nature contemplated through its means, and it may then quit the stage. If now, therefore, we collectively comprise together the several phenomena which refer to the sexual functions, we shall find them to consist of two chief divisions, under which the various functions may be classed. These are, the impulse which brings the sexes together, the copulative impulse, and that which urges the impregnated female to take such care of her eggs and young that they may thrive under favourable circumstances, an impulse which admits of comparison with the maternal love of the human race, and which in insects also exhibits itself in the anxiety of the parent for her progeny.

I. Copulative Impulse.

§ 292.

This impulse presents itself in insects so soon as they have attained their perfect state, and it henceforward predominates throughout the life of the individual. The duration of the lives of insects depends upon their copulation, for the majority die speedily after its accomplishment, and only those which have been prevented from the act can survive longer. Hence copulation is the object for which Nature produces individuals, and she must necessarily be anxious for its most easy and securest attainment. We find several arrangements to promote this object, which facilitate the mutual meeting of the sexes, some of which are merely corporeal, and others are called forth by the instinct. In the majority of cases it is in the male that this impulse first becomes active, and it is therefore they especially which seek the female. When difficulty attends this, Nature has often provided peculiar organs to render it more easy. One of the most usual means consists in the males being more numerous than the females; indeed it is not possible to give the exact proportions of the sexes, but it is, according to De Geer's calculation, among the *Phalenæ,* about three to one; or, according to Lyonet, about four to one. Among the bees there are several hundred males and only one fertile female. Another means is the greater activity of the male. They are generally smaller in size, have longer wings, longer antennæ and legs, or have wings in many instances when the female is without them, as in *Lampyris, Symbius, Psyche,* many *Phalenæ* (*Acidalia brumata,* &c.), the *Mutillæ, Methoca, Myrmosa,* &c. Sometimes, also, the females have peculiar marks of distinction, as in *Lampyris,* in the female of which the light emitted is considerably brighter than that produced by the male. A reversed relation occurs in the *Achetæ, Locustæ,* and *Cicadæ,* in which the males are furnished with a vocal organ not found in the females. We observe the same phenomena also in the singing birds, among which the males only are the songsters. Thus Nature wished, by furnishing the males with distinguishing characters, to place them in a condition to lure the females from their hiding places, which in most of the mentioned instances it is their habit to resort to. Others, as the nocturnal *Lepidoptera,* have received for this purpose a very developed sense of smell, by means of which they can discover the female at considerable distances, to whom they immediately flock. I have myself observed males of *Liparis salicis* fluttering around my breeding-cage, in which there were several just developed females of the same species; upon my letting them into the cage they immediately copulated. This instinctive impulse, the satisfying of which nature has thus facilitated, is most conspicuous also in the *Lepidoptera.* The males of many *Noctuæ* will even copulate with impaled and half dead females, and the excitement of other insects occasionally urges them to an intermixture with individuals of a different species, and even of a different genus. Several such instances have been observed; Rossi *, for instance, detected a connexion between *Cantharis melanura* and *Elater niger*, the former the male, the latter the female; Müller, of Odenbach, observed a connexion between *Chrys mela graminis* and *Chry. polita*, and of *Attelabus coryli* and *Donacia simplex*, in both instances the first was the female; and Heyer, of Lüneberg, saw a female *Cantharis rufa* actually connected at the same time with two males. Treviranus † mentions other cases of such commixture, namely, one between a male *Melolontha agricola* and a female *Cetonia hirta*; and two others, observed by O. F. Müller, in which *Chrysomela Ænea* was connected with *Gallerucа alni*, and *Papilio Turtina* with *Papilio Janira*. It is uncertain whether such mixtures have been productive, but, from the analogy of the superior animals, we might say no; should, however, the copulation of closely allied species actually produce young, these would not be able to unite productively, as is proved by the general rule of analogous instances in the superior animals, yet this, even, is not without exception. Hence Gravenhorst's opinion, that from such bastard copulations of allied species many intermediate forms originate, must be totally rejected, exclusively of the view that in case of such a course in nature, its beautiful regularity and order would speedily terminate in illimitable confusion, of which, however, there is not the least proof.

II. Affection for the young.

§ 293.

The chief business of the male terminates in copulation; but it is this which first excites in the female the impulse that stimulates her to the completion of her most important occupation. This impulse henceforth exhibits itself to us in her affection for her progeny, it is the cause of her activity after copulation, and in aid of which her most distinguishing and remarkable instincts are developed. We will now survey these in detail in the several orders.

In the beetles this instinct presents itself almost solely in the suitable depositing of their eggs. Just as the birds of prey are not distinguished by any artificial preparation of their nests, so we may maintain of the predaceous beetles, that they, as those birds place their nests on elevated inaccessible situations, deposit their eggs in concealed

* Germar's Magazin, vol. iv. p. 404. † Vermischte Schriften, vol. i. p. 22.

and retired places safe from the attacks of their enemies ; it is, therefore, very rarely that we find not merely their eggs, but even their young larvæ. Nor do we know whether the mother furnishes them with food for their first supply, yet it is much to be doubted, as many of their larvæ, which as remarkable exceptions do not feed upon animal matter, as, for instance, the larva of *Zabrus gibbus*, immediately find in their vicinity a sufficiency of food in the young roots of corn *. Thus, also, the eggs of the water beetles may be deposited, without any particular care on the part of the mother, at the bottom of ponds and pools in which the beetles are, for the young larvæ will find in the water a sufficiency of other larvæ to feed upon. The modes of life vary considerably in the *Staphylini* in their perfect state, but the majority live upon animal substances. But the larvæ are rarely found, and least likely to be so there where we discover the perfect insect; we may therefore conclude that they also live beneath the earth, where they find their food in concealment. The larvæ of the carrion beetles are more visible, they are frequently observed in the society of their parents, and we may therefore conclude that the female deposits her egg in the carrion, where the young immediately find nutriment. In the large family of the *Lamellicornia* there exists a great difference both in the nature of the food and in their mode of depositing their eggs. The vegetable feeders lay their eggs in the earth, where we find the larvæ feeding upon roots, or even upon the soil; the excrement feeders, on the contrary, likewise dig holes in the earth, wherein to deposit their eggs, but they supply their larvæ with food, by rolling up balls of excrement, in which they envelope their eggs. We therefore occasionally find the beetle occupied in carefully pushing this ball along, as we have recently related of *Gymnopleurus pilularius*. *Copris lunaris*, which prefers the dung of sheep, is said to use the individual lumps of it as balls for her eggs, depositing a single one in each, and then burying them. Examples exhibiting greater skill are rare among the *Coleoptera*, yet *Hydrophilus piceus*, according to Miger, forms a little boat of substances which it fixes together by means of some viscid fluid, and herein depositing the eggs, closes it, leaving it to its fate. The capricorn beetles, and bark beetles, which busy themselves with the destruction of dead trees, lay their eggs in and upon them, generally beneath the bark, and it is their larvæ which gnaw the wood in all directions. The same is the case

* Germar's Magazin, vol. i. part i. p. 1, &c.

with the *Anobia* and the *Ptini*, but these prefer dry manufactured wood, paper, &c.; they consequently produce, in their larva state, the same injury to furniture and libraries. The fur beetles and fur moths also are destructive only in their larva state, and it is by the care of the mother that they are deposited in furs and wool, which they use as food. The *Chrysomelæ*, as larvæ, live upon leaves, and are deposited upon them in their egg state by the mother; the *Curculios*, which prefer especially the seeds of plants, are deposited in flowers as eggs, and during the development of the fruit they devour its substance, for which purpose nature produced them, and then, instead of a shell producing a kernel, it produces a beetle.

All the other orders furnish us with similar instances of the affection of the parent for her progeny. It would lead us too far were we thus to go through them individually to show their consimility by adducing instances; we will merely remark, that the large order of the *Lepidoptera*, throughout all its members, exhibits the same anxiety and care in depositing their eggs. Almost all caterpillars feed upon leaves, and therefore almost all eggs are deposited upon the plants themselves, or in their proximity. The majority are much exposed, and are therefore enveloped by peculiar coverings, which the mother, precisely as among the birds, procures from her own body. Others have, instead, a hard glue-like case, over which a second woollen covering is spread. The fruit moths deposit their eggs upon ripening fruit, unripe fruit they will not touch.

The eggs of the *Orthoptera* are deposited in general in the earth, usually in particular holes dug expressly for this purpose by the female, and which are again closed so soon as she has placed all her eggs therein. As the young immediately after their development seek the light, and feed upon leaves of all kinds, provision furnished by the parent was here also unnecessary; whereas the *Diptera* and *Hemiptera* lay their eggs generally in such places as the developed larva can immediately find food. We thus find the eggs of the *Syrphodea* among the plant lice, which the larva devours, or in the nests of the bees and wasps, whose honey they help to devour. The eggs of the true flies (*Muscæ*) are laid by the mother in dung or carrion, which substances constitute the food of the larvæ. The gnats let their eggs fall into the water; here the larvæ are developed, and one species of them devours the other with as much voracity as they themselves are again seized by the larger larvæ of the water beetles. The eggs of the bugs we find upon the leaves and stems of plants, the juices of which the larvæ imbibe; the same in the plant lice and *Cicada*, which select the same materials as food. The water bugs live as larvæ also in the water, and feed upon prey. We there find their eggs, but generally placed in rows affixed to the stems and leaves of plants growing beneath the water.

§ 294.

But the maternal care is exhibited most strikingly in the order of the *Hymenoptera*, and here presents itself in such a variety of forms that we cannot refuse ourselves a detailed description of this attractive subject.

The *Tenthredonodea*, whose larvæ, like the caterpillars of the *Lepidoptera*, feed upon fresh vegetable substances, cut with their saw-shaped ovipositor the surfaces of leaves, and in these incisions deposit their eggs. Here the larvæ develope themselves, and subsequently feed upon the same leaves. Thus their care for their progeny perfectly corresponds with that of the majority of other insects. The *Ichneumons* also are not distinguished by a greater anxiety from the rest; they deposit their eggs in other larvæ, particularly in the caterpillars of the *Lepidoptera*, and for this purpose they bore a hole with their pointed ovipositor in the skin of the caterpillar, through which the egg passes into its body. In the gall-flies the egg is also deposited in the parenchyma of the leaf, but steeped in a corrosive moisture, which occasions a powerful influx of the juices to the wounded part. This thereby grows gradually into a cellular body, the so called gall-nut, in the inside of which the larva lives, feeding upon the juices; it changes here into the pupa, and also into the perfect insect, in which state it pierces through the dwelling nature prepared for it through the care of the mother, and then first sees the light of day. But this care is still more striking in the fossorial wasps, all of which dig subterranean cavities, whither they convey insects which they have caught and killed, and in which they deposit an egg; the body serves the young larva as food, and the hole is a secure dwelling. We have before admired the strength and patience which many species of this family apply to the attainment of their object, and we then cited the large *Ammophila sabulosa* as the best known and most striking instance. During the summer we continually observe her incessantly employed in this labour; we may also admire her sagacity in the selection of a suitable soil, neither too loose nor too firm, and feel astonished at the apparent toil to which she must so repeatedly subject herself. But all the allied genera are subjected to the same. *Pompilus* and *Pepsis* proceed in the same way. *Pelopæus* constructs sinuous passages in old timber; *Trypoxylon* and *Crabro* seek such holes in walls and palings, and into which they convey the larvæ they have seized, and where also they lay their eggs. *Cerceris* and *Philanthus* likewise dig holes in the ground, but they select a loose soil, whence they are found most frequently in sandy situations. *Philanthus apivorus* is notorious as a dangerous enemy to bees, as it only makes use of the honey bee as food for its larva, and which it seizes wherever it finds them *.

Many wasps and bees have similar habits. The majority, however, excavate themselves the holes in which they deposit their eggs, and which they line with peculiar substances, either made by themselves or obtained elsewhere. But they are nevertheless distinguished from the former by their not in general supplying their larvæ with other insects or their larvæ †, but either with the pollen or the nectar of flowers, either in its raw state or previously prepared by them. Among the wasps this custom is found in the genera *Odynerus*, *Eumenes*, *Pterocheilus*, &c. They construct separate dwellings for their larvæ in clay walls or clay banks, and sometimes even form a tubular entrance to it, still further to prevent the intrusion of unwelcome guests. The egg is then deposited in the cavity, and provided with a lump of pollen intermixed with honey. Among the bees, the whole group of *Andrenæ* form such nests, yet not in walls, but perpendicularly in the firm earth. The depth of these shafts, which generally descend in a direct line, is not trifling, it frequently exceeding a foot; at the end of the shaft lies the egg, or larva, embedded, as it were, in a quantity of pollen and honey. Many true bees construct them similarly, but the dwellings of their larvæ are generally more artificially formed. Thus the *Megachiles* envelope both egg and pollen in the leaves of plants, which they cut off in pieces, and have gradually wrought together; the *Anthidia* furnish their entire cells with the woolly clothing of many plants, for instance, of the several species of *Stachys*. They thus form in the

* See a paper of mine upon this subject in the first part of the Trans. of the Entom. Society of London.—Tr.

† According to Müller's observations (Germar's Mag. vol. iii. p. 61.), the hornet supplies its young with the bodies of bees, both neuters and drones, as well as with the honey of flowers.

structure of their dwellings a tolerable transition to the elaborate dwellings of the social bees and wasps.

§ 295.

This indication shows that the nests of the wasps and bees which live in society are nothing more than dwelling-places for their progeny. This is their first and chief purpose, and all others which they at the same time execute proceed necessarily from this. If we examine this more closely, we shall find that among the wasps and the humble bees it is always the female which lays the foundation of such a dwelling. The impregnated wasp seeks a place where she can deposit her eggs, when she finds it she constructs a cell, and deposits an egg in it. Instead now of seeking another spot, like the solitary wasps, she remains where she commenced, and adds another cell to the first; thus the first layer is formed. In the interim the first eggs have become larvæ; these larvæ are now carefully fed by the mother until the time of their change into pupæ, when each closes its cell, becomes a pupa, and speedily appears as a perfect insect, which immediately participates in the labour, both in the structure of the nest and in feeding of the larvæ, and upon the increase of the number of those to be fed, by reason of the increasing fertility of the first female, the number of the nurses and labourers also increases, until at last from small beginnings a numerous society is formed. That the first born young wasps may immediately participate in feeding the younger larvæ, they are, as it were, placed in a maternal situation, and it is therefore that they are made barren by being prematurely ripe, and the one female function, that of conception and production, they sacrifice for the other, the feeding and nursing of the young, and it is hence that they are abortive females. Experience has proved that this abortion is produced by the defective feeding of a truly female larva.

If, now, we more closely inspect the several social communities of insects, the object of all of which is the nourishment of the young, the most imperfect of all presents itself in the society of ants. It consists of winged males and females, and apterous abortive females, called neuters, or workers, which are besides distinguished from the rest, especially from the females, by their smaller size. The dwellings in which we find these three members of a society of ants are found in the earth, and consist of passages which lead to larger vacant spaces, all of which again stand in connexion, and which generally have several outlets. The hollow spaces lie in several stories over each other, and are used only as rooms for the larvæ; the ants do not make a provision of food, but hybernate within their dwellings, from which they arouse upon the approach of spring. Their food consists of sweet animal and vegetable juices, which they convey also to the larvæ; they are particularly fond of the juice that exudes from the tubes upon the abdomen of the plant lice; they therefore not merely pursue these creatures, but also retain them in their dwelling. Their pairing time is August; immense multitudes of both sexes then quit their dwelling, and copulate in flight, especially towards evening, about which time they frequently fly up and down in the air in myriads. The males die quickly after copulation, whereas the females are either brought back by the neuters to their former dwelling, or else, either singly or in society, they found new dwellings, which they speedily populate with their own progeny. It is remarkable, that before the commencement of their new labours they purposely deprive themselves of their wings. The young, which pass but a short time in the larva state, during which they are fed by the mother, do not quit the egg before the following spring; and if neuters, they immediately after their development participate in the labours of the mother, they feed the larvæ, increase the dwelling, leaving nothing for the old parent of the nest to do: whereas in the old colonies, to which impregnated females return, or therein pair with the males, the eggs are not laid until the spring, until which time no young progeny is to be found in the nest. Thus the entire society of neuters, with the few impregnated females among them, and without any young ones, hybernate. As soon, however, as the first warm sunshine of the spring rouses them they re-commence their labours, they mend their dwelling, seek food, and convey nutriment also to the female. These then lay eggs, from which the larvæ soon creep, the whole development of which, from the egg to the imago, is so rapid that it is completed in twenty-three days. The males and females now present themselves, but they remain in the dwelling until the middle of the summer, and then quit it for the purpose of pairing. When this is fulfilled the whole series is repeated in the nests founded by the young impregnated females. In the progress of the several occupations exercised by the different members, and especially by the neuters, the ants develope striking art and proofs of the great perfection of their instinct. They always select sunny but not too dry places to lay the foundations of their nests, but they always avoid moist situations, and give considerable preference to the foot of a hollow tree, or its interior when it has but small accesses. They here labour with considerable industry in laying the foundations of the nest, each assisting the other, and in the course of a few days we perceive a structure rise having several outlets. If the nest be upon the ground there are generally affiliated colonies in its vicinity, which are in a constant animated intercourse with the parent state. This intercourse is facilitated by the construction of particular roads, which in a loose soil are tolerably deeply furrowed, and upon these roads we observe innumerable neuters incessantly coursing to and fro. All the obstructions that may here interrupt them are removed, each lends its assistance, and if there be at first too few for the purpose, by means of signs they urge other comrades to participate in the labour. Along these roads they convey into the dwelling the food for the larvæ, which consists in captured insects, caterpillars, small earth worms, and other, mostly animal, substances. We have before related that the ants possess the faculty of communicating their views to their comrades; all that requires the labour of many immediately occupies several, and to this participation they urge each other. Huber *, to whom we are indebted for the most interesting observations upon the economy of the ants, has observed them go out in troops to enjoy some dainty repast when such has been communicated by a compatriot, whither also more and more proceed, until at last nearly the entire population of the nest is found there. Once, upon separating a portion of the community, which he kept in a closed place for several months and then brought them back to the garden where the nest was, he observed their former fellow-citizens gradually emancipate them, after their dwelling had been discovered by some stray ones. But still more remarkable than all this is the warlike and predatory excursions which *Formica rufescens* and *F. sanguinea* undertake upon losing their young progeny of neuters. They then proceed in hosts to the nests of other ants, master its entrances, and convey away their young. These then grow up as helots in the foreign community, execute all the labour necessary for the advance and preservation of the state; they seek food, increase the building, sun the larvæ and pupæ, convey them back into the nest, and assemble with their subduers without recalling their disgrace. Thus originate the variously coloured and intermixed communities.

* P. Huber, Recherches sur les Mœurs des Fourmis Indigenes. Paris et Genève, 1810. 8vo.

§ 296.

The economy of the remaining social *Hymenoptera* differs from that of the ants by their constructing an artificial nest for the reception of the society, and not merely excavating cavities in the earth for this purpose. The wasps, which most closely agree with the ants in their societies, build some their nests in holes in the ground, and others pendant from the boughs of trees. The material they use is wood, either fresh or rotten, which they grind to a fine powder by means of their powerful mandibles, and then moisten it with a viscid liquid, which is probably the secretion of the salivary glands, when they prepare it into thin pasteboard surfaces. The size of the nest varies considerably; in *Polistes gallica* it consists of about twenty roundish cells, open beneath, which form a small convex comb, and which is attached to some object at its highest point; *Vespa holsatica* affixes a second larger, and sometimes a third smaller comb to the first, which are connected together by many perpendicular, tolerably thick pillars, and the whole nest is enclosed by two or three ovate cases, the lowest of which alone envelopes all three combs, each of the succeeding ones being about one-third shorter. The entrance to the interior is in the pendant apex of the first envelope. In the nest of *Vespa vulgaris*, which is placed in a large hole in the ground, the external case consists of a thick, tolerably strong pasteboard, formed of several layers, and the combs are more numerous, the central ones larger, and the entire nest attains about the size of a moderate melon. Others, for instance, the exotic species (*Vespa tatua*, Lat.), build a very large but similarly pendant nest, the entrance to which is also beneath, and the superior surface is covered with a multitude of conical knobs. *Vespa crabro* (the hornet) prefers the cavities of trees for her nest: it differs from that of the common wasp both in size, which is that of a moderate gourd, and also that the external envelopes are separated from each other by the space of at least half an inch, whence passages lead from the exterior to the interior; it therefore appears upon the first glimpse to be covered with large scales. The much smaller nest of *Vespa Germanica* is very similar, but it is placed in the earth, at about six inches from the surface; the form of the cells is originally, as also in the humble bees and bees, that of a cylinder, which subsequently, by the pressure of the rest, take that of a hexagon. This last regular form of the cells has ever been considered one of the most extraordinary things, and its precise repetition in all the societies of the *Hymenoptera* as a proof of the great skill of these insects; but nothing is more natural and necessary in the whole economy of the bees and wasps than this form of their cells; if, for instance, large soft tubes are to be so placed side by side that they may occupy the least space, the form conditionated by the point of contact, and the equal pressure upon all sides must necessarily be that of an hexagonal prism, as may be proved by mathematical demonstration. The bees and wasps, consequently, from the innumerable multitudes inhabiting a nest, or hive, must necessarily apply the smallest space possible to their structure, that they may be enabled to introduce a greater number of cells, and hence they become hexagonal: nature also only aims at what is necessary, and not at what is superfluous, and there would have been a waste had she allowed the bees to construct their cells independent of each other, for much unappropriated space would have remained. Besides, each cell is by no means so determinate an hexagonal prism, but rather a cylinder pressed flat by its contact with six other cells; no sharp angles are found inside, and the sides where the angles of three cells meet are thicker than where two cells lie contiguously with their flat surfaces. Among the humble bees, in consequence of the smaller number of the inhabitants of their nests, so strict an economy of space was not requisite, the cells but loosely touch each other, retaining their original round form flattened only at their extremities.

The inhabitants of a wasp's nest likewise consist of three distinct groups, namely, of males, females, and neuters, which last are also abortive females. The foundation of the community is laid by the female, and indeed very early in the spring. The impregnated female hybernates during winter in suitable places, without laying her eggs, and she first seeks, on the approach of spring, after being aroused from her winter torpidity, a place adapted to the structure of her nest, which she begins as soon as she has found such a situation. When the first cells, or the first and smallest comb is completed, she lays in each an egg, whence in the course of a few days a young larva creeps. These she feeds with the juices of other insects, especially of *Hymenoptera*, until they change into pupæ, when the larva closes the lower aperture with a web of silk. In the course of eight or ten days the young wasp presents itself, which, like all the following ones, is a neuter, and consequently a worker, which immediately proceeds with feeding the larvæ and increasing the nest. When all the neuter wasps are thus developed, the development of the male and female eggs which the old mother has laid in the interim is proceeding, while the neuters continue to increase the nest. The perfect males and females remain for some time in the nest, and it is only towards the end of the summer that they quit it. They now pair, after which the males die, but the females prepare for their hybernation. After the males and females have quitted the nest the community appears to have lost its importance, the neuters disperse, and soon die for want of food; the nest itself then loses also its consequence, its community is dispersed never to return again, and it falls to pieces like a deserted ruin. The skill and instincts which the wasps develope during their lives refer therefore almost exclusively to the preparation of their indeed very artificial nest; combined undertakings like those we observed among the ants, we do not detect in them, yet they nevertheless appear to possess a power of communication, for many of the neuters assemble if an enemy appear before their entrances, and endeavour to beat him to retreat by their desperate attacks. These troops are said to be assembled for battle by the guards placed to watch the entrance.

§ 297.

Among the social bees, the society of humble bees is the least perfect. It also consists of males, females, and neuters; and it owes, like that of the wasps, its first foundation to a female. For this purpose the impregnated female, which has lain torpid throughout the winter, seeks in the spring a place suitable to lay the foundation of her nest. She in general seeks shady places concealed among bushes and tufts of grass, where, with much labour, she digs a cup-shaped but yet very slight cavity, over which she spreads an arch, formed of light dry moss. The internal surface of this arch she clothes with a thin layer of wax, and attaches to it the first comb, consisting of large, oval, waxen cells, very loosely connected together. The entrance to the nest is beneath where the arch joins the margin of the hole, but in general a long vaulted passage leads from the exterior to it, that the entrance of enemies may be rendered more difficult. When the first cells are completed the female lays eggs in them, and then fills them with pollen and some honey, for the nourishment of the young. If this does not suffice she also feeds them. These larvæ merely produce workers, which immediately after their birth assist to feed the younger members, for which purpose they especially collect pollen and honey. The development of the neuter larvæ then proceeds, until all are perfected; when the old female lays male and female eggs in the new or cleansed cells. The neuters are chiefly occupied with feeding the larvæ thence disclosed; they are continually collecting honey, which they convey to the larvæ: this honey is also their sole nutriment, for they do not receive pollen, like the larvæ of the neuters. More honey is conveyed into the empty cells. These consist, singularly enough, not of wax, but of the web spun by the larvæ, which has previously transformed into the pupa state within the cell. When this web is completed the workers convey away the wax encompassing it to form new cells, and subsequently use the web as a jar for the honey. Towards the end of the summer the young of both sexes quit the nest, and pair at large; the males die, but the females return to the nest, where they hybernate in cells prepared by themselves, and filled with moss, and some occupy the succeeding spring the old nest, whilst the remainder go forth to form new ones. The neuters and the hybernating females live in the interim upon the collected honey.

Many writers speak of smaller females among the humble bees, as well as among the wasps, which only lay male eggs, and which appear either with the neuters or immediately after them. These are evidently neuters which have not wholly sacrificed their sexuality, and which are consequently capable of procreation. I doubt whether their existence be absolutely necessary, and also, notwithstanding the uniform assurance, that they lay only male eggs. Perhaps the female maggots, either as being superfluous or less perfect, by proceeding from a weaker mother, are killed, and only the males reared.—Among the bees we also occasionally observe fertile workers, or smaller females.

§ 298.

The society of the bees is doubtlessly the most perfect of all, and it differs also in many respects from those already described. It likewise consists of the same members, namely, of males or drones, and females or the queen, and the neuters or workers; we find a multitude of the first and of the last, but of females only one old one, and, according to the differences of season, two or three young ones.

The first founding and structure of the nest of a community of bees, which is called the hive, originates indeed with the female, but is executed by the neuters. If, for instance, an old hive be provided in the spring with a multitude of youthful progeny, so numerous that the old abode can no longer retain them, a great portion of the neuters, led by a single female, migrates or swarms, and proceeds to form a new colony. This swarming is repeated several times even in one hive, which may thus give rise to as many as four other colonies. The first swarm quits it about the middle of May, and the following ones from week to week, until the middle of June. The first that migrate consist chiefly of the older inhabitants of the hive, and their queen is also the old one who had hybernated with them; the subsequent swarms are led by young impregnated females. The swarm quitting the parent hive has at first no dwelling place, but the queen, after a short flight, settles at some spot, and all the workers accompanying her do the same around her; single neuters now fly forth to seek a place which the swarm can inhabit. They in general select for that purpose hollow trees, or other dry situations that they may meet with; when such a cavity is found the entire swarm, with the queen, immediately occupy it. So soon as the swarm has taken formal possession of the dwelling the neuters commence their labours: they first investigate all the entrances, and close all excepting one, which forms the true entrance, which is in general of but small compass, but which is decreased to the requisite size if it be too large. The material with which they close the entrances, and also cover the interior surface of the cavity, is called propolis, metys, pissoceros; it is a resinous substance, which they collect from the clammy and resinous buds of the birch, the sallow, poplars, chestnuts, &c: it differs from wax by its peculiar balsamic smell, by its combustibleness, and its resinous components. They do not appear to prepare it, but apply it to their purpose just as they find it. Their second building material, but of which the cells alone are made, is wax, which is a peculiar secretion of the bees; of the organs which prepare it we have before spoken. The tablets secreted between the ventral segments are removed as soon as a bee wishes to build, then crumbled and dissolved by means of the alkaline saliva into a pap, when it is applied to the construction of the cells. These cells they do not construct like the wasps and humble bees, in horizontal combs, but in perpendicular ones, which run from the summit of their dwelling to its base; both sides also of these combs are occupied by cells, and not, as in the former insects, the lower side only. The cells are of a roundish, slightly hexagonal form, and terminate at their base in triangular points bordered by indistinct rhomboidal surfaces, each of which borders a third of the opposite cell: thus each cell rests upon three of the opposite ones, and their centre meets exactly where the edges of the three cells join. This phenomenon, however skilful it appears to be, has but the object of saving all space, which could be attained by this and no other means, and which admits of being mathematically demonstrated. We here find another proof of the wisest adaptation to the purpose so constantly observed in nature; but the choice of means for attaining it must not be ascribed to the free intellectual power of the creature that employs it; it is but the expression of the eternal necessity and uniformity to which the instinct of the creature is subjected. The number of combs in a hive depends upon the space; the central one is first constructed, and brought down to the ground, on each of which others then follow at the distance of about half an inch from the first; thus by degrees the whole hive is filled with combs. The size of the cells also varies, the smaller ones serve for the reception of the neuters and the provisions, the larger ones contain the male maggots; for the royal maggots, of which there are from three to four in each hive, distinct cells are formed upon the margin of the comb, but which, however, never touch the walls of the nest. They are in the form of a very large, spacious, ovate cell, which is not horizontal, like the others, but perpendicular, opening beneath. The aperture is smaller than the body of the cell, and increases with the larva, for the neuters increase both the cell and the aperture upon the growth of the larva.

Being thus acquainted with the structure of a young bee-hive, we shall now pass to the examination of its inhabitants and their several occupations. After the workers of a young colony have built a requisite number of cells, others then busy themselves with filling them with honey; thus a portion of them are constantly occupied with enlarging the dwelling the while another portion are busied in collecting provisions. This gathering continues the whole remainder of the spring and summer, and is carried on even late in the autumn, and they do not cease until the flowers cease blossoming. The substance they collect is honey, a thick yellowish fluid, consisting of crystallising sugar, liquid sugar, and a peculiar viscid substance insoluble in alcohol, which the neuters imbibe by means of their long tubular tongue from the nectaries of plants, and conserve in their sucking stomach, which thus supplies the place of a crop; hence it is thrown up when the bees wish to get rid of it, when probably it does not repass through the tube of the proboscis, but through the aperture of the mouth, beneath the valve of the œsophagus, or second tongue.

During this time the true stomach receives no honey for digestion, but we invariably find in it a crumbly mass called bee bread, consisting of pollen, which constitutes the true food of the bees, and which alone is given to the larvæ as food. This mass of pollen does not appear to be received through the canal of the proboscis, but through the true aperture of the œsophagus. As soon as the colder season interrupts the collecting of honey the bees gradually become more inactive, when a few alone loiter about the entrance of the hive, whereas the majority are preparing for their hybernation within. They then so constrict the opening that one bee only can pass through at a time, they cling together in the hive, and appear to have lost much of their former vivacity; but they do not become absolutely torpid, but feed temperately upon the honey collected in the summer.

During this whole time the queen reposes quietly in the nest, enjoying the respect shown to her by the neuters. As soon as some of the small cells are completed for the workers she commences laying her eggs, impregnated by the preceding year's pairing, notwithstanding having previously laid many in the old hive; or if she be a young queen she will have been impregnated by the drones of the old hive prior to her quitting. In the course of three days after laying the egg the young larva is disclosed, which is full grown in five days more; the larvæ then close the cells themselves, in three days more they become pupæ, and in the course of seven days and a half the perfect bee comes forth, thus its development is completed in the twentieth day after the laying of the egg. A great number of workers being thus born, the queen begins to lay male eggs in the larger cells, and from three to four female ones in the royal cell. When the old queen has laid all her eggs she dies, and the hive is without a head until the young royal larvæ are developed. This the bees bear very quietly, whereas the loss of the queen without the survivance of a royal progeny produces the total dissolution of the society. But if the young royal maggots are developed whilst the old queen still lives she kills them, which the neuters freely allow; it will therefore sometimes happen that a swarm, after the female has laid all her eggs, is without a royal successor. This evil it is said the neuters remove by transferring a one-day old maggot from the cells of the neuters to the royal cell, where they rear it with superior food, whence a queen is developed. The correctness of this assertion, which is however supported by many direct observations, has been doubted, and Treviranus has endeavoured to deny it, but it has so much analogy in its favour, and is related by such credible observers, that it may really be considered as a fact. Thus, therefore, the hive receives a new queen when the old one dies. This new queen quits the dwelling, in company with the drones, in the middle of summer, pairs with some of them, and then returns impregnated to the hive; she is here then treated with greater respect than before, she is stroked with the antennæ, licked with the tongue, and they on all sides offer her honey. Forty-six hours after pairing she lays her first egg, and then continues uninterruptedly until the 1st of November, from whence until April she ceases, but which she again resumes in April, upon the return of fine weather, when the workers again collect. Now, after having laid none but the eggs of neuters, she lays about 2,000 male eggs, whence, at their appointed time, the drones proceed. From this time until their pairing with the female they live undisturbedly in the hive; they fly out for food and again return, but they do not form cells or collect honey, and do nothing else than go out to feed for their own support. At the time of pairing, which takes place in June, a great multitude of them fly out with the queen, and return again after she has paired with one of them, for which it sacrifices its life; for, according to Huber and Audouin, the penis torn off remains for some time in the vagina of the female, fixed in the neck of the spermatheca. The remaining drones quietly rest until August, even after the remaining young queens which lead out the subsequent swarms have been impregnated by them, but at this period the general slaughter of the drones commences, in which, in the course of three days, all the males are destroyed by the neuters, and even whilst still living are cast from the hives. Thus, without males, and provided with one female, who is however impregnated, and without any progeny for males and females, the inhabitants of the hive hybernate as well as the young maggots of the workers, all subsisting upon the collected provisions. It is then also the time to destroy the hive, to remove the bees, and to take their honey.

The instincts developed by the bees during their life are extremely remarkable and surprising. Their attachment to the queen, their endless anxiety for her welfare, the affection and self sacrifice with which they rear the young, have ever excited the greatest admiration, and also well merit it. No individual bee cares for herself, her whole anxiety is for the entire community, and so long as she perceives that her labours do not miss their aim—the preservation and prosperity of the hive, she is contented with her fate. But as soon as by the death of the queen this prospect is obstructed, by there being no possibility of obtaining a new queen, she becomes depressed, without courage, ceases her work, and is lost in the conviction of having lost her labours. We cannot here relate in detail the several phases and very special facts which exhibit the comprehensiveness of her instinct, and they are the less necessary as other works fully show them; we therefore refer to the Introduction of Kirby and Spence, as well as to the admirable work of Huber *. As willingly as we could wish to refer the actions of the neuter bees to reflective powers, we yet feel ourselves obliged to deny them this reasoning; they act rather from eternal invariable laws, for they have added nothing to it in so many thousand generations, nor have they lost anything, which therefore announces their want of freedom, as well as the other side the endless wisdom of nature is clearly exhibited in the consistency and suitableness of all their proceedings. They are but the wheels and instruments in a higher hand, imperceptible to us, and still more so to them, which holds the universe; and to which science must always refer, but which is depicted to the fancy in a beautiful and attractive image. What Johan von Müller † has expressed to be the result of his researches into the history of the human race we may apply to the life of bees, to the actions of the rest of the world of insects, and indeed to the great effects of organic nature in general. The whole is an infinite machine, to whose eternal motion every individual, be it plant, animal, or man, must contribute, and he who of all that can obey this law is wantonly deaf—he is judged.

§ 299.

There are two orders, namely, the *Neuroptera* and *Dictyotoptera*, to whose care for their young we have as yet paid no attention, and to which we now therefore proceed. Among the first, the young larvæ of the *Semblodea* and *Phryganea* live in water, and without any especial care on the part of the mother, are confided to this element. We are still ignorant of where the eggs and larvæ of the *Panorpæ* are to be found, for their larvæ are as yet unknown. The larvæ of

* F. Huber, Nouvelles Observations sur les Abeilles; addressées à M. C. Bonnet. Genève, 1792. 8vo. Nouvelles Observ. sur les Ab. Paris et Genève, 1814. 8vo. 2 vols.

† Vier und Zwanzig Bücher Allgemeiner Geschichte, vol. iii. p. 532.

Raphidia live in the stems of pines, and here hunt up their food, which consists in other insects; we might doubtless find their eggs there also, and presume that they are deposited by the mother at suitable places upon the stem. The larvæ of *Myrmecoleon* and *Ascalaphus* live in the sand, the first, as we have before mentioned, in pitfalls made by itself, where it watches for prey; the mother doubtlessly therefore conveys her eggs there, and deposits them in suitable places, sheltered from the weather and from enemies.

The same is doubtlessly the case among the *Dictyotoptera*. The parasites, or *Mallophagi*, deposit their eggs at the base of the feathers or hair of those animals upon which they dwell, and upon which their young are to reside. It is not yet known where the eggs of the *Thysanura* are placed. The eggs of the *Ephemeræ* and *Libellulæ* are deposited in the water, where the young also dwell, and they are laid singly, the mother the whilst fluttering over the water. To conclude, the last families of *Psoci* and *Termites* differ considerably from each other in their modes of life. The majority of the species of the genus *Psocus* live in the old stems of trees, and here appear to hunt for prey: *Ps. pulsatorius* is a voracious enemy to collections of insects, and it will devour dry animal substances, namely, the smaller soft-winged *Diptera*; it doubtlessly, therefore, deposits its eggs in the vicinity of such things, and there leaves them to their fate. This the *Termites* do not do, but they build dwellings similarly to the *Hymenoptera*, where they lead a still more artificially regulated social life. We indeed possess several treatises upon the remarkable economy of these insects, distributed between the tropics (two species are found in the South of France), and especially an early one by Smeathman *, but still their complete economy is not fully illustrated, in as far as these tracts contain so much that is striking and divergent that it cannot well be compared with the social life of other insects. Their community is said to consist of five different members, namely, winged males and females, apterous neuters, or soldiers, which have large heads furnished with strongly projecting mandibles, unwinged pupæ, having a smaller head and the rudiments of wings only, and lastly, of similarly formed larvæ, or workers, differing from the latter only in wanting the rudiments of wings. The last of these construct the dwelling, in which they are assisted by the

* Phil. Trans. vol. lxxi. 1781, completed from more recent observations in Kirby and Spence, vol. ii.

pupæ; the neuters are the guards at the entrances, and defend the nest against enemies; the males and females are inactive, and remain until they pair in the nest, they then fly forth, pair, and a single couple of them are conveyed back again into the nest by the workers, and here kept prisoners; the rest die or are destroyed, losing immediately their wings, when they are quite helpless.

If we receive this description as true, particularly as the *Termites*, according to general assertion, belong to the tribes with an imperfect metamorphosis, and therefore might be active and industrious in their larva state, yet the circumstance of its being without any analogy in the whole animal world may be urged against it; we have no other instance of the young still undeveloped labouring for the old, and which as larvæ and pupæ they must necessarily be. Besides, the assertion that the neuters are apterous is not correct, for I have had the opportunity of dissecting winged *Termites*, through the kindness of the Privy Councillor Klug, the Conservator of the Royal Berlin collection, and I did not find the least trace of either external or internal genitalia: nor had they the large head with projecting mandibles, but one perfectly corresponding with that of the males and females. But these *Termites* readily lost their wings upon the least touch, and retained but a small triangular basal piece at the thorax. There is, namely, at the base of the wing, close to its root, an apparent joint, in front of which the wing is horny, but behind it soft and membranous, and provided only upon its anterior margin with ribs. The wing is easily broken off at this joint, and therefore the neuters very speedily lose their wings, but they are not, as maintained by writers, wingless. Nor do I see why the neuters should be merely the defenders, as these among all other social insects are the true workers. If it may be allowed to start hypotheses upon subjects that can only be satisfactorily explained by experience, we might also, with reference to the society of the *Termites*, admit of the community consisting of merely males, females, and abortive females, or neuters, and that the latter were likewise winged, but from external causes speedily lost their wings after their development. To these might be added the larvæ and pupæ which would intermix with the swarms of neuters, but not participate in the labours; they have no wings, and consequently resemble the neuters when the latter have lost them, thence has sprung the assertion that the larvæ are workers. The larvæ and the pupæ, in consequence of their much greater voracity, may especially contribute to the destruction of furniture, as well as of all other dead vegetable substances, and are therefore, as well as from their being necessarily the most numerous portion of the community, the most dangerous members of the society. For instance, the *Termites* have a habit of gnawing all dead vegetable and animal substances which they can reach, and so vexatiously to mankind that they merely destroy its interior, leaving the external form unchanged. They thus bore the balustrades of houses, excavate the planks of the floors, tables, chairs, and all kinds of household furniture, and they frequently leave so very slight a case remaining that the whole falls to pieces upon the least touch. Man has therefore much difficulty in defending himself from these concealed enemies, and finds his only means of escape in leaving those parts inhabited by *Termites* unoccupied. The *Termites* gnaw these objects chiefly to obtain thence the materials for their buildings, or even also for food. The building that they construct is often of the shape of a sugar-loaf, and about twelve feet high, which gradually grows from several small towers of the same description. When, for instance, they have raised a small cone of about one or two feet high, they lay around the foundations of several similar cones, which are contiguous at their base; these are then connected together by a thick wall, which is continued by degrees in an oblique direction, until a cone of the given size is thence constructed. Whilst they are still building, the original small community inhabits the interior of the central cone; this has in its middle an arched cell about an inch thick, which is on the same plane with the ground, and in which the old male and female live. In the circumference of this cell there are many smaller ones for the soldiers, and around these again others for the eggs and provisions, which consist of collected drops of gum, pieces of wood, and other substances which they have found upon their desolating forays. When the large arch is completed they remove the apex of the first cone, the entire surface of the described cells is flattened, and here, as well as upon the walls of the arch, new cells are constructed for the provisions. Passages which run along the wall of the arch lead to their upper cells, and bridges are sometimes constructed, which spring from the surface above the royal cell, and extend to the internal wall of the arch. The materials of which they form this structure is clay and earth, which they artificially combine together, it then speedily dries in the sun and becomes a hard, firm covering, that in time is covered with grass, and will easily bear the weight of a man; the internal cells, especially those for the eggs and provisions, are doubtlessly constructed of splinters of wood fastened together with gum. All these cells are connected by means of small apertures, and several apertures also open from the surrounding spaces into the central royal cell; the exterior outlets are not perceptible, they lie at the foundations of the house, and consist in passages, which also pass beneath the earth, and only at distant points open to the surface. At these the *Termites*, which pass in and out, present themselves.

The following is the economy of the state:—At the termination of the hot season, when the moderated temperature of the rainy period announces itself by cooler winds, the young males and females disclosed in the nest quit it, and appear upon the surface of the earth; here they swarm in innumerable hosts, and pair. The busied workers then convey a pair back into the dwelling, and imprison them in the central royal cell, the entrances to which they decrease and guard. Through these apertures the imprisoned pair then receive the nutriment they require. The male now, as among all other insects, speedily dies after copulating, but the female commences from this period to swell considerably from the development of the eggs; this swelling continues until the time of her commencing to lay them, when her abdomen is about 1,500 or 2,000 times larger than the rest of her body. During the period of this swelling the workers remove the walls of the royal cell, uniting the nearest cells to it, so that in proportion to the increase of the body of the queen the size of the cell she inhabits is also increased. She now commences to lay eggs during the constant undulating motion of her abdomen, which exhibits the peristaltic motion of the egg-ducts. The eggs are conveyed away by the workers as they are laid, and conveyed to the distant rearing cells. It is impossible to give the exact number of the eggs laid, but it must be enormous, which is proved as well by the size of her abdomen as by the long time she is laying them, as well as by the number she lays in a minute, namely, sixty. In these nursery cells the larvæ are first fed by the workers, they afterwards intermix among the workers, and participate in their destructive expeditions, which they make without any impediment, by means of their subterranean passages to the vicinity of the substance they purpose to destroy. Thus far extends the information of naturalists who have travelled. They are silent upon the mode in which a new colony is founded, and what induces the old ones to their formation, and we may, if we will not remain wholly dark upon the subject, start the hypothesis that the communities of *Termites*, at the time when the number of the inhabitants of a nest is too numerous to admit of its accommodating them all, swarm in a similar manner to the bees. But such a swarm would only consist of workers and soldiers, which select at the time of pairing a couple from the numerous royal pairs, and raise them to be the lords of the colony.

We terminate here with the consideration of this family, in which the interesting facts of the earlier ones are again repeated, the description of the intellectual impulses that have appropriately been designated as instinctive phenomena, as perfectly as a short outline will admit. As anxious for self-preservation, and therein exhibiting especially its intellectual functions, the insect steps forth into the series of independent organic beings, and as still anxious for the conservation of the species, it again quits this large community. It was requisite to illustrate this result, already expressed in the introduction to the second chief division, as concisely as possible, and therefore all facts which remain more or less isolated were necessarily omitted. This we could the more satisfactorily do, as another work, to which we have here frequently referred, as well as below, has endeavoured to give a similar solution to the same problem, yet with infinitely greater detail; we mean Kirby and Spence's Introduction to Entomology, a book which, for the animation of its description, fidelity of portraiture, and fulness of facts, vainly seeks its equal, and will with difficulty be surpassed. We will therefore refer our readers to it, who may here have observed many defects, and none, we can assure them, will quit it undelighted or without regret.

THIRD SUBSECTION.

RELATIONS OF INSECTS TO THE EXTERNAL WORLD.

§ 300.

We have now become acquainted with both the corporeal and intellectual natures of insects, and might therefore consider their general natural history as concluded; but having as yet left untouched one portion of the history of the lives of these creatures, namely, their relation to the rest of organic nature, we will therefore appropriate a few pages to the investigation of this subject. That the whole of organic nature stands in close connexion together must be evident to every one who has paid the least attention to the subject. When the plant dies it becomes the parent of a thousand others, all chiefly indeed of lower station; the animal supports itself by deriving its nutriment from the vegetable kingdom, and then itself supplies other animals, which are not appointed to feed upon vegetables, with means of preservation. This relation of insects to the vegetable kingdom and to other organisms will form the immediate subject of our present investigation; we shall here class the conditions under which the insect continues in the external world, in so far as it is only by this favourable relation that that first object is attained, and these we distinguish as the places of resort and the distribution of insects; their geographical division should form a component part of this chapter, and we may then devote our attention to the insects of a past creation, concluding their general history with this last inquiry.

TENTH CHAPTER.

INSECTS IN RELATION TO OTHER ORGANIC BEINGS.

§ 301.

It is a proved fact that all animal bodies derive their nutriment originally from the vegetable kingdom. In no class of animals is this more evident to us than among insects. We have before seen, where we spoke of the food of insects, that vegetable substances constitute their chief subsistence, and that entire orders, as, for instance, the *Lepidoptera*, from the first moment of their existence, feed upon nothing but plants and their juices. In the innumerable multitudes of different species, and the hosts of individuals of one species, this might eventually prove injurious to the vegetable kingdom, if also many insects did not likewise aid to promote the growth of plants. This observation leads us to recognise the true relations of the insect to the vegetable world, and whilst discovering this we perceive at the same time the precise object nature accomplishes in its capacious economy by means of insects. It is double; in the first place to set a limit to the preponderating increase of plants, and also, as such a relation might easily degenerate into their total destruction, it is also careful, by another course, of preserving the vegetable kingdom.

The first object is attained by means of those insects which derive their nutriment from vegetable substances, consequently by means of those which devour leaves, flowers, wood, fruits, and their seeds. These organs provide for the continuance of plants as individuals or species, and every plant would more or less suffer if one or all of them were totally destroyed by insects. Let us examine this more closely in individual instances.

§ 302.

With respect to those insects which destroy the roots of many plants, and thereby restrict their superfluous growth, we must remark, that it is generally larvæ only which feed upon that part. Among the *Carabodea* the larva of *Zabrus* belongs to these, for in the spring of the year 1812, in the vicinity of Halle, whole corn-fields were devoured by their voracity *. During the day it buries itself six inches deep in the earth, and towards evening it comes to the surface, and then eats into the pith of the roots, biting off the blade closely above the ground. Thus in the above year twelve hides of wheat, rye, and barley were destroyed. As the genus *Amara*, which is closely allied to *Zabrus*, has in its perfect state a very similar mode of life, particularly the division of it known by the name of *Leirus*, we may conclude that their larvæ also live upon the roots of grass. We may perhaps also class here the larva first described by Walfrod, and which he considered as a wire worm (the larva of *Elater segetis*, Gyll.). Kirby and Spence † consider it as the larva of a *Staphylinus*, but this is contradicted by the difference of the mode of life of the other individuals of this tribe. It lives, namely, at the roots of wheat, devours the just germinating grain, and in older plants it consumes the root only. According to Sir J. Banks the same larva destroys turnips, and sometimes from forty to fifty individuals are found in one root.

In addition to these it is especially the larvæ of many of the *Elaters* which attack the roots of corn and other plants. We know that the wire worm, which is the larva of *Elater segetis*, Gyll., (*E. lineatus*, Lin., *E. striatus*, F.), feeds upon the roots of corn, as well as that the larva of the allied *Elater obscurus*, Lin., (*E. variabilis*, Fab.) feeds upon the roots of almost all kinds of garden plants and culinary vegetables, and sometimes, in places where they have much increased, produce great injury.

The majority of the larvæ of those *Lamellicornes* which in their perfect state feed upon leaves, as the *Melolonthæ* and *Cetoniæ*, devour, in that state, the roots of plants; these thick, fat, yellowish white larvæ are well enough known to farmers, and frequently produce great injury to corn. Multitudes of the larvæ of *Melolontha ruficornis* actively participated in the devastation committed by the larvæ of *Zabrus gibbus* in the vicinity of Halle. The more numerous and more generally distributed larvæ of *Melolontha vulgaris*, the common cockchafer, are not less injurious, particularly as they pass several years as larvæ, and every year new ones are produced. An instance occurred near Norwich, in

* Germar's Mag. vol. i. part i. p. 1, &c.

† Introduct. to Entom. iv. Letter xlv.

which all the fields of a farmer were entirely destroyed, and he and his labourers collected eighty bushels of them. The larvæ of *Hoplia pulverulenta, H. graminicola,* and *H. argentea,* dwell in humid meadows, where they destroy the roots of the different grasses. Some few years ago I myself discovered all the blades of high grass of this description completely covered with the perfect *H. argentea.*

It is especially among the *Curculios* that we find larvæ which are destructive to roots; but less so among the other families, yet the larva of *Lathridius porcatus,* according to Kyber *, feeds at the roots of *Rhaphanus sativus,* and especially in that of the variety known by the name of the radish. Kirby and Spence reared from a small larva that was found in the root of *Sinapis arvensis* the *Curculio contractus,* Msh., and the *Rh. assimilis,* Fab., two species of insects belonging to the genus *Ceutorhynchus,* which, even as perfect insects, like all their congeners, attack the young shoots of plants.

Besides the above larvæ of the beetles, many of the maggots of the *Diptera* are fond of the roots of plants. Thus the maggot of a fly has been found in a carrot (the root of *Daucus carota*), but it was not reared; in the radish (the root of *Rhaphanus sativus*) the maggot of *Anthomya radicum,* Meig.; and in onions a similar maggot, which produced a fly that Kirby and Spence call *Scatophaga ceparum.* Other dipterous larvæ Reaumur † found in the bulbs of the narcissus, and reared from them a fly belonging to the family of the *Syrphodea,* which Meigen calls *Merodon equestris.* The root also of the cauliflower feeds the maggots of flies; in that, as well as in the other varieties of the cabbage, is found the maggot of the *Tipula oleracea,* Lin.

Although the majority of the caterpillars of the *Lepidoptera* feed upon the leaves of plants, yet there are some which prefer their young roots; thus the caterpillar of *Noctua* (*Episema,* Tr.) *graminis,* Fab., which consumes the tender roots of the softer grasses, and spares the elder harder ones, for instance, those of *Alopecurus pratensis,* Lin., as well as those of corn and of the *Trifolium pratense,* Lin. ‡

§ 303.

Those insects, however, are more numerous which either bore into the stems of plants or into the woody trunks of trees; but their pre-

* Germar's Mag. vol. ii. p. 1, &c.

† Mémoires, vol. iv. part xxxiv.

‡ Ochsenheimer Schmetterlinge von Europa fortges. von Treitschke, 5 t. part i. p. 122.

sence does not in general so speedily occasion the death of the plant, as the stem is a larger and less easily wounded organ than the root.

Among the beetles we may place here the several boring and bark beetles that form the family of *Deperditores* (*Xylotrogi*, Lat.) and *Bostrychodea* (*Trogositariæ*, Lat.), as well as the large family of the *Cerambycina*. The majority, however, destroy the woody substance of the stem in general only when the tree is felled or already prepared for manipulation, in the latter case especially it is attacked by those of the *Deperditores*, which belong to the genera *Ptinus* and *Anobium*: they appear to be created more for the dispersion of dead vegetable substances than for the destruction of living plants. As Nature produces the more rapid dissolution of corrupt animal matter, by means of the onthophagous and carrion beetles, so it appears that she accomplishes the same object with respect to the dead stems of plants, through the agency of these insects. The larvæ also of the *Buprestodea* and of many *Elaters* live in the stem, for instance, the larva of *Buprestis biguttata* in the stem of oaks, *Elater rufus* in the stem of pines, and both especially in the remaining stumps of felled trees. There also do we particularly find the larvæ of the capricorns, and living trees they do not appear to care for, yet the larva of *Saperda linearis* lives in the pith of the young twigs of the stem of the hazel (*Coryllus avellana*), and that of *Lamia amputator* in the pith of tropical plants *, that of *Callidium bajulus* in timber, rafters, and roofs. But the family of the bark beetles (*Bostrychodea*), thus named from their dwelling-place, beneath the bark, are most destructive to woods, especially to those consisting of firs, pines, and oaks, for example, the genus *Platypus*. The commoner species, namely, *Bostrychus typographus*, *B. laricis*, *Hylesinus piniperda*, *Hylurgus ater*, &c., occasionally so much undermine the bark that it becomes quite loosened from the stem, and the tree, having lost in its liburnum its nutritive layer, dies. Formerly many instances occurred of whole forests of pines being thus destroyed in the Harz, in Franconia, and in Silesia, and it was called the (wurmtrocknisz) worm dry rot. Tropical trees are also visited by such guests, for instance, the stems of palms by the *Calandra palmarum*, but they are chiefly found in felled trees lying in the woods, and which they speedily destroy through the great size they attain. It is thus also that the large larvæ of exotic capricorns live, as those of *Prionus cervicornis*, *Pr.*

* Lansdown Guilding in Linnæan Trans. vol. xiii.

damicornis, Lamia tribulus, &c., which live in the stems of Brazilian or tropical plants, particularly those of the genus *Bombax*.

The stems of corn also serve as a dwelling-place for many larvæ; thus we find the maggot of a fly belonging to the genus *Mosillus*, of Latreille, subsisting in the blade of wheat. Another, known by the name of the Hessian fly, also lays its eggs in the blade of wheat, and thus frequently destroys entire fields, from the increasing maggot devouring all the leaves. *Musca pumilionis*, Lin., lays its eggs in the heart of young rye, and the larva destroys the shoot, commencing with the germen and then consuming the leaf. *Pyralis sicalis* attacks in a similar manner the blade of barley, depositing its eggs in a cavity bored between the leaf and stem. Exotic grasses also are destroyed by enemies which consume their pith. An ant (*Formica analis*, Latr.) makes its dwelling in the interior of the sugar-cane, and feeds upon its sweet pith; another (*F. saccharivora*, Lin.), takes up its abode between the cellular roots of the same plant, and thus destroys it by drying it up. In the fortieth year of the preceding century this ant had so much increased in the island of Granada that every plantation was destroyed by it, and every means applied to remove the evil was fruitless. The larvæ also of the *Elater noctilucus*, of which we have already spoken, lives in the pith of the sugar-cane, and feeds upon it *.

The larvæ of many *Lepidoptera* live in the interior of the stems and of the twigs, or beneath the bark, and thereby prevent the growth of the plant: thus, for instance, we find the caterpillars of several moths, as that of *Tinea corticella*, Fab., beneath the bark of trees; and another caterpillar, that of *Tortrix Weberana*, F., is the cause of great injury to fruit trees, by boring through their bark. The caterpillar of *Thyris fenestrina*, O., lives in the annual twigs of the common *Sambucus niger*, L., and of *Arctium lappa*, and destroy their soft pith. But the caterpillars of the genus *Sesia* are well known as borers of the stems of trees, but from their small number we have never heard of extraordinary devastations committed by them. Thus the caterpillar of *Sesia apiformis* lives in the stems of all kinds of poplars, as does that of *S. asiliformis* in the young stems of *Populus dilatata*, L.; *S. spheciformis* in the stems of the elders and birch trees; *S. hylæiformis* in the branches of *Rubus idæus*, L.; *S. culiciformis* in the bark of plum and apple trees; *S. formicæformis* in the branches of

* Humboldt, Essai sur la Geographie des Plantes, p. 136.

different willows, for instance, of *Salix alba* : *S. tipuliformis* in the pith of the stem of the red currant (*Ribes rubrum*, Lin. *). It is, lastly, very generally known that the caterpillar of the goat moth (*Cossus ligniperda*) lives for several years in the stems of old willows, where by degrees it transforms the internal dead part into powder.

Among the other orders we are acquainted with the family of the *Sirices*, which all live as larvæ in the stem partly of pines and partly of oaks, and there change into pupæ, as well as individual genera of bees, for instance, *Xylocopa*, which bores into wood, especially door-posts and gates, and there forms cells for its young *. The same in the *Dipterous* family of the *Xylophagi*, the larvæ of which live in stems beneath the bark.

§ 304.

The leaves of plants and their young germens or eyes are more universally destroyed by insects. Among those which make the just developing eyes their dwelling place are the larvæ of the *Tortrices* and the skip-jacks (*Hatticæ*). Many plants are absolutely infested by these inimical guests, and we frequently hear the gardener and farmer complain of these terrible enemies of their fruit harvest, when they have resumed their activity in the destruction of the young buds. The larvæ of the *Tortrices* fold up by their webs the just developed leaves, and thus obstruct the younger ones, and then conveniently eat away the innermost core of the eye, which in fruit trees consists especially of the blossom buds. They do not appear to have any particular preference among the different kinds of fruit, but attack all at the same time or successively. The skip-jacks do not weave the leaves together, but merely devour the young shoots. Among these also no species appears to be especially restricted to one and the same plant, but choose them at caprice. Yet *H. oleracea* and *H. nemorum*, being the most common species, are the most notorious. The first especially attacks young culinary plants, particularly those belonging to the family of the *Crucifera*, namely, cabbage, turnip, mustard, rape, &c. *H. concinna* lives in the young shoots and buds of the hop; *H. nemorum* in the turnip; and the remaining numerous species in the buds of wild uncultivated plants.

The host of insects that destroy the leaves of vegetables is so innu-

* Ochsenheimer Schmetterlinge von Europa, vol. ii. p. 121, &c.

merable, that even a superficial account of our native plants, and the insects that dwell upon them, would fill a volume: we will therefore limit ourselves to the enumeration of the chief families that consume leaves, and cite from them the most interesting genera. Among the beetles we find the large family of the *Chrysomela*, both as larva and imago, select leaves for their food, and they are therefore usually found upon plants. Thus we find *Galleruca tanaceti* upon the *Tanacetum vulgare; G. viburni* upon *Viburnum opulus; G. nymphea* upon water plants *Nymphea, Alisma, Sagittaria; G. Alni* upon *Alnus glutinosa; Chrysomela pallida* upon *Sorbus aucuparia; Chr. varians* and *Chr. centaurei*, F., upon *Hypericum perforatum; Chr. Sophiæ* upon *Sisymbrium Sophia* L.; *Chr. vitellinæ* upon *Salix vitellina; Lema Asparagi* and *L. 12-punctata* upon *Asparagus officinalis; Lema merdigera* and *L. brunnea* upon *Lilium martagon*, &c. All these beetles and their larvæ have the peculiarity of not in general consuming the leaf from its margin, like the caterpillars of the *Lepidoptera*, but they bite a hole into the substance, around which they continue to eat. Thus both these destroyers may be distinguished from each other by the appearance merely of the leaf that has been attacked. Other families of beetles do not restrict themselves so exclusively to leaves, yet many, for example, the *Malacoderma, Melolonthodea, Vesicifica*, the *Cassidæ* (particularly the larvæ) and other genera devour leaves by preference.

Of the remaining orders it is, especially in that of the *Hymenoptera* and among the family of saw-flies (*Tenthredonodea*), that we find leaf-devouring insects. The pseudo caterpillars of these insects, deposited even by the mother as an egg in the parenchyma of the leaf, devour the leaves with incredible voracity, and thereby frequently destroy entire plantations. Thus the large larva of *Cimbex variabilis* lives chiefly upon willows, of *C. lucorum* upon the birch, of *Hylotoma rosæ* upon roses, of the different species of *Lophyrus* upon different pines and firs, *L. pini*, for instance, upon *Pinus silvestris*, of *L. laricis* upon *Pinus larix*, &c. The true saw-flies (*Tenthredo*) are the most numerous of all, and destroy cherries (*Prunus cerasus*), alders (*Alnus glutinosa*), willows (*S. alba, S. capræa*, and many others), roses (*Rosa canina*), and many other plants. Where they are numerous upon a tree they speedily destroy all the leaves, and the tree, already sickly from the loss of its organs of respiration, dies. Thus, one known by the name of the slug-worm, living upon the plum, some few years ago destroyed whole districts of orchards, as Peck has related in a distinct treatise *. The larva of *Lyda pratensis* also, which lives upon the fir, a short time since, in the vicinity of Muskau, in Silesia, committed dreadful devastation, according to the communication of K. Hapf †.

But in no order are leaves used so universally for food as among the *Lepidoptera*, of which the majority as caterpillars consume them. We imagine we shall give a sufficient proof of this by mentioning some of the numerous trees and plants indigenous with us, and which are eaten by caterpillars. The oak, in the first place, feeds innumerable caterpillars, for instance, *Gastropacha quercus*, *Smerinthus quercus*, *Harpya Milhauseri*, *Notodonta camelina*, innumerable *Noctuæ*, and *Geometers*; according to a calculation of Roesel's, this tree supports in its several parts and organs about two hundred distinct species of insects, whence it will be easy to deduce their relation to the rest, as well as of insects to the vegetable kingdom in general. Thus every forest tree has not merely one, but three, four, and even as many as a dozen caterpillars which feed upon its leaves, and which often seriously injure them. We will merely refer to the destruction occasioned by *Liparis dispar* to poplars, *L. salicis* to willows, *L. chrysorrhea*, *L. nudibunda*, *L. fascelina* to different fruit trees, *L. monacha* to the fir, and a multitude of others, which are known as tree and forest destroyers. The number of injurious forest caterpillars is so large that we cannot wonder at the great devastation we so frequently hear committed by them. Thus there are found upon the pine, besides those already enumerated, *Gastropacha pini*, *G. pityocampa*, *Sphinx pinastri*, *Noctua* (*Trachea*, Tr.) *piniperda*, *Lithoria quadra*, *Geometra* (*Fidonia*, Tr.), *piniaria*, *G.* (*Ellopia*, Tr.) *prasinaria*, *G.* (*Ell.* Tr.) *fasciaria*; *Tinea resinella*, which occasions the escape of resin from the young twigs of the fir; *T. dodecella*, *T. strobilella*, *T. pinella*, &c., which dwell partly in the young buds, and partly in the eyes of the firs. We will not extend this list to other forest trees, but refer at once to Bechstein's ‡ Natural History of Injurious Forest Insects, where there is ample detail. We will only further mention that many of our fruit trees support their peculiar enemies, among which the cater-

* W. Peck, Natural History of the Slug-worm. Boston, N. A., 1799. 8vo.

† Bemerkungen über Raupenfrass v. K. Hapf. Bamberg. in Aschaffenberg. 1829. 8vo.

‡ Bechstein's Naturgeschichte der schädlichen Forstinsekten. Leipzig, 1805, 3 vols. 4to.

pillars of *Gastropacha neustria* and *Episema cæruleocephala* are the most common and the most dangerous.

The different kinds of corn, as well as the grasses in general, are less attacked by leaf-devouring caterpillars, yet the caterpillar of *Episema graminis* has been observed to destroy them *. The numerous members of the order of the *Orthoptera* feed very generally upon these plants, but they do not despise even others. Thus the grasshoppers can be fed with all kinds of leaves, but they seem to prefer those of grass to all others. One insect of this order, the migratory locust, has acquired a widely dispersed notoriety from the devastating expeditions it undertakes in immense hosts, and it has thence been unjustly considered as an introduced insect. This it is certainly not, it being indigenous with us (Germany), and it is only occasionally that it appears in vast hosts, which quit their birth-place from having there destroyed all their vegetable food, and they proceed further to seek fresh. We will refer to Kirby and Spence for a full account of their mode of migrating, as well as for the details of their several excursions, and merely mention that an instance of this occurred in June, 1832, near the Bavarian town Weissenburg. They passed from east to west over the town, in some places but a few ells above the surface, and their number was so great that it took three quarters of an hour for the entire swarm to pass. Wind and rain, which speedily came on, adds the informant, prevented further observation †.

These remarks sufficiently prove how many insects derive their food from leaves, and how great the destruction is when their numbers disproportionately increase: we will now proceed to notice those insects which attack by preference the fruit and stem.

§ 305.

Upon returning to the order of the *Coleoptera*, we immediately find a large family among them which are chiefly occupied with the destruction of the seeds of plants, namely, the *Curculios* (*Rhynchophora*). The majority of the species have their peculiar plants upon which they live, and in the fruits of which they are found as larvæ. In the large genus *Bruchus*, which is the nearest allied to the *Curculios*, all the species whose transformations we are acquainted with live as larvæ in seeds.

* Germar's Mag. vol. iii. p. 433.

† Vossische Berliner Zeitung for the 21 June, 1832.

Thus, in the pulse of the pea (*Pisum sativum*) the larva of *B. granarius* dwells, devouring the seed. In North America the same plant is attacked by another species, which is also sometimes found with us, namely, *Br. Pisi*. A third, the *Br. pectinicornis*, destroys peas in China. And a fourth species, perhaps *Br. scutellaris* F., attacks the seed of a pulse (*Phaseolus* or *Dolichus*) in India, which is called by the natives *Koloo*, and by the English *Gram*. A very large species, native to South America, *Br. ruficornis*, Germ., lives in the kernel of the cocoa-nut, and is sometimes even found in it in Europe *; and *Br. nucleorum*, according to Fabricius (*Br. bactris*, Hbst.), is found in the same fruit. Another genus, *Apion*, Hbst., has the same habits. We find the numerous species of this genus upon the plants in the seeds of which the larva lives, for instance, *Apion flavofemoratum*, Kirb.; upon *Trifol patense*, Lin.; *Ap. Ulicis*, Kirb.; upon *Ulex Europæus*, *Ap. vernale*; upon *Ballota nigra*, L., and *Lamium album*, L. *Ap. æneum*; upon *Alcea rosea*, Lin. *Ap. frumentarium* in the seeds of corn. The larva of this beetle, known by the name of the red corn worm, frequently causes great injury in granaries: it consumes the farinaceous portion, and leaves the case untouched. But the black larva of *Calandra granaria*, which is frequently found in houses, granaries, &c., is even more injurious. A second species of this genus *Cal. Oryzæ* we frequently find among rice. The third enemy to corn warehouses, known by the name of the white worm, belongs to the order of the *Lepidoptera*, and is the larva of *Tinea granella*. We might considerably enlarge this list were we to enumerate all the *Curculios* injurious to seeds, but we will merely remark that it is particularly the smaller species which appear to prefer this food. Thus the genera *Balaninus* and *Anthonomus* are known as attacking nuts and stone fruits. The larvæ of *B. nucum* live in the common hazel nut, and that of *A. druparum* in the stones of the sour cherry. The smaller *Ceutorhynchi* all dwell upon plants, and doubtlessly feed upon their seeds or leaves. The *Cioni* attack the species of the genus *Verbascum*, and live in the stem beneath the epidermis. Very many other *Curculios* live similarly in the substance of plants. Thus, the larva of *Lixus paraplecticus* lives in that of *Phellandrium aquaticum*, and of *Cryptorhynchus Lapathi* upon *Rumex hydrolopathum*, Lin. &c.

Among the other orders it is especially the *Lepidoptera* and *Diptera*

* Germar's Mag., vol. iii. p. 1, &c.

which, as larvæ, live upon fruits. Among our fruits, the plum, apple, and pear are attacked by a small moth, *Tinea* (*Carpocapsa*, Tr.) *pomona*, and which, although it does not destroy the propagative powers of the seed, yet it renders the fruit disagreeable to us. Thus another caterpillar of a moth attacks the fruit of the chestnut (*Castania vesca*), and destroys. by causing the fruit to fall before it is ripe, a rich and profitable harvest. The date also is destroyed by a larva which Haselquist observed, and refers it to the genus *Dermestes*, but certainly incorrectly. Another larva of a moth, *Pyralis fasciana*, F., lives in grapes, and destroys the most beautiful and largest grapes. But not this only attacks the vine, but many other insects in different countries. *Pyralis vitana*, F., as larvæ, devour the leaves. In the Crimea, the larva of a *Zygæna* attacks the young shoots as well as the larva of *Eumolpus Vitis*, F., and of *Rhynchites Bacchus*, Herbst. In Silesia, in the vicinity of Grünberg, where the vine is extensively cultivated, *Thylacites geminatus*, Germ., is a destructive enemy to young shoots, as it entirely consumes them immediately upon the budding. *Lethrus cephalotes* does the same in Hungary. In southern countries where the vine is cultivated, a species of *Coccus* sometimes destroys the entire vintage by sucking the young shoots. A caterpillar also lives in the fruit of the olive, which destroys the kernel and produces *Tinea oleella*, F. A second larva lives in the same plant, that of *Oscinis oleæ*, Lat., an insect belonging to the family of the flies, whose nearest ally, namely, *Dacus Cesari*, and the species of the genus *Tephritis*, follow a similar mode of life. *Tephr. cardui* especially attacks thistles and burdocks, and partly lives in the pith of the stem and partly in the fruit and flower which it then distorts. Other dipterous maggots distort plants by gall-shaped excrescences, for instance; the genera *Cecidomya*, *Lasioptera*, &c. One of these maggots especially attacks the ripening ears of corn, and thereby occasions great destruction. Kirby has described this fly by the name of *Tipula tritici* *.

§ 306.

We will now drop the thread of our inquiry into those insects which are injurious to plants or which restrict their superabundance, convinced that the instances adduced above sufficiently prove a strong relation between plants and insects. We must now prove, on the opposite side,

* Lin. Trans., vol. iii. p. 243—245; vol. iv. p. 224—239; and vol. v. p. 96—110.

that very many insects quite unconsciously promote the growth and advance of them.

If we inspect the organisation of those parts of plants upon which its further existence as a species depends, namely, the sexual organs, we shall speedily observe that their position is such, that, without extraneous means, the male seed could not reach the female organ. Thus, therefore, in all plants which, without such assistance, could not be impregnated, the procreation of new individuals by the planting of a ripe seed is rendered almost impossible, and would also in fact but seldom occur, were it not for the intervention of insects. A great number of insects, therefore, namely, all the *Lepidoptera*, the bees, wasps, ichneumons, the majority of *Diptera*, and many beetles find their food either in the pollen itself of the plants or in the honey juices secreted by the nectaries, and for this purpose they visit flowers to procure their food from them. In these visits made without care for disturbing the parts of flowers, or mixing them together, they convey the farina which has burst from the anthers to the stigma of the female pistil, and thereby cause impregnation. This relation, for the observation of which we are indebted to the venerable Ch. K. Sprengel *, perfectly explains to us the relative connexion existing between plants and insects. To obtain at some period this object, the plant, by great self-sacrifice, and, indeed, with sometimes the loss of its own life, has nurtured the insect within its bosom, and fed it with its own juices, and, what it is not enabled to attain individually, being destroyed by its enemy which it reared as a friend, it conveys over to its congeners. We may possibly be misunderstood in thus speaking of the reciprocal relation existing between plants and insects, as insinuating a species of consciousness of their calling and a recognition of their duties; for it is not the plant or insect that thinks or reflects, but Eternal Wisdom has felt and thought for them, and has so strengthened their mutual attachment, that the human mind in explaining it may well illustrate it as affection and friendship, and as a recognition of what the one is indebted to the other, and what it may thence expect in return, thereby exhibiting the infinite love distributed throughout the universe †. But we are diverging from the path of facts, to which we shall

* Das Entdeckte Geheimnisz im Baue und der Befruchtung der Blumen. Berlin, 1793. 4to.

† See Burdach's Physiologie, tom. i. p. 322 and p. 399, &c.

therefore return, further explaining this reciprocal relation in individual instances.

Very many, indeed we may say the majority of plants are furnished with nectaries which secrete a honey, which many insects, particularly the *Lepidoptera* and bees, seek very greedily. To procure this honey, those insects fly, some by day in the sunshine, and others in the twilight from flower to flower, visit each, and here for a time imbibe the freshly-secreted juices. They cannot avoid sweeping off the farina that has just escaped from the anthers with their rough hairy bodies, and which they bring into contact with the stigma, for both organs must frequently be pushed on one side by the insect visiting the flower before it can reach the nectaries. Some observers have remarked that insects are very particular in the selection of flowers, and at one flight visit but the blossoms of one kind of plant. This, according to Ch. K. Sprengel, occasions the impregnation of flowers, for in the majority of flowers the anthers and stigma have not the same degree of ripeness, but either the one or the other is the earliest. As insects visit only flowers of the same species, they now meet with those that have ripe anthers and now with those with ripe stigmata, and cause impregnation by bringing the ripe pollen into contact with the ripe stigma. Also, as Kölreuter has already remarked, and later observations have tended to confirm, the majority of flowers cannot be impregnated by their own pollen, but require that of other individuals, just as the hermaphrodite *Mollusca* require a mutual connexion, and cannot impregnate themselves; and if this law be general, which, however, does not appear to be the case, insects alone can be the means by which nature attains the full object of plants, namely, their impregnation and formation of seed.

If in many cases by other means, namely, by wind and rain, both of which shake the flowers, and thus bring the pollen into contact with the stigma, impregnation is effected, yet in very many it appears to be possible only through the assistance of insects. This is the case in diœcious plants, namely, in the sallows and poplars, which blossom early in the year. In these also the male flowers are the earliest, the female ones the latest; both contain nectaries, and are therefore much visited by bees and flies. It is only thus that the female flowers can be impregnated by means of the pollen hanging to the insect. This is the case also with the diœcious palms, namely, in *Phœnis dactylifera*, the male of which is the rarest in its country, and is frequently at many miles distance from the female. Also many monœcious plants, in which, as in *Ricinus*, the female parts are above the male ones, can therefore be only thus impregnated. The same in the whole family of orchideous plants, in which indeed the anthers are placed above the stigma, but frequently consist of a viscid waxy mass, whence the pollen, upon the shaking of the plant, cannot fall upon the stigma, but only by means of insects which visit the plant, and who smear themselves with this clammy substance, can it be rubbed upon the stigma. The *Aristolochia clematitis*, in which there is also observed a growing together of the filaments with the style, is impregnated by a little fly peculiar to it, the *Tipula pennicornis*, Lin., and which belongs to Meigen's genus *Ceratopogon*. This little creature creeps through the tubular portion of the flower into the lower cavity where the nectaries are placed, but cannot return back,—hairs placed in that direction preventing it. Whilst it now flutters about for several days until the flower fades, it brings the pollen into contact with the stigma, and thus causes impregnation. It appears also that other plants require certain species of insects to facilitate their impregnation; and it may originate thence that so many exotic, and especially tropical, plants, produce no seed in our hot-houses, as they have not the peculiar insects requisite to promote it. This appears to be confirmed by the observations made upon indigenous plants, namely, upon *Nigella arvensis*, *Iris xiphium*, and the species of *Antirrhinum*, that they are also visited by insects of only one species or of one genus, and therefore more frequently remain unproductive than others to which many insects resort, as the *Umbellata*, *Syngenistæ*, &c. Many insects, namely, bees which live solitary, and especially the males, pass the night also in flowers, for instance, *Chelostoma truncorum*, Labr., which reposes in the large *Campanulæ* with pendent flowers. In these visits they likewise must bring the pollen into contact with the stigma. The *Syngenistæ*, in which the stigma in general projects far above the coronet of anthers, are visited by innumerable small beetles, particularly *Nitidula ænea* and the *Thripes*, which creep down into the recesses of the flower, and naturally upon their return touch the stigma with their body covered over with pollen, whence arises, as we have before remarked, the great fertility of these flowers.

These remarks may suffice as a proof of the reciprocal relation between plants and insects. A more detailed account of it may be found in the book that we have before referred to of Ch. K. Sprengel.

§ 307.

With respect to their relation to other animals, it is probable that none takes place between them and the lowest in the scale, as the majority of the latter dwell in water, whereas insects are air-animals. The lower animals also are especially found in the sea, which no insect inhabits. The lower fresh-water animals are partly too small to supply insects with sufficient food, and partly again too large to be conquered by the rapacious water insects. Yet I have sometimes observed leeches (*Hirudo vulgaris* and species of *Clepsini*) in the power of the large *Dytici*. We may also admit that these water animals exercise the right of retaliation, and also devour small insects, at least those among them which are appointed to feed upon animal matter; yet they would doubtlessly offer but little nutriment to the leeches, as these seek the blood of the vertebrata. Nor do insects appear to stand in any very near relation to the *Mollusca*, particularly as the majority of these inhabit the sea. The larvæ of many insects may serve fresh-water snails as food, whereas the land snails, which feed upon vegetable substances, are attacked by many insects which as larvæ live parasitically upon them. Mielzinsky first discovered the larva and apterous female of *Drilus flavescens* in the shells of snails in the vicinity of Geneva, and described it under the generic name of *Cochleoctonus*. Subsequently Victor Audouin and Desmarest made further observations upon this parasite, which is not rare upon *Helix nemoralis*, and explained its development to the perfect insect *. The larvæ also of the *Lampyri*, which are closely allied to the genus *Drilus*, live parasitically in snails, as Audouin has communicated †. A third insect, the maggot of a small fly, the perfect state of which, however, is not known, is said to live as a parasite in the body of the garden snail, and even to show itself in its feelers. These are the only instances hitherto known of insects living as parasites upon *Mollusca*.

But we find the relation of insects to other articulata, namely, to the *Arachnodea* and to other insects, much more common. The *Crustacea* almost all live in the sea, and are therefore secured from the attacks of insects, and no parasitic insects have yet been found upon the *Myriapoda* and wood lice. The spiders are also free from their

* Annales des Sciences Nat., tom. i. p. 67; tom. ii. p. 129 and 443.

† Ib. tom. vii. p. 353.

attacks, but not insects from the spiders, for almost all of the latter feed upon insects only. Indeed there are no parasitic spiders, for they are all absolutely animals of prey, which capture insects either by cunning or by nets, they then kill them, and suck out all their nutrimental juices. A great portion of the *Acari*, however, are parasitic upon insects, and not, indeed, as we find the parasitic *Acari* upon birds and *Mammalia*, beneath the epidermis, but upon it, and chiefly where a delicate connecting membrane binds two plates together. We thus find *Gamasus coleoptratorum* especially upon the dung and carrion beetles, namely, *Necrophorus, Scarabæus*, and the Histers; several of the *Trombidia* upon different winged insects, namely, *Libellulæ*, gnats, aphis, &c., and *Ocypeta rubra*, as a small cochenille spot, upon several also often very small *Diptera*, and, lastly, the genus *Aclysia*, even upon the water-beetles. They dwell also upon their connecting membrane, and are besides enveloped in a peculiar case, whence through a particular aperture the creature projects its mandibles, and bores into the skin of the beetle *.

Much more numerous are the relations, considered from our present point of view, in which insects of different families stand to each other. We might assert that the predaceous beetles and those which live upon animal substances, carry on as it were a war against those which feed upon vegetables, and upon which they feed with the same voracity as the latter do upon plants. Some, as the *Carabodea, Dytici*, and *Staphylini*, do this, particularly in their perfect state, hunting down the larvæ of the herbivorous ones, and devouring all that they can catch; whereas others, and these especially are the most dangerous enemies, seek to lay their eggs in the bodies of the larvæ, thus presenting their young with food in the body of a living creature. We find this habit among the Ichneumons and the *Tachinæ*. Both select for this purpose almost exclusively the caterpillars of *Lepidoptera*, and as a caterpillar thus pierced must sooner or later die, they therefore considerably restrict the influence such caterpillars have, by the destruction of plants, upon the advance of the vegetable kingdom. The larvæ of the minute *Pteromali* live in a similar manner in the bodies of the *Cocci* and *Aphides*, the influence of which is not less upon the decrease of the vegetable kingdom than that of the caterpillars of the

* Vict. Audouin in Mém. de la Soc. d'Hist. Nat. de Paris, tom. i. p. 98, Pl. V. f. 2. —Dict. des Sc. Nat. Art. *Aclysia*.

Lepidoptera. Many of them also live in the caterpillars of several butterflies. We cannot yet determine with certainty whether these enemies of the vegetable feeders are as select in the choice of particular insects as the latter are in the choice of their vegetable nutriment; yet this appears to be the case among the larger Ichneumons. Thus, for instance, *Ophion amictus,* Fab., lives upon the caterpillars of *Sphinx pinastri, Ichneumon lapidator* in those of *Noctua Typhæ.* The large families of *Sphecodea* and *Crabronea* also destroy the larvæ of *Lepidoptera* to use them as food for their young, as we have frequently before mentioned. It is remarkable that all these enemies of other insects belong to the order of the *Hymenoptera,* of which we already know that its members, by visiting flowers, contribute directly to the advance and increase of the vegetable kingdom. We have now, therefore, also seen that they even go still further in promoting this, as they destroy and remove insects inimical to plants. This double function we perceive also in the majority of the *Diptera*, in as far as these in their imago state visit blossoms, but as larvæ thrive frequently in or upon insects that feed upon vegetables. These two orders it is, therefore, especially, which exhibit to us the closest connexion of insects to the vegetable kingdom, as they in a double manner promote the increase of plants.

§ 308.

With regard to the relation of insects to the vertebrata, we may observe, that the same holds good with respect to fishes as what we have observed upon the *Mollusca.* By their living especially in water and in the sea, they are removed from the direct influence of insects, and only those fishes which inhabit fresh water appear to lie in wait for the larvæ of the *Ephemeræ, Semblodea, Libellulæ,* and gnats, and use them as food. It has not yet been observed that insects are parasitic upon fish, yet the larger *Dytici* and other water-beetles doubtlessly feed upon the spawn of fishes, and even *Dyticus latissimus,* as well as its larger congeners, attack small fishes and eat out their eyes.

Nor do the reptiles either supply insects with food or serve them to dwell upon, unless, which is very probable, the spawn of frogs is frequently consumed by the large predaceous water beetles. These beetles also frequently devour the little tadpoles, whereas insects supply the reptiles that live upon land, namely, the frogs, salamanders, lizards, and small snakes, with their sole and favourite food.

The relation between insects and birds is somewhat different. This class, which we have found analogous to insects in their type of organisation, overlooking their internal skeleton, stand in the closest relation to insects. This relation is double, as we find insects deriving their food from birds, and birds again feeding upon insects. With respect to the first, there is probably not a single bird which is not inhabited by one or even several clearly distinct species of parasitic insects, and which even sometimes belong to distinct genera. All these insects form a peculiar large group among the parasites, which Linnæus classed with the lice, but which De Geer, from their mandibulate oral organs, separated by the name of *Ricinus*, from the lice (*Pediculus*), and Nitzsch, lastly, collected together in a separate family which he called *Mallophaga* (fur destroyers), and classed with the *Orthoptera*. Their most correct situation is perhaps amongst the *Dictyotoptera*, with which we formerly placed them. This group falls into four very natural genera, of which *Philopterus* and *Liotheum* are the most numerous, and are distributed among all species of birds; *Trichodectes* and *Gyropus* are the smallest in number, and are found only upon the mammalia, namely, upon beasts of prey, the *Glires* and the *Ruminantia*, they dwell between the softer down or woolly hairs, and feed upon that and not upon the blood of the animal, at least Nitzsch found in all those which he anatomically investigated portions of down in their stomach *. Besides this large group there are smaller genera and species, which likewise live as parasites upon birds, especially upon young nestlings, particularly the genus *Carnus*, discovered by Nitzsch, upon young starlings, a form allied to the *Conopica*, as well as the genera *Ornithomya*, Lat., and *Strebla*, Wied, both of which belong to the pupiparous family of the *Diptera*, which are found upon other young birds, especially swallows.

Insectivorous birds are those chiefly which belong to the *Passerines* and the *Cuculines*. The *Laniadæ* feed almost exclusively upon insects, but some are said also to prey upon small warm-blooded vertebrata. The *Coraces*, or crows, devour chiefly carrion, but also very many feed upon insects, namely, the jays and blackbirds; some also eat fruits, which we find likewise in the true singing birds. The genera *Fringilla*, *Emberiza*, *Tanagra*, and *Euphone* eat fruits and seeds; *Sylvia*, on the

* See Nitzsch über die Familien und Gattungen der Thierinsekten. In Germar's Magazine, vol. iii. p. 261.

contrary, *Motacilla, Anthus, Certhia, Muscicapa,* and *Hirundo,* devour insects only, namely, flies and larvæ. Among the *Cuckoos* it is especially the large genera of *Cuculus* and *Picus* which attack insects, and *Upupa, Epimachus, Merops,* and many exotic ones; whereas the genera *Rhamphastus, Buceros,* and *Psittacus* prefer vegetable food, particularly fleshy fruits, to insects, and therefore feed chiefly or exclusively upon them. We besides find among the snipes many genera which feed upon insects and preferably upon their larvæ, for instance, *Charadrius, Œdicnemus, Scolopax, Tringa,* and *Totanus,* particularly their smaller spècies; the other waders and water birds prefer to insects as food the amphibiæ, molluscæ, fishes, and other marine animals.

§ 309.

We find a similar relation between insects and the mammalia. Many of them are inhabited by parasitic insects, which either belong to the already mentioned genera *Trichodectes* and *Gyropus* among the *Mallophagi,* or come under the genus *Pediculus,* peculiar to the mammalia. The genus *Pulex* also lives principally upon the mammalia. Among these also may be classed the pupiparous genera of the *Diptera,* which family is also distributed upon both classes, yet only upon individual species, and lastly, the family of the *Œstrodea,* which is peculiar to the mammalia. *Trichodectes* and *Gyropus* likewise devour the soft woolly hair of the mammalia, and perhaps also their epidermis; whereas the lice, by means of their hooked proboscis, which they thrust through the integument, suck their blood. Many species of them are found upon very many mammalia, for instance, upon the *Glires, Ruminantia,* and swine, but not upon all. The genus of the flea is parasitic only in its perfect state, as a larva it lives in putrid substances, especially in dirty sleeping apartments, in the stalls of animals, &c. The flea lives upon men, bats, beasts of prey, *Glires,* and they have even been found upon pigeons and swallows; they were all formerly classed under one species, which Linnæus called *Pulex irritans,* but they have since been correctly separated into several species *, and characterised, as is usual among parasites, according to the animal they inhabit. I have myself only yet closely examined the flea of the rat, and I have found it distinct from that of man. Among the *Pupipara,* the genus *Hippobosca* (*Nirmomya,* Nitz.), of which only one species, the *H. equina,* is

* J. F. Stephens' Catalogue of British Insects. Lond., 1829. 8vo. Part 2, p. 328.

known, inhabits the horse, particularly beneath the tail and in the softer parts; the genus *Melophagus*, Lat. (*Melophila*, Nitzsch), is also only known by one species, the *M. ovinus*, which inhabits the sheep, among the downy hair; the only species of the genus *Lipoptena*, Nitz. (*Melophagus*, Autor.), namely, *L. Cervina* (*Pediculus cervi*, Autor.), frequents the different species of deer, and the genus *Nycteribia* the bats, particularly the membrane of the wing.

The remarkable family of *Œstrodea*, of which we have before made frequent mention, live in their larva state parasitic upon the hoofed quadrupeds, especially the *Ruminantia*, and they quit the animal when they change into pupæ: this takes place in the earth; but the flies, which must be numerous, to judge from the multitude of larvæ, are seldom visible; and we are as yet ignorant upon what they live. But the parasitic larvæ are deposited by the fly upon the skin of the animal as eggs, and bore through it when, as is the case with *Œstrus bovis* and *Œ. tarandi*, they live beneath the epidermis; or if they live in the viscera of the animal they are conveyed in either by suction or licking. The animals most subject to them are oxen, whose skin this fly pierces and deposits its egg therein, the larvæ here cause swollen excrescences, from which their tails project, that they may respire. Another species, the *Gastrus pecorum*, lives, according to Fabricius, in the intestines of oxen. The sheep is still more tormented, which receives a species (*Œstrus ovis*) into its nostrils and temporal cavities. The giddy sickness of sheep, which has been attributed to this larvæ, may doubtlessly be more correctly ascribed to the worm (*Cœnurus cerebralis*) living in its brain, whereas these larvæ are the cause of the sneezing, from which many sheep suffer in summer. But the horse is chiefly annoyed by these parasites: one species, the *Gastr. nasalis*, dwells in its œsophagus; a second, *G. equi*, and third, *G. salutarius*, in its stomach; a fourth (*G. hæmorrhoidalis*) even in the colon. The larvæ hang here, holding by means of their hooked mandibles, in rows, and look like thick, blunt, long cones, which are surrounded at the apex by many rows of spines, and at the base have two kidney-shaped horny laminæ at their stigmata. The deer besides is tormented by the *Œstri*; one species, *Œstrus tarandi*, lives beneath the skin of the rein-deer, like *Œ. bovis* in the ox, whereas *Œ. trompe* inhabits the temporal cavities of the rein-deer. This fly is also found in Saxony, so that it is probable that it also inhabits other species of deer. It is certain that *Œstrus lineatus*, Meig., which, according to Schrank, hangs from the superior gums of the deer, as well as *Gastrus nasalis*, attacks, besides the horse, likewise the ass, mule, deer, and goats. Beyond Europe we also find several species, one of which, *Trypoderma cuniculi*, Wied, (*Œstrus cuniculi*, Clark) lives beneath the skin of North American hares and rabbits. *Œstrus buccatus*, Fab., and *Musca Americana*, Fab., likewise belong to this genus, established by Wiedemann, and without doubt live in a similar manner. The genus *Colax*, Wied., which is native to the Brazils and Java, admits of presuming a similar mode of life, from its affinity to them.

The mammalia, which feed upon insects, are less numerous than the insectivorous birds. We will enumerate as such the smaller *Makis*, for example, the genera *Stenops*, *Otolicnus*, the last of which lives especially upon grasshoppers; the majority of indigenous bats, the shrew, the hedgehog, mole, and the other genera belonging to the *feris insectivori*. Besides, very many of the *Edentata*, namely, *Dosypus* and *Manis*, feed upon insects. The species of the allied genus *Myrmecophaga*, devour only ants, which they lick up with their long vermiform tongue, like the woodpecker among the birds.

§ 310.

There still remains, as the subject of a short notice, the relation existing between insects and man. The human body, like that of the mammalia, serves as a residence for several parasitic insects. The best known and most generally distributed parasites are the lice, four species of which man nurtures in different parts of his body. The most numerous of these is the head louse (*Pediculus capitis*), which lives in the hair of the head of many children, and of such adults who are not clean, where it pierces the skin and sucks the blood. It prefers the inclined parts of the head, and especially the back of the head, where it deposits its eggs (nits), which are little pear-shaped bodies, which it fastens to the base of the hair by means of a clammy substance. The clothes louse (*Pedic. vestimenti*, De Geer), which differs from the head louse by its larger size, more slender form, and by having black spots upon the sides of its body, dwells upon the whole surface of the body, but not upon the head, preferring particularly the breast and back, and is less general than the former, and only found in very dirty people among the lowest classes; it is exceedingly abundant in Poland and Russia. It lays its eggs at the base of the small hairs of the skin, and conceals itself upon the skin and in the folds of the vestments. A third species, the louse of Phthriasis (*Ped. tabescentium*), which is the nearest to the two preceding, has longer antennæ, a larger and more distinctly separated thorax, and an indistinctly ringed abdomen, especially at the sides; at its apex there are four strong setæ. It only originates with Phthriasis, and lives like the former upon the skin at parts where folds are formed and much perspiration collected. It has been recently observed by Alt, in Bonn.* The fourth, or *Ped. pubis*, Lin., has a contracted body, a very broad thorax, short thick legs, and a two-pointed abdomen, it being emarginate at its apex. It is found amongst the hair of the arm-pits and of the pubis, and sometimes even in the eyebrows, and is also found only amongst dirty people. According to Fabricius † the louse of the Negro is a fifth specifically different species peculiar to mankind. It is black, and has a large, flat, triangular head, two-pointed in front, and a wrinkled uniformly black abdomen.

Next to the louse the flea is the most general parasite upon man; yet, as we have already mentioned, it is parasitic only in its perfect state, and accompanies man by day and by night, tormenting him with its painful punctures. Children and girls are particularly annoyed by it. That the flea of man is of a peculiar kind recent observations have made probable. A second species of the genus *Pulex*, the *chique*, *pique*, *jigger*, *nigua*, *tungua* (*Pulex penetrans*, Lin.), is found in America, and nestles in the flesh beneath the nails of the toes, where it deposits its eggs. It thus speedily raises such swelling and irritation that if the dangerous enemy be not speedily removed inflammatory swellings originate, which quickly affect the whole limb. If, as some observers have remarked, this creature does not pass through a perfect metamorphosis, it will, notwithstanding its resemblance to the flea, not belong to the genus *Pulex*, but must form a distinct genus of the *Hemiptera*, in the vicinity of the lice. *Pediculus ricinoides*, of Fabricius, is, without doubt, the same creature, and, from the information he had received of its imperfect metamorphosis, was placed by him among the lice ‡.

Besides the flea, the bed bug (*Acanthia lectularia*, Fab.) is known as a parasite of man. It is found in the joints of bedsteds, and is not rare, especially in large towns, and when once they have nestled

* Alt Dissertatio de Phthriasis. Bonnæ, 1820. 4to.

† Systema Antliatorum, p. 240. 2. ‡ Ibid., p. 341. 4.

themselves it is but with the greatest trouble and cleanliness that they can be removed. All day long they repose tranquilly, and it is only at night that they attack mankind. Towards morning they retire into their retreats, and do not, like the flea, accompany man also by day, secreting themselves between the clothes and the body. They are sensible of all kinds of odours, for example, citric acid, the sweat of horses, assafœtida, sulphur, &c. will drive them away for a time.

Besides these constant parasites there are a multitude of other insects which as blood suckers annoy man by their punctures: such are the gnats (*Culices*), the genera *Ceratopogon* and *Simulia* (to which, according to all probability, the mosquitos belong, if this name be not applied without distinction to all kinds of small puncturing *Diptera*, and which thence comprises in different countries very different insects), the *Tabani* (especially *Chrysops* and *Hæmatopota*), and the *Stomoxys*. It is usually said of the true gnats that the females only sting, but this is incorrect; it is true that the males are observed less frequently, as they die immediately after pairing, yet do they sting as well as the females, as I have myself observed.

Many larvæ are also classed among the true parasites of man, as they have been found in isolated instances in his evacuations. Kirby and Spence relate several instances in their classical work in which larvæ were either cast up or down. Thus the larvæ of *Tenebrio molitor*, of *Dermestes* (*lardarius ?*), and of butterflies; and even perfect beetles, for instance, *Meloë*, have been rejected. According to Azara there is a brown moth in South America which glues its eggs to the skin of sleeping persons; the young larvæ bore into the skin, and here live for a time, until they betray themselves by the pain they occasion, and when they are pressed out. If this be true it can be referred only to the genus *Œstrus*. Indeed it is said that there is a species of this genus (*Œstrus hominis* *) the larva of which resides beneath the skin of man, as is confirmed by Humboldt's more recent enquiries †. That maggots of the flies are sometimes evacuated is a frequently occurring fact known to all physicians, and indeed one instance came under my own observation during the short period I practised. The maggots were of the size of the half grown maggots of the flesh fly, and corresponded with them; but they were dead when I saw them, other-

* Gmelin Systema Naturæ, vol. i. p. 5. page 2811, No. 10.

† Essai sur la Geographie des Plantes, p. 136.

wise I should have endeavoured to rear them. There is no Scolechiasis, as Kirby and Spence call it, in opposition to Phthriasis, but the instances in which sick people have evacuated the larvæ of insects have been accidentally occasioned.

The advantages which, on the other side, man derives from insects are also not insignificant. We cannot indeed maintain of any individual insect that it forms a very important and necessary food to man, but there are instances of insects being used as food, and indeed as delicate dishes. The *Cossus* of the Greeks and the Romans, which at the time of the greatest luxury among the latter was introduced at the tables of the rich, was the larva of a large beetle that lives in the stems of trees; and was, according to Keferstein *, the larva of a large species of *Calandra*, a native of Persia and Mesopotamia. In the Brazils, also, the larva of the large *Calandra palmarum* is eaten, and even considered by many as a choice morsel. The grasshoppers are said to furnish good food to the Bedouins of Egypt. The ancients were likewise acquainted with this food of the Africans, and they distinguished a particular tribe by the name of *Acridophagi*. Even among the natives of Senegambia and the negroes of the coast of Guinea we find locusts used as food. The *Cicada*, which are in many respects closely allied to the locusts, were eaten by the ancients, especially the fat gravid females; the males were less so, as they, from their large air-bladders, were considered as empty. Amongst the *Hymenoptera* there are two families, whose economy has been already described, which yield food, namely, the ants, which, from their agreeable sour flavour, are eaten by several Brazilian tribes; and the bees, whose collected provision consists of honey, of which mention is made as food even in the earliest records, and which is everywhere used as such at the present day. Manna also, which is the juice of an Arabian plant, the *Tamarix mannifera*, dried in the sun, is caused to flow by the puncture of a small species of *Coccus*, and is an agreeably flavoured substance, frequently used in the East as food. If the pleasant taste of these substances readily explains their adoption as articles of food, it is, therefore, the more incomprehensible how certain tribes, for instance, the *Adyrmachidæ*, according to Herodotus, the Hottentots and the South American Charruels, can devour as delicacies their own vermin, a fact related and confirmed by many travellers.

* Uber den unmittelbaren Nutzen der Insekten. Erfurt, 1829. 4to. P. 8—10.

As insignificant as all these insects are in point of the supply of food with which they furnish man, yet many others are extremely important medicinally. The chief place among these is doubtlessly occupied by the true Spanish fly (*Lytta vesicatoria*), a beetle belonging to the family of the *Vesicifica*, the majority of the members of which more or less possess the same quality. They are applied, when dried, pulverised, and spread upon wax or salve, as blisters against rheumatic affections and the inflammation of the internal organs, and thereby occasion an external attraction. It is for this purpose, not only the most universal, but also the most powerful and effective means. The ancients knew this blistering property, but they did not apply our beetle, but a species of the allied genus *Mylabris*, to effect this. This beetle they called *κανθαρὶς*, a name applied by Linnæus to a genus of beetles of a different family, whence Latreille, supporting himself by the authority of the ancients, calls Fabricius's genus *Lytta*, *Cantharis*, which, however, is not to be justified, as properly our genus *Mylabris* contains the *Cantharis* of the ancients. In different countries, however, different species of the genus *Lytta* are used for this purpose; thus *L. atomaria*, Fab., in the Brazils, *L. gigas*, Fab., in Guinea and the East Indies, *L. violacea*, Brandt and Ratzeb. *, likewise in the East Indies, *L. vittata*, F., in North America, *L. marginata*, F., also in North America, particularly in Maryland, *L. atrata*, F., the same, *L. cinerea*, F., in Pennsylvania, *L. rufipes*, Illiger, in Sumatra and Java. Besides, the following insects of this family have been used for blistering, *Lydus trimaculus*, Fisch. (*Mylabris trim.*, F.), in the East and in Southern Europe, *Mylabris Cichorei*, F., in China. The species used by the ancients appears to have been *Mylabris Füeslini*, Panz., it is sometimes found in Germany, and is very abundant in the south of Europe. Another genus of this family, namely, *Meloe*, has been used for a somewhat different purpose. There are twenty-seven species of this genus distributed over the earth; all, as far as they are known, secrete a peculiar yellow fluid, which flows from between the joints of the legs, which, like all the parts of the *Cantharides*, has a sharp blistering effect, and, as this consists of the camphor of *Cantharides*, it has been therefore applied as a remedy against the bite of mad dogs and the consequent hydrophobia, sometimes with success, and at others without any effect whatsoever, yet modern physicians strongly recommend it.

* Arzneithiere, vol. ii. p. 121, &c.

No other insects that have been used as medicines, for instance, the ladybird (*Coccinella*), against the toothach, have exhibited such general utility, nor are there any insects in any of the other orders which have shown themselves as useful or important as medicines. Formerly the formic acid was used as a volatile stimulant, whence it was applied to paralytic affections, but it does not appear to have exercised much influence upon it. The tannin of galls, produced by the punctures of many small hymenopterous insects belonging to the genus *Cynips*, has been applied as an astringent.

Among those insects which either in themselves or in their productions present man with materials which his skill has converted into clothing or articles of luxury, the first place is occupied by a lepidopterous insect, namely, the silk-worm (*Liparis mori*). The web in which this caterpillar encloses itself upon its change into the pupa is the raw silk, from which, after passing through several preparations and manipulations, the most beautiful material which human skill ever produced is woven. Originally a native of China, this material was early conveyed to the Greeks under Alexander, and subsequently to the Romans, who also knew the mode whereby it was obtained from a caterpillar * ; but this itself remained unknown to them, until, lastly, some monks, in the reign of Justinian (about 550 after Christ), brought the first cocoons to Constantinople. From here the cultivation of the silk-worm spread about 1150 to Sicily and Italy, whence, under Charles the 8th and Henry the 4th, the French transplanted it to France; since this period silken raiments have become more general and cheaper. Even in Germany its cultivation has been attended with success, but which does not appear to be profitable. Upon the Rhine, in Wurtemberg, and in Westphalia, it is still cultivated, where the silk is manufactured as a native produce. Thus the worth of silk has infinitely fallen, and consequently its use has increased in the same ratio. Other allied caterpillars also produce silk, especially the species of the genus *Attacus* and some South American *Papilios*, which are no further known. In Peru, even in the time of Montezuma, materials were manufactured from the silk, known by the name of *misteka*, of these caterpillars.

* See Dr. J. F. Brandt and W. F. Erichson, Monographia generis Meloes. In Nova Acta Cæs. Leop., t. xvi. part ii. p. 101, &c.

† See Keferstein upon the Bombyx of the ancients, in Germar's Magazin, vol. iii. p. 8, &c.

We may class with the silks, among the useful materials produced by insects, and which is almost of greater importance, the red colouring matter that several species of the genus *Coccus* present us with. Many of these insects contain within their whole body a very beautiful red colour, which is extracted by acids; and these admit of being used as a colouring matter for all materials. Among the German species there is one called *Coccus Polonicus*, which is abundant at the roots of *Scleranthus perennis*, and which was universally sought, prior to the introduction of the cochineal, as a red colouring matter. Since the introduction of the cochineal, however, which is a species of this genus, known by the name of *Coccus cacti*, Lin., and which lives upon the leaves of the *Cactus coccinellifer*, the Polish cochineal has lost its importance. A third species also, which is native to the South of Europe, the *Coccus Ilicis*, which is found upon the branches of the *Quercus coccifera*, Lin., and which in the middle ages was especially used by the Arabians, who applied the still used name of *Chermes* to it, has likewise, owing to the more useful Mexican cochineal, been discontinued. A fourth species of this genus, the *Coccus ficus*, Fab. (*C. lacca*, alior.), which dwells in the East Indies upon *Ficus Indica*, *F. religiosa*, and *Mimosa cinerea*, and which, by puncturing the young twigs of these plants, occasions the exuding of the clammy resinous substance which when dry is known by the name of lac, or gum lac, likewise produces a red colour, which is most concentrated in the eggs, and the use of which has recently increased so much as to threaten equalling that of the cochineal.

Lastly, the tannin contained in gall-nuts, and which we have above mentioned as a medicament, has been used as a colouring matter, as it forms with iron a black precipitate, that is admirably adapted to this purpose. The ink also, which to the learned is a very important article, is made by the assistance of this acid. The species of galls used for this purpose are of two kinds; one, the true gall-nut, proceeds from the *Cynips gallæ tinctoriæ*, which pierces the leaves of *Quercus infectoria*, Oliv., which causes those smooth spherical excrescences upon them; the second kind, which are distinguished by being rugose, and of an angular form, are found on the fruit of *Quercus ægylops*, and are either the fruit itself distorted by the puncture, or merely the scaly cup, which is developed into a gall. The insect which pierces it is, according to M. von Burgdorf, *Cynips quercus calycis*. Both are found in southern countries, the latter in Greece and in the islands of the Archipelago, and the former in Asia Minor.

ELEVENTH CHAPTER.

THE HABITATS OF INSECTS.

§ 311.

When the question is asked where are insects found, we may unconditionally reply everywhere except in the sea, for there is no spot upon the earth accessible to organic beings that is not inhabited by insects. In this universality of their abode it will appear desirable to class them under several heads, that we may be thereby enabled to combine them more closely together; we may therefore consider this subject under the differences of elements, the differences of season, and lastly, the differences of climate, the last of which has usually been called their geographical distribution, and which, although it has been already elaborated by several entomologists *, is as yet laid down in a very meagre outline. The materials we have collected for the completion of this subject are as yet too imperfect to submit them to the public, and which we therefore defer to another opportunity, and shall here consequently only examine them with reference to their abode, as respects the elements and seasons.

§ 312.

As regards the elements, we have already in several places indicated that insects are animals of the air, and are referred especially to live in that element. Yet this means only that the majority of them possess the power of raising themselves in the air, and there moving at will for a time, and not that they exclusively dwell in it. The air is absolutely necessary to every organic being, and in so far every animal is an air animal; for although many live in the water, they even here make use of the air intermixed with it for the preservation of their lives. But there is yet a certain difference between the different classes of animals with respect to this necessity, and if insects do not belong to those ani-

* P. A. Latreille, Considerations sur la Geographie des Insectes. Mém. du Mus. 1815.—W. S. M'Leay, Horæ Entomologicæ. Lond. 1819—21. 8vo. vol. i. p. 1.—Kirby and Spence, Introd. to Entom. vol. iv. p. 486, &c.

mals which can least bear the withdrawal of air, as some instances cied above prove their great tenacity of life, they are yet doubtlessly he animals in which respiration of atmospheric air is most perfectly deve-loped, and may therefore especially lay claim to the distinction of air animals. If now, proceeding from another point of view, we shold characterise those groups among insects which of all chiefly reside in the air, they are doubtlessly the *Lepidoptera*, to which succeed in he order of their respective claims the *Hymenoptera*, *Diptera*, and *Lilel-lulæ* (compare §§ 125, 126).

There is not a single species among the *Lepidoptera* which dwells in the water or exclusively upon the ground, all seek the air, and fluter about in it, with the exception of a before-named apterous femle. Even their larvæ, more than the larvæ of any of the other orders, sek a place in the air, and are best contented in this element. There is but one caterpillar of a moth (*Botys stratiotalis*) as yet observed to be an inhabitant of the water, whereas the caterpillars of some of the *Noctuæ* (*Noctua graminis*, &c.) are found among stones, or at the roots of grass, others in the stems of plants (*Noctua typhæ*, &c.), or in fruits (*Tinea* (*Carpocapsa*) *pomona*, &c.) Similar habitats in conceaed places less accessible to the air are peculiar to several of the infeior families of the *Lepidoptera*, whereas the more perfect ones, for instance, the butterflies and crepuscular moths, all live in the open air upon plants. The perfect insects of each family, lastly, are constantly in motion during that portion of the day in which the time of their growth as larvæ falls, and then only occasionally repose: thus the butterfies are found on wing in the sunshine during day, the crepuscular mochs and *Noctuæ* in the twilight; the *Tinea*, again, chiefly by day, but especially towards the afternoon.

The *Hymenoptera* are, the next to these, the principal air insects; they also, in their perfect state, are never found in the water, and as rarely as larvæ; yet at this early stage of their existence they consi-derably diverge from aërial life, and live chiefly in confined close places, for instance, in holes in the ground, in nests, in the excrescences of plants, in their stems, and parasitic within other larvæ. The pseudo-caterpillars of the saw-flies only seek the air, and dwell in it openly upon leaves. The perfect insects possess excessive motion, are constantly flying about in the air and sucking flowers, and the femles only of some of them as well as the neuter ants are deprived of the power of flying.

Among the flies, or *Diptera*, there are several which live as larvæ in the water, as, for instance, the gnats, many *Tipulæ*, and the *Stratiomyda*, but no perfect insect of this order dwells in this element. The other larvæ, like those of the *Hymenoptera*, all seek dark remote places, removed from the air, and come but seldom, and as exceptions, into day-light.

The same is the case with the *Libellulæ*, for as much as these in their perfect state are aërial insects, so strictly as larvæ are they confined to the water.

In the other orders the habitat differs more and more, until among the beetles it attains its greatest degree of dissimilitude. If we examine in the first place the *Hemiptera*, the majority of them are indeed aërial insects, but also very many are inhabitants of the water. The family of the lice live parasitic upon mammalia, they therefore live, although in the air, for the water mammalia have no lice, yet in places secured from its free access. The *Aphides*, or plant lice, partly live in a similar manner, namely, in the excrescences of plants formed by themselves, but partly also in the open air upon leaves and young twigs. The *Cocci* and *Chermes* have similar places of abode. The true bugs are chiefly found upon the ground, in the grass, or on trees, or lastly, upon leaves; but few are apterous, and these must necessarily crawl about upon the ground; some genera (*Hydrometra*, *Velia*, &c.) run upon the surface of the water, or dive into it. One genus of this group, namely, *Halobates*, Eschsch., courses about upon the surface of the sea between the tropics, and is the only insect that that has familiarised itself with the sea. The true water bugs (*Hydrocorides*) live exclusively in the water, exactly as the *Cicadaria* course about exclusively in the air, upon the leaves of plants and on their twigs.

All the *Neuroptera* in their perfect state live in the air, where they fly tolerably constantly and rapidly about, yet their larvæ are found partly in the water, as among the *Phryganeæ* and *Semblodea*, and partly in sand, as in *Myrmecoleon* and *Ascalaphus*, or in the air upon plants, where they hunt down other insects, as is the case with *Rhaphidia* and *Hemerobius*.

The *Orthoptera* have received as their chief dwelling-place the earth itself; here they are found concealed among grass and plants, and a few, as *Locusta viridissima*, upon the elevated parts of plants. They are therefore especially animals of the earth, which is still more strongly expressed by the habits of some of the genera, for instance, of

Acheta and *Gryllotalpa*, which excavate holes for their dwelling-places. Some, as the cockroaches (*Blattaria*), are true nocturnal animals, which conceal themselves during the day, and only at night run about upon the ground.

The habitats of beetles are as different as their entire organisation. Large families, as the *Melanosomata* and *Helopodea*, are strictly fixed to the earth, and scarcely ever quit it. The majority of the *Melanosomata* have consequently lost the organs of flight with its capability. Others, as the capricorns, *Chrysomelæ*, ladybirds, and cockchafers, are found only upon plants, and consequently seek the air, although they, and chiefly the former, but seldom fly. The *Curculios* are partly fixed to the earth, as *Brachycerus*, *Plinthus*, *Meleus*, *Cleonis*, *Thylacites*, *Sitona*, &c.; others live upon plants, as *Ceutorhynchus*, *Cionus*, *Orchestes*, *Phyllobius*, *Apion*, *Rhynchites*, &c.; a few, as some species of *Bagous*, *Hydronomus*, *Alismatis*, Schön., &c. are found also in the water upon roots, but they do not swim. The true water beetles are the *Dytici*, *Gyrinus*, *Hydrophilus*, *Helophorus*, *Elmis*, and the other *Macrodactyli*. The larvæ of these also are found only in the water, whereas the larvæ of the preceding families, as far as they are known, seek remote and concealed places, for instance, the earth and the interior of plants. The larvæ of the *Chrysomelæ* and *Coccinellæ* live chiefly upon plants, partly from which they support themselves, and partly from the plant lice found upon them. Many insects also seek dark remote places removed from the open air; some therefore live in dung, as the *Coprophagi*, some in carrion, as the *Peltodea*, or in both substances, as the *Brachyptera*: their larvæ also live partly in these substances or in the earth in their vicinity. Some perfect beetles likewise, as the genera *Heterocerus* and *Prognathus*, live in the earth, particularly in the moist sand of the sea coast, but towards evening they quit these places of abode, and fly about in the dusk. The majority of the small *Carabodea* do the same, seeking for prey, although they but rarely quit the earth during the day. The larger ones are for ever fixed to the earth, for they have no wings, although the genus *Calosoma* forms an exception, the species of which are winged, and frequently fly. The last family of the beetles, the *Cicindelacea*, live chiefly upon sand, but the majority of them can fly as well as they can run, and immediately exercise this faculty when in danger or if pursued.

§ 313.

With respect to the several seasons of insects, in cold and temperate climates, they first present themselves during the warm days of spring, but, in hot climates, it is during and immediately after the rainy season, which there supplants winter, that they are seen. We know but little of the appearance of insects in the highest latitudes. Otto Fabricius mentions in his "Fauna Grœnlandica" sixty-two species of insects observed by him in Greenland, of which eleven were beetles, nine *Lepidoptera*, two *Hymenoptera*, nineteen *Diptera*, seventeen *Dictyotoptera* (one *Libellula*, seven *Poduræ*, and nine *Mallophagæ*), two *Neuroptera*, and two *Hemiptera* (lice), the most of which he caught in the months of July and August. But we may readily admit that many escaped him, as may be presumed from Zetterstedt's "Fauna Lapponica," where very many more are enumerated. In temperate climates the number of species increases considerably, for in Europe only there are doubtlessly more than 20,000 species, at a moderate calculation. Their time of appearance varies considerably, yet the time of their greatest activity is the summer: during the whole of winter there are but few insects in the open air. The reason of this we may, with Kirby and Spence, consider to be the deficiency of their aliment, for although many insects do not feed upon vegetable substances, yet the majority of the flesh feeders obtain their nutriment from the herbivorous ones, and whose existence is thus therefore bound to the vegetable kingdom. It therefore thence happens that winter, by putting aside the green vesture of the earth, likewise chases the insects that feed upon it. If we examine this more closely we shall find that this relation of insects to plants is very absolute, for the majority of those insects which hybernate in their perfect state are flesh eaters, which find food even in the young larvæ just escaped from the egg-shell, whilst the latter are feeding sparingly upon the just developed leaves. If we look to those insects which pass through their earlier stages during the winter, we may assert generally that all insects likewise exist during the winter, but in very different states. Some hybernate as eggs only, others as larvæ, others again, and perhaps the majority, as pupæ, and the fewest doubtlessly as perfect insects. From all these very different states they all assemble as perfect insects in the summer, and this also is truly the season in which insects are consequently most active.

As eggs, insects of all orders hybernate, yet these are but few in comparison with their collective numbers. The reason of this is, that many young larvæ, if they were disclosed from the egg early in the spring, would not find their necessary food; and other eggs are deposited in substances which are found only in the summer, as leaves of plants, the larvæ of other insects, &c. But we may maintain as a general fact that those insects especially hybernate as eggs, which develope in the course of one year two or three generations, as we have already mentioned of the plant lice; most of these do not hybernate, except as eggs. Those also hybernate as eggs whose development as perfect insects takes place very late in the year, as most of the *Orthoptera*, for instance, *Acheta*, *Gryllotalpa*, *Locusta*, *Gryllus*. They can therefore pair only very late in the year, so that the young, should any be disclosed, would no longer find food during the same year. The females consequently excavate holes in the earth and bury their eggs therein, when they die, as the males have before done. The same is the case with the second autumnal generation; in this instance also the larvæ would no longer find food, the eggs are therefore disclosed in the spring. Amongst the *Lepidoptera*, *Gastropacha*, *Neustria*, and *Liparis dispar* hybernate as eggs. In each case the mother deposits her eggs on the twigs, and never on the leaves, of such trees the leaves of which the caterpillars feed on. *Geometra grossulariata*, on the contrary, is disclosed the same year, and hybernates as a larva. It is remarkable that only those *Lepidoptera* whose caterpillars live upon perennial plants hybernate as eggs or as caterpillars, and the rest chiefly as pupæ, a phenomenon which even Roesel observed, and which finds its natural cause in that the leaves of all annual plants appear later than those of perennial ones. The pupæ consequently are developed later than the eggs, because the imago finds food only in the flowers, whereas the caterpillars find it in the leaves. The degree of cold that exposed eggs can endure is not trifling. Spallanzani placed the eggs of the silkworm in a temperature of 38° Fahr., and yet larvæ were disclosed from them, as well as from others that had been exposed to a temperature of 56° Fahr.

Many insects are found as larvæ also during the winter, namely, all such which pass more than one year in this state, as, for instance, *Melolontha vulgaris*, *Oryctes nasicornis*, *Lucanus cervus*, the large capricorns, many *Elaters*, *Buprestes*, and a multitude of *Lepidoptera*, namely, *Euprepia matronula*, *Cossus ligniperda*, &c. Many of them are said to form a sort of dwelling, for example, *Cossus*, in which they pass the winter in a species of torpidity. The rest creep into slits, holes, or between fallen leaves, where they also fall into a lethargic state. But this kind of hybernation is the least usual, as the majority of larvæ live but one year, and most of them, even during the summer, pass into the perfect state. Those larvæ which hybernate can, in their lethargic sleeping state, bear a high degree of cold. Lister says that he has seen frozen caterpillars, which, upon falling upon hard substances, rebounded like stones, and yet, after thawing, return again to life. Although Reaumur was unsuccessful in this experiment, Kirby and Spence assure us that the larvæ of *Tipula oleracea* have come to life again after thawing. Bonnet also has observed the same in the caterpillars of the common white butterfly.

Those insects which hybernate in the pupa state are chiefly the *Lepidoptera,* nine-tenths of which, according to Kirby and Spence, do so. As their entire pupa state is a species of lethargy, it must be very easy for them to hybernate in it, and consequently endure severe cold, yet the majority of pupæ are nevertheless protected by particular coverings and places of repose from this influence of the cold. Many lie tolerably deeply in the ground, in cavities which have been previously excavated by the caterpillar. Others which hybernate merely between fallen leaves, as the pupæ of *Deilephila Galii, D. Euphorbiæ, D. Elpenor,* &c., weave these by means of their web into a covering; others, as the caterpillars of the *Noctuæ* and *Bombyces,* weave a perfect cocoon, which inside is covered with a glue-like substance. The lethargy of these pupæ continues also frequently towards the commencement of the summer, for the imago only appears when the plants are in blossom. The larvæ also, which live several years, pass their last winter generally in the pupa state; we therefore find the perfect insect, as, for example, the cockchafer, early in the spring.

Perfect insects, which hybernate as such, prepare themselves early in the autumn for this purpose, especially in the warm days of October. They consist chiefly of beetles, but also of individuals of all the other orders, which, like these beetles, have not yet paired. They then run in troops in every direction, seeking places where they can pass the winter. These are the apertures and holes of trees, especially those between the bark and stem of old ones still existing only as stumps. Here they may be found during winter in multitudes. We especially find all such insects there, which, as larvæ or as perfect insects, inhabit wood, as the genera *Lyctus, Colydium, Rhyzophagus,* with their allies

Also *Nitidula, Engis, Allecula,* and the *Securipalpa.* Also the smaller *Carabodea,* as *Lebia* and *Dromius,* and many others. Some *Hymenoptera* also, as the *Ichneumons* and *Diptera,* we likewise find in such situations. Others, as the *Harpali, Amaræ,* and *Feroniæ,* prefer lying beneath stone, generally in small holes, chiefly with their backs turned downwards, clinging to the stones with their legs. Others, again, at the root of trees, in woods, amongst the moss, sometimes in holes prepared for the purpose, like the large *Carabi,* the *Elaters,* the *Silphæ,* &c. We in general find them alone in such situations, but sometimes they lie in multitudes collected together, as *Brachinus crepitans,* and other *Carabodea.* Between leaves the *Curculios* delight, and we find the *Staphylini* under grass. Some *Lepidoptera* also hybernate at suitable places in granaries, &c., as *Vanessa Urticæ,* O., *V. Polychloros, V. Cardui, V. Io,* also *Colias Rhamni,* and many *Noctuæ.* These, therefore, appear very early in the year, as soon as they are aroused by the warm sunshine. All, especially those which creep beneath bark, are said to place themselves on the south side, and never, or very seldom, on the north. Whilst remaining in these hiding-places, they are generally, unless excessive cold intervenes, pretty lively, and they are even lured during warm days to quit their retreats, as for instance, the *Carabi, Aphodii,* and *Staphylini,* which then, even in winter, are seen swarming upon the snow. At what degree of cold torpidity is produced cannot be easily determined, and it also differs considerably in different insects. According to Huber, the ants become torpid at—2° Reaum., and previously lay themselves as closely as possible together: this may happen also earlier or later. In others, its degree also is very different, according to the temperature. That such a torpid state is actually found in insects, we may easily convince ourselves by seeking them in their hiding places, and bringing them by degrees into a warmer temperature, when we see them gradually arouse themselves and become active. The flies also, which give us their society even during the winter in our apartments, are active near the fire-place, whereas at the windows they appear weak and inert.

Some few insects do not appear to become torpid, but even in winter present themselves. This is well known of *Geometra* (*Acidalia*) *brumata,* which appears towards the end of the autumn, and flies about in orchards, to which, as larva, it is very injurious, until late in the winter. Others become torpid on cold days, but present themselves on mild ones, and again gnaw the buds, as the caterpillar of *Noctua fuliginosa.* This is also the case with the *Trichocera hiemalis*, Meig., for it is not rarely that we find it upon clear sunny winter days, dancing its choral round in the air over the snow. Others, again, present themselves only with and upon the snow, as *Boreus hiemalis*, Lat., a genus allied to *Panorpa*, but wingless, which is not rare in woods upon warm winter days; as also the *Poduræ*, which swarm like black dust sometimes upon the surface of the snow; and, lastly, the equally apterous *Chionea araneoides*, which belongs to the *Diptera*, with many jointed antennæ, and which Dalman * has described, and which, according to him, is found in Sweden upon the snow at a temperature of 2°—3° (of the scale divided into a hundred).

If we now cast a glance upon the time of appearance of tropical insects, the information we have yet received upon this subject is so imperfect, that scarcely anything satisfactory can be deduced from it. According to the letter of Westermann to Wiedemann †, at Kiel, which is so interesting from the intelligence it gives us of the habits of many tropical insects, insects are found in Java, Bengal, and at the Cape, only during the rainy season, during which the whole tropical vegetation is in its highest luxuriance, and they then swarm upon flowers and leaves, seeking nutriment. Where they conceal themselves during the hot season is not yet known with certainty, yet they doubtlessly seek places of retreat similar to those sought out by our own during winter. Thus the hot temperature of a tropical summer has the same effect upon insects as the cold of winter with us, and what lures them from their hiding places with us, drives them there into their concealed places of resort. Yet it is the same law which is in force, and by which insects are especially bound to the luxuriant increase of the vegetable kingdom, for it is only during the warm rainy season that tropical plants are in blossom, and they are then visited by insects of all descriptions.

* Analecta Entomologica, p. 33. † Germar's Magazin, vol. iv. p. 411, &c.

TWELFTH CHAPTER.

INSECTS OF A FORMER WORLD.

§ 314.

Since, in modern times, more attention has been paid to the organic remains of a former world, communications have occasionally been made of insects of this description, but this class has not yet received all the elaboration that has been given to the others. The reason of it may be that insects are not generally found in those formations where the remains of the other classes are so abundant, namely, in the calcareous strata of the tertiary period, but are chiefly imbedded in a vegetable resin known by the name of amber, and which is cast up by the Baltic, or found in the more recent strata. This substance is found at places, which, although not lying beyond the limits of scientific cultivation, yet where the study of a destroyed organisation is not heeded, either from their remains not presenting themselves, or in very solitary instances; and amber, which is the sole substance in which the remains of organised beings have been frequently found there, is generally applied to mercantile purposes, and it seldom happens to fall into the hands of learned men or the there very isolated naturalists. But within these few years the incentive to the investigation of native productions has very much increased, and attention begins to be paid at home to what the country's produce has previously only advanced abroad. We cannot however deny that the study of destroyed organic beings has been much stimulated and promoted in and by France, especially by Cuvier's immortal works. Hence have originated also the labours upon destroyed insects which are found in other formations, namely, in calcareous marl, by Marcel de Serres *, who, in a distinct treatise, has characterised the insects found in it. Berendt has promised a detailed description of the insects found in amber, and his prefatory remarks upon the existence

* Annales des Sciences Nat., tom. xv. p. 18.

and origin of amber are already published *. From these preludatory labours and our own investigations, which we have been enabled to make in the academical collection at Greifswald and Berlin, the following summary is drawn.

§ 315.

Upon commencing with insects which are found in amber, as the organic remains belonging to an earlier formation, namely, to brown-coal, we may assert there is not the least doubt that amber is a vegetable resin, which must have originated like the present copal, that exudes from the stem of a North American tree, namely, the *Rhus copalina*, Lin. The tree which produced amber was doubtlessly lost with the vegetables whose remains form the strata of brown-coal, and, therefore, amber is still found in isolated masses in this formation. It more frequently occurs, as I have above mentioned, amongst the rejectamenta of the Baltic, and imbedded in the recent strata of its southern coasts, especially in moory peaty places, where the ground still continues covered with woods, namely, on the Prussian coasts in Pomerania, upon the coasts of the peninsula Dars, which partly forms the frontiers towards Mecklenburg. I have there myself frequently found it in the situations above described. The way in which insects have been enclosed in this amber can be no other than that they stuck to the resin when this was in a fluid state, and were enveloped in it by what continued to exude. According to the rapidity with which this took place, depends the condition of the enclosed insect. Those which were quickly enveloped are perfectly well preserved with their natural colours, but those which first died and remained for a time exposed to the open air, are more or less injured, and are surrounded upon the surface with a white mouldy covering, and which has occasionally obscured and disfigured the approximate resin. I have observed this mould in many insects of the Berlin Museum, which came from Prussia, and which are enclosed in a dark bubbly amber, whereas I have never observed it in the bright yellow Pomeranian amber. We might thence conclude that the latter was originally more fluid and the former slower in exuding, and thence building a further hypothesis that the two kinds proceeded from different trees.

With respect to the families, genera, and species of insects which

* Die Insekten in Bernstein von Dr. G. C. Berendt. Danzig. 1830. 4to.

are thus found in amber, we may repeat what has been observed by earlier inquirers, that they present a conformity, in the majority of instances, with existing forms, and even an identity of species can be shown; but this yet remains undecided, and, in many instances, is not the case. Among all the amber insects that I have seen, I have rarely found a completely new or very dissimilar form, but I have in general immediately recognised still existing genera. I must also agree with the earlier observers, that the insects found in amber are not those which belong to our latitudes, yet there are many forms which perfectly agree with ours. This may especially be said of the smaller flies and gnats; but particularly in the cockroaches, many beetles, and the majority of the *Hymenoptera*, the resemblance to exotic forms is still greater. The number of different species of insects that have been found in amber is not inconsiderable, and convinces us that the class of insects in a former world, as even now, must have been the most numerous in species; but we find in amber only the members of those families which are found in woods or trees, and scarcely ever water-beetles, whence, from the abundance of these, we may draw conclusions as to the multitudes of all the rest.

§ 316.

After these prefatory remarks, we may proceed to the consideration of the enclosed insects themselves. I shall, however, only give what I have myself observed, merely mentioning the orders, families, and frequently also the genera of insects that I have detected in amber, and reserve their detailed description for another distinct work. I have been induced to this by the work announced by Berendt of the amber insects observed by him, and for the appearance of which I shall wait.

In the order of the *Coleoptera* I have never detected an individual belonging to the *Cicindelæ*, and of the *Carabodea* I have only observed a small *Dromius* in the collection at Greifswald, whereas Germar * has discovered another, which he has described and called *Lebina resinata*. I have never yet met with a *Staphylinus*; it is not improbable that they, especially the *Aleochara*, may be found in amber. Nor have I observed any carrion-beetles nor any pentamerous beetles with clavate or capitate antennæ. I have detected several *Elaters*, for example,

* Magazin der Entomologie, vol. i. Pt. 1, p. 13.

one very similar to the *Elater cylindricus*, Gyll., and many smaller species, but I have not found a single *Buprestis*, although these might readily offer. The *Deperditores* are, however, not rare, namely, forms resembling *Anobium pertinax* and *An. rufipes*. Desmarest found, also, an *Atractocerus* in amber. A *Cantharis* very like *C. nigricans*, Fab., I have seen in the Berlin collection. Among the *Heteromera* I have hitherto only observed a small *Opatrum* allied to *Op. sabulosum*. Germar has described a *Mordella* (*M. inclusa*). Of the *Tetramera*, I detected in the collection at Greifswald the leg of a capricorn-beetle, but no other insect of this family except a little creature very like the *Obrium testaceum*. The *Chrysomelæ* are more numerous. I saw a small purple shining *Haltica*, several *Crioceris*, and a few *Gallerucæ*. The *Bostrychodiæ* are very numerous, but I could not determine one with certainty. In Greifswald I met with a species of *Platypus*, and in Berlin with several true *Bostrychi* and *Apata*. The *Curculios* also are tolerably abundant, particularly species of the genera *Phyllobius*, *Polydrusus*, *Thylacites*, &c., and some forms allied to exotic groups, which I could not more closely determine. I have never observed any of the smaller *Curculios*, as *Ceutorhynchus*, *Cionius*, or *Apion*.

The *Hymenoptera* are very abundant, but I have never observed a *Tenthredo* or a *Urocerus*, although both families live especially in woods and feed upon vegetable substances, and the latter, as larvæ, bore the stems of trees. But in the Berlin Museum there are several *Ichneumonodea*, whose generic affinities I have not yet been able to determine satisfactorily. One of them has antennæ swollen in the middle like *Bassus* (*Euceros*) *Crassicornis*, Grav. An *Evania* also, allied to *Evania minuta*, Fab., is at Berlin and Greifswald. I have not yet observed a *Cynips* in amber, although I have seen a *Sphex* that certainly belonged to the genus *Pepsis*, but which is entirely faded, so that it is impossible to determine the species. It is of about the size of *Pepsis lutaria*, Fab. (*Ammophila*, Kirby), but the thorax is more slender, and the abdomen has not so long a petiole, whence it resembles the American and particularly the African species. *Crabros*, *Scolias*, *Mutillas*, and wasps, I have not found, but I saw a small form of bee, which appears to belong to the South American genus, *Trigona*, Lat. The ants are the most numerous in this order, particularly true *Formicæ* and *Myrmicæ*, which have frequently a close resemblance to our native ones. The majority are apterous neuters, which have fallen into the fluid resin in their excursions. I have also observed in the Greifswald collection a peculiar form of ant, which I consider new, as it appears to be no longer existing, at least I know no allied form among the still living ones.

Amber *Lepidoptera* are amongst the greatest rarities. I have never seen one yet. Berendt mentions a large *Sphinx* in his collection, and several caterpillars, which also have never occurred to me.

The *Diptera,* on the contrary, are extremely numerous, and, indeed, of all the families. Berendt mentions amber *Tabani* and *Bombylii,* none of which have I seen; whereas in the Berlln collection there is an *Anthrax* of the size of our *A. semiatra.* Besides, I there saw two of the genus *Leptis,* not dissimilar in size and figure to the *L. aurata,* several *Empes,* and several species of the genus *Tachydromia.* Besides, there are in both collections innumerable small *Muscaria,* and, among the larger ones, species of the genera *Musca, Anthomya, Scatophaga,* &c. I observed a great number of individuals of the family *Dolichopodea,* and, among them, the genera *Dolichopus, Medeterus, Porphyrops,* and *Rhaphium. Diptera* with multiarticulate antennæ are even more numerous, especially the *Bolitophagi.* I found species of *Boletophila, Mycetophila, Leia,* and *Sciara,* frequently perfect, and with all their colours preserved. I think I have also observed *Bibios.* True *Tipulæ* are more rarely seen, but I detected one resembling the *T. pratensis,* several *Limnobiæ,* some small, like *L. pulchella,* and others larger. There is also an abundance of gnats, particularly species of *Psychoda, Lasioptera, Cecidomya, Ceratopogon,* even some *Tanypus* or *Chironomus,* but a true *Culex* I have never discovered.

Next to these the *Neuroptera* are probably the most numerous. Berendt possesses the larva of a *Myrmecoleon.* I myself have seen but a small *Hemerobius,* like *H. hirtus* or *fuscatus,* a *Semblis* about the size of *S. marginata,* as well as a larva of this family, which is the more remarkable, as they all live in water; and innumerable *Phryganeæ* of various sizes.

Among the *Dictyotoptera* I observed two individuals of the genus *Ephemera* in the Berlin collection, as well as two specimens of *Machilis polypoda.* According to Berendt, *Libellulæ* are also found in amber. The most numerous of this order are the *Termites* in both collections. I saw several pieces completely filled with them. The winged ones as well as unwinged larvæ and neuters with large heads are found in it. Germar's *Hemerobius antiquus* is a true *Termites,* which

I know from my own inspection of the identical piece of amber in the collection at Halle. In the Greifswald collection I observed two distinct species of *Psoci.*

In the order of the *Orthoptera,* the *Blattaria* are the most numerous. Berendt assures us that he has distinctly detected some American forms; those which I saw had a greater resemblance to our own native *Blatta Germanica,* which is not rare in woods. To these we may add some *Achetæ,* particularly small not fully developed individuals. The Berlin collection possesses a piece of amber with an insect of this family, that is distinguished by having short filiform antennæ composed at most of sixteen joints, gradually increasing in size, and a short straight ovipositor. It is of the size of *Forficula minor,* but is still a larva. According to Berendt, there are larger grasshoppers. I have myself only seen a small locust in the Berlin collection.

In the last order, the *Hemiptera,* we frequently observe *Cicada* preserved in amber, for example, in the Berlin collection there are several specimens of a *Flata* allied to the *F. cunicularia.* In Greifswald I also saw several species of *Jassus.* I have never discovered bugs, but Berendt and Marcel de Serres have both observed them. Even a *Nepa* the former found enveloped in amber. That species of *Chermes, Aphis* and *Coccus* would necessarily occur in amber, might be absolutely supposed, yet have I never fallen upon any forms belonging to these families.

§ 317.

Passing hence to the fossil insects that have been discovered in recent formations, we will first mention the impressions noticed by Knorr * in the Œnningen calcareous formations, and which chiefly represent the larvæ of *Libellula* and other water-insects. Impressions of cockchafers have also been observed in them. Van der Linden likewise describes a *Libellula* found in this formation †. The most complete list of fossil insects has been given by Marcel de Serres, in the above treatise. According to him, they are found in calcareous marl, which separates the several strata of gypsum in the quarries of

* G. W. Knorr. Lapides, Diluvii univers. Testes, &c. Norimb. 1755—1773, folio, vol. i. p. 151, Pl. XXXIII. f. 2—4.

† Notice sur une Empreinte d'Insecte renfermée dans un Echantillon de Calcaire schisteux. Brux. 1827. 4to. av. f.

Aix, in Provence, and, consequently, belong to a still more recent formation. They are accompanied by impressions of different plants, but never by fish, the impressions of which are also found in distinct strata. The majority of the insects enclosed by this marl have preserved their horny integument, and mere impressions are more rarely found; but their colour appears to be gone, as they are of a uniform brown or black. They are chiefly such insects which live upon a dry sandy or clay soil, and which partly still are found in the vicinity of Aix, as *Brachycerus undatus, Forficula parallela,* and *Pentatoma grisea.* The list given by the above author includes the following forms.

1. *Coleoptera.* A *Harpalus* of moderate size; a *Dyticus* also of moderate size; a small *Staphylinus;* a *Melolontha,* remarkable from its deep furrows on the elytra; a *Buprestis* of the form of *Trachys nana,* Fab.; several *Melanosoma,* among which one like *Asida grisea,* also a *Chrysomela* like *C. cerealis;* two species of *Cassida,* one like *C. viridis;* many bark-beetles; one *Apate,* allied to *A. capucina;* an *Hylurgus,* a *Scolytus,* and a *Trogosita* like *T. cerulea;* lastly, innumerable *Curculios,* two *Brachyceri,* one like *Br. nudatus,* Dej., the other like *Br. algirus,* Fab.; several species of *Cleonis,* one like *Cleonis distinctà, Larinus,* Germar (*Rhinobates,* Meig.); several *Meleus,* the still living form of one species; then *Hyperæ, Naupacti,* one like *N. lusitanicus,* Dej., and one *Cionis,* like *C. Scrophulariæ.*

2. *Hymenoptera.* Three species of *Tenthredos,* one smaller than *T. viridis,* the second larger, and a third of moderate size; an *Ichneumon;* an *Agathis,* Lat.; two *Polistes,* one species like *P. Gallica,* the second like *P. morio,* Fab.; several *Formicæ,* some larger, some smaller like *F. subterranea.*

3. *Lepidoptera.* One butterfly of the genus *Satyrus,* from the communication of another party; a *Zygæna,* a *Bombyx,* perhaps a *Cossus* of moderate size.

4. *Diptera.* An *Empis* like *E. tesselata,* a *Nemestrina* like *N. reticulata,* an *Oxycera* of the size of *Stratiomys chamæleon,* and one allied to *Xylophagus ater;* a *Microdon* and an *Ochthera.* Of *Diptera* with multiarticulate antennæ, there are several *Bibios,* two *Penthetriæ,* some minute *Sciaræ,* and one *Platyura* like *P. cingulata.*

5. *Neuroptera* there are none.

6. *Dictyotoptera.* Many *Libellulæ,* some as large as *Æschna grandis,* and their larvæ are tolerably abundant.

7. *Orthoptera.* One *Forficula,* like *F. parallela;* several *Achetæ,* one like *A. italica,* Fab., one like *A. campestris,* a third very small, a small *Gryllotalpa,* perhaps the larva of our species; a *Xya,* Ill., allied to the *Xya variegata,* Ill.; a *Gryllus,* like *Gryllus cœrulescens,* F.

8. *Hemiptera.* Bugs especially of several genera, for instance, two *Pentatomæ,* one like *P. grisea,* the second like *P. oleracea;* two species of *Coreus,* from ten to twelve different species of *Lygæus,* a small *Syrtis,* F., three species of *Reduvius,* of moderate size, a very characteristic species of *Hydrometra,* F., a small *Gerris,* Lat., a *Nepa* smaller than *N. cinerea,* a *Cicada* like *Cicada plebeja* (*Tettigona plebeja,* Fab.).

FOURTH SECTION.

TAXONOMY.

FIRST CHAPTER.

GENERAL IDEAS.

§ 318.

Taxonomy, which is the last division of the general portion of Entomology, has to exhibit the means whereby the large host of insects may, according to certain principles, be classed in divisions and groups, and also the connexion of these groups together. The necessity of this grouping and subdivision is not so evident in any class of animals as the present, as the number of their different forms is very great, and doubtlessly greater than those of the entire vegetable kingdom. A computation of the known species has not been indeed latterly made, and can scarcely be so, as all the known forms are nowhere yet brought together, or even described, yet a tolerable result may be deduced by comparing the number of known species of any country with its indigenous plants, and then forming a comparative computation with that of all known plants. There are, for instance, in Germany, including the *Cryptogamea*, at most 6000 different plants, but certainly more than 12,000 insects, so that if this proportion be constant, which may be admitted, the number of known insects, according to the 60—70,000 known plants, will evidently rise to 120—140,000 species. If, now, in concordance with the estimation of the latest and most successful botanists, we say that about one-third of the collective species of plants are known, then the number of insects inhabiting the earth would amount to from 360—420,000 species, or, in round numbers, we may say 400,000. But this number has neither been collected nor described. Even were we to calculate all that are preserved in the large museums of Paris, London, Berlin, and Vienna, the number of known species would scarcely extend to one-fourth of this. M'Leay and Latreille consider 100,000 to exist already in cabinets, yet I much doubt whether a positive calculation of them would give so many species. Count Dejean in Paris, whose collection is known to be the richest private one, calculates the number of his beetles at 21,000, and in the Berlin collection, according to a general computation, there are about 28,000 beetles. The beetles stand in proportion to all the other insects in the ratio of two to three, consequently the Berlin Museum should therefore possess about 78,000 species, a number which is not, however, attained, because, as every one knows by experience, the beetles are more anxiously sought by travellers than the other insects. Hence I believe the number of known species in collections may be considered at 80,000, which is certainly not too few, but many more would not certainly be found. Of these there may be 36,000 beetles, 12,000 *Lepidoptera*, 12,000 *Hymenoptera*, 10,000 *Diptera*, 4,000 *Hemiptera*, 1,000 *Orthoptera*, 1,000 *Neuroptera*, and 2,000 *Dictyoptera*, including the parasitic *Mallophaga*. Taxonomy instructs us in the division, determination, and the description of these species, as well as furnishes us with the history of all preceding arrangements.

§ 319.

Every division and grouping of natural bodies has for object the easier survey of the whole, and thus to facilitate the knowledge of all by a course easier than the study of the separate individuals. Proceeding from a somewhat different point of view, their division has for object to render the discovery of any individual more easy from certain determinate and essential characters, and this can be attained only by the arrangement of the characteristic marks found in all natural bodies. We thus obtain a classification which commences with the most general characters, whence, proceeding to other more limited characters, the groups are formed, which must be strictly exclusive, if the utility of the subdivision is to be preserved. By means of such generally-opposed groups, the list then gradually descends to the lowest of all, the species, and with the definition of which its purpose is fulfilled. We call a division made upon these principles artificial or an artificial system, yet unjustly so, for a system can never be artificial, but must be necessary and natural. A second point of view proceeds from the idea that in nature there is a concatenation of beings in every direction, and it seeks in their arrangement to express this interlinking in their subdivision, and, thereby to produce the proof of the correctness of the opinion. It thus creates a system which therefore must be natural, that is to say, such as appears expressed in nature itself. This system can, however, only be constructed, when not only all the forms, but also all the ideas which express themselves in these forms, are known, and when it is seen that every form has absolutely a thought as its foundation, and that it is not an accidental but a necessary one. But the idea to which the study of natural bodies leads is their gradual development, to exhibit which is the proposition of the systematist.

Both subdivisions, for the system is also a subdivision, have this in common, that they form groups, the members of which possess certain characters, and by collecting these groups together by means of still more general characters, a survey of the entire contents is effected. They nevertheless sometimes lead to very different results, by separating a division that connects the rest, and *vice versâ*. But system has the advantage of not regarding solitary characters only, but all collectively, and can therefore only separate and connect where nature itself has marked a separation and connexion.

§ 320.

The methods whereby both attain the goal are different, for artificial subdivision proceeds from the characters of the last group, which we generally call species, and collects similar species under one common character, and thence forms the genus; the characters common to genera give those of the higher groups, the orders and their common characters combine to form those of the classes. It depends, therefore, upon every classifier how far he will proceed in separation and subdivision. Indeed, much difference of opinion exists upon the determination of the groups between the species and the order, whence have arisen the several definitions of sub-genus, genus, and tribe. In fact, opinions will never harmonise upon the claims of genera, because no universal principle for the structure of genera in an artificial subdivision can be given. This principle is in itself exceedingly capricious, and if one maintains thus far a genus extends, and another thus far, both are certainly right, if only every group which they distinguish as genera are distinguished by similar and exclusive characters.

The natural system, the object of which is to discover analogies and affinities, does not proceed from characters, but from the idea expressed in each group, and forms from these, according to the laws of thought, a philosophical structure. It is requisite, as well for the discovery of the conception and its formation into an idea, as for the constructing of the system, to be thoroughly acquainted with all forms, both in their external and internal characters, for it is these which express the concealed idea: when these ideas are found, their arrangement offers of itself, if we but keep in view the object of the natural system, namely, the discovery of analogies and affinities. This concealed idea is properly the true character, and which is expressed in a natural group, and so distinguishes it; if we have the idea, the character is conveyed with it. These ideas are expressed in the history of the development, or in the manner in which the individual has evolved itself from its origin; then in the form and composition of the internal organs; then in the figure, structure, and number of its external organs; and, lastly, in its functions, both external, and more particularly those of the internal organs. Where there is a resemblance or similarity in all these relations, there is found a perfect affinity; but where only some resemble and others differ, there it is only partial, and it is the greater the more and more perfectly the several determinate causes harmonise together. We hence distinguish several kinds of affinity, namely, the following *:—

1. Gradational affinity. This is founded upon the resemblance of the several organs in the grades of development, for example, upon a conformity in the development of the organs of the mouth, whether these are mandibulate or haustellate; upon a conformity in the metamorphoses, &c. Insects which present these resemblances in their organs, and the development of these organs, are brought together in the same group.

2. Parallel affinity. This is expressed in the mutual relation of the developed forms of individual organs to the rest. It may happen that whilst the remaining organs have acquired a tolerably equal development, one passes through several, either higher or lower, forms of development. Thus are produced:

a. Changes of external form in the same grades of organisation, for instance, beetles with elongate proboscideal mouths imitate the mouths

* See Schulz natürliches System der Pflanzenreiches. Berlin, 1832. 8vo. p. 132, &c.

of haustellate insects, although their oral organs are formed as in all beetles.

b. Repetition of the same form in different grades, for example, a resemblance between genera of different orders, namely, *Tipula* and *Bittacus*, *Mantis* and *Mantispa*, &c.

c. A change of form in individual organs, with a general resemblance in the rest, for instance, clavate antennæ of *Hellwigia* among the *Ichneumons*, filiform antennæ in *Anthribus* among the *Curculios*, &c.

3. Typical affinity.—It will be found that in general all forms and grades of organisation in a natural group stand in a certain degree of resemblance to each other, which relation is considered as the type or characteristic expression of the group; where this resemblance is found there is typical affinity. This can present itself as

The generic type—if the species of a genus agree in form, sculpture, and colour.

The family type,—if, for instance, the oral organs, antennæ, legs, or the entire form resemble each other in the genera of a family; and as

The type of the order—if the grades of metamorphoses or the construction of the body evince a certain conformity, as is very evidently the case in the *Coleoptera*.

These three kinds of affinity separate and connect at the same time the several groups. Gradational affinity presents the characters of the classes, orders, and higher groups; typical affinity distinguishes the natural limits of the lower groups. Parallel affinity again connects the several groups together. Thus, upon the similitude and dissimilitude of all the qualities and characters is the natural system founded.

§ 321.

It may now be asked what course does the natural system follow in the consecutive arrangement of the groups? In reply to this, we can scarcely say more than that it arranges the groups according to their affinities, and this series regulated by affinities is the course of the system. Nevertheless we can, proceeding from the essence of the natural system, characterise its course *à priori*. It is also the task of the natural system to show the developments which a group has passed through from its simple beginning to its extreme perfection. These developments are shown to us by physiology, and therefore every natural system must proceed upon physiological principles.

The physiological principles whence the natural system proceeds are:—

1. That the entire organisation takes its origin from a most simple beginning, whence by the development of this into several organs, it elevates itself to its most perfect form. This development exhibits itself partly in the internal and partly in the external organs, and almost throughout presents itself in antitheses, for instance, insects with a metamorphosis and insects without a metamorphosis; the former are again divided into those with a perfect and those with an imperfect metamorphosis, &c. The more these antitheses are divided the more do they seek to re-unite, in the first place, to preserve their original unity, and in the second place to produce a new antithesis, as, for instance, both groups into insects with haustellate oral organs and with mandibulate oral organs, each of which again strives to approach the other. Thus lower groups with individual superior organs stand opposite in equal value to the lower groups of the superior grades.

2. This equivalent value produces the mutual relations of the groups, which re-produces their more intimate concatenation.

Thus we find insects with an imperfect metamorphosis possessing mandibulate organs, which, from their second degree of development, strive to rise above those with a perfect metamorphosis and haustellate oral organs, as, for instance, the *Orthoptera* are placed by the majority of systematists above the *Diptera* and *Lepidoptera*, which, however, is inadmissible, from their imperfect metamorphosis.

3. The external organisation can attain a higher grade, while the internal remains stationary, and thus mark the prefiguration of a superior group in one that is inferior. It thence happens that the natural system does not ascend in a direct line from the most simple to the most complex group, but sends forth on all sides lateral branches, which, proceeding from a lower grade, strive to attain the highest.

According to these principles, which we have thus made to harmonise with the views of modern systematists, was the system sketched that we formerly published *, and which we shall have an opportunity of presenting, in the historical survey of systems.

Upon passing from these general observations upon the nature and difference of both divisions to the groups characterised in both, we shall find them to consist of the following:—

* De Insectorum systemate naturali. Halæ, 1829. 8vo.

§ 322.

I. Idea of Species.

A species is that group of natural bodies which agree together in all their essential, unchangeable characters. The idea of species comprises in it a congruency, that is to say, not a mere conformity, but also a resemblance of its individuals.

A species is the lowest of all the systematic groups, and consequently the most fixed and conformable; no further differences are observable amongst its individuals, all have consisted from the commencement of this form, and continue so by the propagation of new and congruent individuals. Yet differences in less essential characters may occur, for example, in colour, and even in size, and such forms have been called varieties. They originate from accidental circumstances, which cannot be predicted. Others, which have been called sub-species, exhibit a greater conformity together, but which differ in some characters from the type of the species, and these differences are continued through all subsequent generations, which is not the case in mere varieties. But they yet announce themselves as true individuals of the species by a conformity in essential unchangeable characters, and therefore cannot, notwithstanding these differences, be separated from it.

§ 323.

One important character which especially identifies the sub-species with the species is, that they are fertile together. This is a very definite character, and which is subjected to no divarication; for howsoever much the several sub-species of *Coccinella variabilis*, Ill., differ from each other, so much so that Fabricius considered them as forming several species (viz. *C.* 10-*punctata*, *C.* 13-*punctata*, *C.* 10-*pustulata*, &c.), we however find them in reciprocal connexion, and there is consequently no doubt that they are all one species. Truly distinct species never regularly *, or at least but rarely, intermix in a state of nature, and certainly not fruitfully, although bastards (*species hybridæ*), that is, new intermediate ones originating from the intercourse of two species, produced in a state of captivity, or in a state of life differing from their original natural state, is not rare among the superior animals. In reference to this, we may therefore say that sub-species and varieties

* See above, § 292.

are met with pre-eminently among such insects as are found in the proximity of mankind, and there in great multitudes, as, for example, in the recently mentioned *Coccinella*, in the cockchafer (*Melolontha vulgaris*), the garden chafer (*Anisoplia horticola*), &c. It is also possible that the influence the universal cultivation of the country has had upon even the nutrimental plants, has extended also to them, and has united together several originally distinct species, as may with much probability be asserted of the sub-species of the domestic dog.

§ 324.

Many differences of sub-species and varieties depend also upon the nature of the country and of the climate. Several of our recently established species have originated from such circumstances, and must therefore be re-arranged with their original species, as has also been occasionally done by several authors. *Carabus arvensis*, F., for example, is found not so much in fields as in sub-alpine situations, and here presents itself in its usual form ; *C. pommeranus*, Oliv., a native of the north of Germany, is one of these sub-species, which is distinguished by its less brilliant colour and less distinct sculpture ; *C. Harcyniæ*, St., also is a sub-alpine variety of the *C. catenulatus*, F., which is found in the woods of plains ; and there are doubtlessly many new described species of the *Carabodea* which stand in the same relation to old and long-known ones.

We must also enumerate with the sub-species the smaller individuals of many of the *Lamellicorns*, which have long been separated as true species under a distinct name, for example, the smaller variety of *Lucanus cervus*, or *L. capreolus*, of many writers. I think it very possible that these smaller individuals have originated from a deficiency of food or of a less nutritive quality in the larva state *, and that in the larger insects this variety must be greater than in the smaller ones, as the former require more for their support, and are more exposed to the effects of temperature than the latter, the duration of whose lives besides is limited in general to one year, whereas the larger ones pass several years in the larva state. We find smaller, and indeed sometimes very small, individuals of almost all the larger, and especially of the very large beetles ; and the *Lamellicorns* particularly exhibit this variety, for instance, *Oryctes nasicornis*, *Scarabæus stercorarius*,

* This idea I find suggested also in Meckel's vergleichenden Anatomie, tom. i. p. 335.

Typhæus, and many exotic species. A striking instance of the influence which good or bad nutriment has upon the development of the larva is exhibited to us in the practice of the bees rearing queens from the larvæ of the neuters.

These facts show that the establishment of a true species is not so easy an affair, and that it requires very comprehensive tact. Good specific characters however may be derived from the general form, the form of individual parts, especially of the head and thorax, the sculpture or markings of the external integument; after which the size and the relative proportions of different parts; and lastly, also even colour.

The specific character, or sum of all the essential characters that define the species, serves for the distinction of a species.

§ 325.

II. Idea of a Genus.

Above the species stands the group, which has been called the genus. A genus is composed of several species, which agree in certain qualities of essential parts or organs; its idea consequently comprises that of conformity.

This, in itself correct definition, admits however of a variety of interpretations, according to the object aimed at in the foundation of the system. Artificial classification divides where it observes divarications and differences in the organs adopted as the basis of the subdivision; whereas the natural system regards the harmony of all the organs, and only forms divisions where divarications of decided importance are observed in those organs. An example will speedily illustrate this. Fabricius, whose classification, founded upon the oral organs, is evidently artificial, divided the *Chrysomelina*, according to the structure of the parts of their mouths, into several genera, and referred to these genera all those leaping beetles which Geoffroy and Illiger united in the one genus *Haltica*, according as the parts of the mouth, or even merely the external form, appeared to agree with the characters of this or that family; the most prominent character, that of leaping, he left quite unnoticed, keeping merely the principles of his system in view. Latterly, however, and even indeed formerly, as soon as it was wished to form natural genera, the greatest attention has been paid, and justly, to this power of leaping, and it has consequently been considered as the chief characters of these creatures, and indeed they appear to be particularly distinguished by it.

§ 326.

The method whereby we pass through several qualities and characters which constitute groups, down to the genus, is analytic. The last group before the species is generally considered the genus. But it is possible that one or the other of such determinate genera may be still further subdivided by divarications in isolated characters: are now such groups to be raised to positive genera? In general this must be negatived, for as the higher groups were defined by the simultaneous differences of all the organs, and the peculiarities deduced from them, so must the genera of a family, besides a decided difference in the generic characters, exhibit likewise a general transformation in shape. If this be not the case the genera will necessarily be of unequal value, and it will therefore never be possible to settle the contest upon the generic rights of any determinate group. Every discussion and dispute upon any subject rests upon principles; if upon these a difference of opinion prevails all further argument is useless, and no satisfactory result can ever be obtained until one of the contesting parties can be convinced of the falseness of their principles.

§ 327.

In the structure of new genera there are two wrong roads to be avoided; the one is too circumstantial a dividing, and the other is the unnatural connexion of absolutely different groups.

The first is most easily followed, when, upon the increase of the number of the species of a genus, the survey of the whole is rendered difficult. Hence has proceeded in modern times the host of genera which are in general deficient in all fixed characters, and are frequently exceedingly superficial, being constructed merely from the external form and general impression. A distinction, as, for instance, that which has been used for the separation of *Ophonus* and *Harpalus*, namely, the deeper punctures of the superficies in the former, whereas in the latter it is smooth, must indeed be regarded when it is extensive; but it never justifies the construction of a genus, and can at most serve for a subdivision of the species within the limits of the genus. Another instance is exhibited likewise in the same family, namely, the *Carabodea*, in the genus *Feronia*, the former subdivision of which into distinct genera was founded chiefly upon the form of the prothorax, and which modern writers have very justly, from its being untenable, reunited into one genus. If, for example, genera might be formed from mere outline, we might readily form new genera in the large family of the *Elaterodea,* from the figure of the prothorax, which would be equally inadmissible. There are, in fact, among the *Elaters,* as well as among their close allies the *Buprestes,* several natural genera, but we much doubt whether the many genera of *Elaters* recently constructed by Eschscholz *, from the form of the tarsal joints, may be considered as natural.

§ 328.

The second by-way we find to have been pursued chiefly by the older entomologists; but it originated in the nature of the thing when but few species were known, and thence their family characters were adopted as generic characters. Thus all the Linnæan, and many of the Fabrician genera have become families, and the divarications they were either not acquainted with, or did not regard, have never supplied the characters of genera.

§ 329.

It may be asked how are these by-ways to be avoided?

It has often been considered that exactitude and acuteness were the qualities that gave a right to found genera. Indeed, every naturalist who is deficient in these qualifications will vainly endeavour to form new genera, and never produce anything useful: but, on the opposite side, is every considerate and acute observer competent to found new true genera? We should even here doubt constant success. A judicious eye corrected by experience, an equally secure feeling of the value of the discovered differences, as well as the conviction that only natural genera may be admitted, are the qualifications that combine to form the happy talent in which we may repose unconditional confidence in the formation of genera. This talent, which, by the exercise of years, may be extraordinarily increased, was especially and distinctly exhibited in Fabricius and Illiger, but in the former it decreased with increasing age, whence many of the genera he last constructed are devoid of naturalness; whereas Illiger rejoiced in its complete perfection throughout the whole of his indeed short but very active career. This happy talent, or, as it may be called, judicious tact, is

* See Thorn's Archiv., vol. ii. part i. p. 31, &c.

never doubtful of the characters requisite to the formation of a genus. Fabricius could not have made a better choice for the determination of genera than of characters deduced from the oral organs and the antennæ, as these organs are of the greatest importance to the existence of the insect, both for procuring its nutriment and in its economy. Their structure is regulated by the former, and they instruct us upon the latter. If, indeed, much may be said against this selection, from the difficulty of their investigation and observation, yet it affords no sufficient ground entirely to reject them. Industry and patience overcome much, and the excellent labours of many modern entomologists, for instance, of Savigny, prove that a new era in the history of entomology may be dated from his comparative representation of the oral organs, and especially from his inquiries into the mouth of the *Lepidoptera* *.

When such an important point is discovered the definition of the genus is no longer difficult; it is only necessary to inspect, if the other parts of the body present the same differences as the organs of the mouth; if this be the case the genus is natural, if not it is artificial and superfluous. This is likewise the case in the introduction of the neuration of the wing for the determination of genera. In many families the divarication is in such close connexion with the structure of the entire body that a mere view of the wing suffices to show us the difference of genera; but this is often not the case, and to separate the genus *Rhamphomyia*, Meig., from *Empis*, because it has one nervure less at the apex of the wing, is very artificial, and cannot consist with the principles of a natural system. These differences can only be used to characterise the divisions within the boundaries of a genus, and thus to facilitate the discovery of a species among a multitude, as Meigen himself has done in the genus *Limnobia;* but the divarication in the neuration of the wing cannot be raised to the character of a true genus. But let all entomologists who occupy themselves with the formation of new genera remember the dogma of Linnæus,—“It is not the character which forms the genus, but the genus, constructed by nature, brings forth the character.”

§ 330.

Little that is universally applicable can be said upon the value of certain organs for the determination of genera, for even the oral organs are

* See his Mémoires sur les Animaux sans Vertèbres. Paris, 1816. 8vo., with figures, vol. i.

sometimes exactly alike in truly different genera; but the stability of genera depends in many instances much more upon the judicious balancing of all the parts of the body, and their differences, in which case it is only the above mentioned happy tact that can securely guide the observer. For, however fixed the number of the joints in the antennæ, for example, may be in certain families, yet instances occur in which they are subjected to much variety. The genus *Cimbex* is a case in point, the antennæ of which consists sometimes of six, sometimes of seven joints, of which sometimes one, or two, or three of them are swollen into a knob. If we compare with this the number of the joints in the antennæ in the whole family of the saw-flies, we shall speedily perceive that genera formed merely from the number of those joints cannot absolutely be considered as natural. This number is still more variable in the genus *Forficula*, in which almost every species has a different number, and which likewise is not even uniform in the individuals of the same species; and yet Leach has formed distinct genera founded on these differences.

§ 331.

The sum of the characters adopted for the definition of the genus forms the generic character, which is either natural when deduced from all the organs, or artificial when it merely refers to the characters admitted as the basis of the classification. This again constitutes the essential character when it merely cites the distinguishing marks of the genus. The generic description refers neither to the natural nor to the artificial generic character, but presents the entire form, even to its most minute divarications; it is, as it were, a figure in words, whereas the characters depict in words particular organs only.

III. Idea of the Superior Groups.

§ 332.

It is from characters of greater generality, especially from resemblances in form, or the similar structure of certain parts, as the feet, wings, &c., which yield no generic characters, that the genera group themselves into superior divisions. This grouping must follow the principles adopted in characterising genera, if no violence is to be done to nature. We must here also strive for an equality of value in the groups formed.

The division immediately above a genus is usually called a family It is peculiar to the natural system, and by this only is it called forth Linnæus and Fabricius, who formed artificial classifications, had no families.

The characters which distinguish the families are derived not only from their resemblances in structure in general, but also frequently from their economy. Thus the allied families of the *Carabodea* and *Hydrocantharides*, which both live upon prey, are distinguished, as well from their dwelling-place, and a very definite and easily recognisable form of the body, and also by a very marked difference in the structure of their posterior legs, whereas the organs of the mouth and the antennæ agree in the types. Were we to deduce the characters of families from such relations, it could be defined only as one of resemblance; in the similar structure of certain parts in several genera lie the characters of a family.

§ 333.

We sometimes also remark within the boundaries of a family, especially of a very comprehensive one, subdivisions, which bear the same relation to the families as do the subdivisions of a genus to the latter. Such groups have been indeed called sub-families. They are as useful for the easier discovery of the genera, as the former for facilitating the discovery of the species, and they are therefore more artificial than natural groups. But it depends much upon their mode of division, for this does not admit of being said of the sub-families of the large family of the *Ichneumonodea*, and as little of many others. For the sake of an example, we may be allowed to state that those three sub-families differ in the structure of their palpi. The genuine *Ichneumonodea* have five-jointed maxillary palpi, and four-jointed labial palpi; the *Braconodea* five-jointed maxillary and three-jointed labial palpi; the *Bassina* six-jointed maxillary and four-jointed labial palpi. Similar groups, founded upon analogous relations, are found in the families of the *Carabodea*, *Lamellicornia*, *Rhynchophora*, *Vespacea*, *Apiaria*, *Muscaria*, &c.

§ 334.

The chief group above the family is the order; it does not so much depend upon a similarity of individual parts, as upon the entire body, for instance, whether the thorax be divided in its three segments, or whether these are closely jointed together; upon the form and structure of the larva; upon the type upon which the oral organs are formed, whether mandibulate or haustellate; or upon the fundamental form in the structure of the wings. All these relations, indeed, produce an external resemblance, but these resemblances are the result of physiological divarications. The orders are properly families of greater compass, yet with the distinction that the family characters are founded upon a similarity of form of individual limbs, as the feet, antennæ; whereas the characters of orders are derived from a similarity of form of the body.

There are likewise other subdivisions between an order and its families, as between a family and its genera, which have been called sub-orders, or tribes. The characters of such groups generally consist in the different form of a certain organ, but which differences, from their wider distribution, admit neither of being applied to family divisions nor to generic divisions. Thus the *Coleoptera* are divided into tribes from the number of their tarsal joints, the *Diptera* according to the number of the joints of the antennæ, the *Hymenoptera* according to the structure of the sting, &c. Yet such tribes are more artificial than natural, which admits of being demonstrated in the three examples cited; they can merely serve to facilitate finding the families, and are not to be considered as natural groups.

§ 335.

The classes, lastly, are the highest groups of animals; which, like the orders, are founded upon the differences of an otherwise uniform grade of structure, and consequently repose upon the differences of the grades of organisation. An equal structure and form of the organic systems and the thence produced very general conformity of external figure, a similarity of periods of development, and other similar relations are the characters which justify the formation of classes. All insects collectively form one class, in as far as they actually agree with each other in the above characters.

The objects forming classes consequently neither require to be congruent nor equal, nor even externally to resemble each other, as these qualities are deduced from a conformity of external figure, but they must all, physiologically considered, be of equal value; they must all, to make use of a mathematical illustration, be pure geometrical inconstant magnitudes, and not at the same time likewise algebraical constant magnitudes, both of which are virtually different.

§ 336.

Some naturalists admit, and certainly correctly, still further divisions, which comprise several classes, but which have no name. They also are founded upon similarities in the structure of the organs and of the organic system. The four above explained (§ 88) organic systems, stand in three different relations to each other; namely, in the first group they retain their vegetable character, with the mere addition of the animal character of voluntary motion; in the second and third groups the animal character predominates; so that in the second, motion, and in the third, sensation, are especially developed. We thus obtain the chief types under which all animal forms may be arranged.

SECOND CHAPTER.

HISTORY OF THE CHIEF ENTOMOLOGICAL CLASSIFICATIONS AND SYSTEMS.

§ 337.

The earliest essay to group animals in general, and consequently insects, is that of Aristotle (about 330 B. C.). In his works, one of which is exclusively devoted to Zoology, he indeed nowhere gives a complete system of animals; but from hints here and there expressed, it appears that he separated the *Crustacea* as a particular group (Μαλακόστρακα) from other insects (Ἔντομα). A further division of insects is deduced from their wings, and from their presence or absence they fall into Ἔντομα πτιλωτά and Ἔντομα ἄπτερα; both again consist of several groups, which are partly perfectly natural. The divisions of Aristotle are in general so successfully made, that we are perfectly astonished at his vast genius, which whithersoever it directed itself, always found the right, and he maintained in everything he attempted an equal greatness.

The labours of his successors are very different. Pliny's "Natural History" is merely a systematised Encyclopædia, in which all those works are abridged that the author had read in the course of a life devoted to science, and which was sacrificed in the contemplation of a magnificent natural phenomenon. Much is therefore collected without any criticism; what was new was not at all introduced, and the old frequently distorted by the mode of communication.

Ælian's "Natural History of Animals" properly contains merely anecdotes and characteristic features of individual animals, and no zoological description, and may be therefore merely noticed.

§ 338.

Since Aristotle, nothing of any consequence, either in antiquity or in the middle ages, was done for the natural history of animals; so that we leap over a space of more than 1800 years, and with Conrad Gesner re-commence our historical detail.

He, a poor but industrious Swiss (born in 1516), collected everything that was known relative to the history of animals; he filled up many gaps by his personal observations, and thus filled five large folios with merely the natural history of the vertebrata. Before he reached insects, death carried him off (1558). His posthumous papers upon this subject fell into the hands of the well-known Joachim Kamerarius, of whom they were purchased by an Englishman, Dr. E. Wotton, who sent them to Thomas Penn, in London, to be published; he, however, did not fulfil the commission, but these papers fell, when he died, into the hands of Thomas Moufet, who incorporated them with his "Theatro Insectorum," and they were thus imparted to the world about a century after their origin (1634).

Gesner is justly considered as the restorer of natural history; it was by means of his extraordinary industry that long lost treasures were again made known to that age, which was thus stimulated to further researches; had he not existed the world would doubtlessly have still much longer slept.

His influence, however, did not so much exhibit itself in the natural history of insects from the above causes, and it was still several lustres before they were independently and satisfactorily elaborated.

Ulysses Aldrovandus was the first who took notice of these forgotten creatures, and described them and their natural history in seven books. We here find the first division of insects into land and water dwellers, two chief groups, which were still further divided according to the structure of their legs and wings.

After a commencement was thus made to the study of entomology several amateurs speedily collected. The imperial court painter, Hoefnagel, figured insects very beautifully; Franciscus Redi observed their origin and propagation; M. Malpighi made a masterly dissection of the silkworm; and Swammerdamm, lastly, investigated insects in the several stages of their existence, and formed the first essay towards a natural system. His arrangement of insects was this:—

I. Insects without a metamorphosis.

They, indeed, change skin, but retain their original form. Spiders, lice, woodlice, and *Myriapodæ*.

II. Insects with a metamorphosis.

1. The creature moves throughout all the stages of its existence: in the first it is wingless, in the second (pupa) it obtains the rudiments of wings, and in the third entire wings.

Here are arranged the *Neuroptera, Orthoptera*, and *Hemiptera*, but he did not separate them into distinct groups.

2. The creature, in its central grade of development, is motionless, but has limbs.

Here the *Hymenoptera, Coleoptera*, and as appendix, the *Lepidoptera*.

3. In its central stage of development the creature has neither motion nor wings, but appears as an ovate pupa.

Here the *Diptera*.

In the author's Book of Nature, "Biblia Naturæ," which was published after his death, which took place in 1685, this system was illustrated with examples, and the anatomy of insects especially is admirably presented.

The now increasing writers upon entomology offered each his own arrangement, and according to which their subject was presented, but system still remained subordinate to observation. Thus Joh. Gœdart wrote upon the metamorphosis. Sybilla Merian observed the development of the *Lepidoptera*, and, from affection to the science, went herself to Surinam, to continue there her observations. Ant. von Leuwenhoek made microscopic experiments; and Antonio Vallisnieri pursued the path trodden by his predecessors, of describing the metamorphoses of insects: works which are still worthy of regard as well as of emulation.

§ 339.

The first true systematist was an Englishman, John Ray; the following is the arrangement published by him in his "Method. Insectorum." Lond. 1705, 8vo.

I. *Ametamorphata* (insects without a transformation).
  1. *Apoda* (annulate worms).
    a. *Terrestria.*
    b. *Aquatica.*
  2. *Pedata.*
    a. *Hexapoda.*
      α. *Terrestria* (lice).
      β. *Aquatica.*
    b. *Octopoda* (spiders).
    c. *Quatuordecempoda* (lobsters and crabs).
    d. *Polypoda.*
      α. *Terrestria* (centipedes, woodlice).
      β. *Aquatica* (*Amphipoda* and *Isopoda*, Lat.).

II. *Metamorphota* (insects with transformation).
  1. *Larvis et pupis agilibus* (*Orthoptera, Hemiptera*).
  2. *Pupa immobili.*
    a. *Coleoptera* (beetles).
    b. *Aneloptera.*
      α. *Alis farinaceis* (*Lepidoptera*).
      β. *Alis membranaceis.*
        † *Diptera, bipennia* (flies).
        †† *Tetraptera, quadripennia* (*Hymenoptera*).

III. *Metamorphosi simplici e vermiculo in animalculum volatici, interposita aliqua quiete* (dragon-flies).

A posthumous manuscript of his, containing a detailed history of insects, Martin Lister published after Ray's death (1707), at the command of the Royal Society of London (Historia Insectorum, ed. M. Lister. Lond. 1710-11), and at the same time appeared a new classification, which we will also subjoin. It is the following:

I. *Insecta ex ovis sphæricis, quæ nullam subeunt metamorphosim.*
    a. *Pedibus senis* (lice).
    b. *Pedibus octonis* (spiders).
    c. *Pedibus plurimis* (crabs, wood-lice, centipedes).
    d. *Pedibus nullis* (worms).

II. *Insecta ex ovis longiusculis, quæ metamorphosim subeunt.*

a. Coleoptera.

b. Anelytra.

α. Pennis quatuor nudis.

β. Pennis quatuor farinaceis.

γ. Pennis duabus.

This arrangement is in fact nothing more than a mere modification of that already given by Ray, and only differs in that its author has brought Ray's third chief group under the second, and unites it with the *Anelytris pennis quatuor nudis.*

§ 340.

From Ray to Linnæus, nothing extraordinary took place for the arrangement of insects. But when this master of natural history published his System of Nature, in the year 1735, in three folio sheets, in which he gave a complete survey of all the then known groups of animal bodies, insects also were placed by him in a new order, which he skilfully determined according to the form and structure of their wings. The following is his division.

The fifth class of his animal system, which comprises those with a simple heart, white blood, and jointed antennæ, contains within it all the insects and *Crustacea*. Both together, therefore, form a single chief group (*Insecta*), which is thus subdivided:

I. Insects with four wings.

1. The anterior ones horny. 1. *Coleoptera.*

2. The anterior ones half horny and half membranous. 2. *Hemiptera.*

3. The anterior and posterior membranous.

a. All covered with scales. 3. *Lepidoptera.*

b. All naked. The nervures.

α. Reticulated. 4. *Neuroptera.*

β. Ramose. 5. *Hymenoptera.*

II. Insects with two wings. 6. *Diptera.*

III. Insects without wings. 7. *Aptera.*

1. With six feet (louse, flea, and some others).

2. With more than six feet.

a. Head connected with the thorax (spiders, crabs, &c.).

b. Head free (centipedes, wood-lice, &c.).

It is not to be denied that by this arrangement many natural, and therefore, very constant groups, were formed, but, s often the case, when, in the arrangement of natural bodies, only one principle of division is adopted, others comprise, in every instance, very different animals. This deficiency must necessarily be recognised upon continued inspection, and, therefore, an anxiety must exist to remove it as much as possible. Above all, the order of the *Hemiptera* is subject to many objections, for, in the first place, the character attributed to it is not found in many of its members, for instance, in many *Cicada*, the *Aphides*, the genus *Chermes*, &c., as they possess four perfectly membranous wings, and, secondly, there are insects united in it, which exhibit the greatest differences in their oral organs.

These circumstances caused the next systematist after Linnæus, who was also a Swede, namely, De Geer, to separate the Linnæan *Hemiptera* into several equivalent groups, as well as to the adoption of a new system, which is the following:

I. Insects with wings. *Alata*.

A. *Gymnoptera*.

1. *Lepidoptera*.
2. *Elingula* (*Ephemeræ*, &c.).
3. *Neuroptera* (*Libellulæ* and other Linnæan *Neuroptera*).
4. *Hymenoptera*.
5. *Siphonata* (*Aphides* and *Cicada*).

B. *Vaginata*.

6. *Dermaptera* (bugs and water-bugs).
7. *Hemiptera* (cockroaches and grasshoppers).
8. *Coleoptera* (beetles).

C. *Diptera*.

9. *Halterata* (*Linnæus, Diptera*).
10. *Proboscidea* (the genus *Coccus*).

II. Insects without wings. *Aptera*.

D. *Saltatoria*.

11. *Suctoria* (the genus *Culex*).

E. *Gressoria*.

12. *Aucenata* (the genera *Lepisma*, *Podura*, *Termes*, *Pediculus*, and *Ricinus*).
13. *Atrachelia* (the spiders and crabs).
14. *Crustacea* (the *Isopoda*, *Ampiphoda*, and *Myriapoda* of Latreille. See below).

This system, which cannot be called a purely artificial one, as it is founded upon several principles of division, is yet deficient in its object as a natural one; the second and third orders are falsely separated, although a division of the Linnæan *Neuroptera* was desirable; the fifth must be again united with the seventh, and the tenth belongs as an integral portion to both; the twelfth and thirteenth, however, are both an intermixture of the most distinct creatures, and the fourteenth cannot make claim to be very natural.

§ 341.

Twelve years (1764) after De Geer's subdivision, a French naturalist of the name of Geoffroy stepped forth as a systematist, where hitherto Englishmen and Swedes had for half a century alone presented themselves. Indeed, the French had not been idle during this time, to prove which we have merely to refer to the labours of Reaumur; but they had not yet presented themselves as systematists, which is the more remarkable, as their countrymen subsequently have been most active in this branch of natural inquiry. Geoffroy's system, which, exclusive of other points, is important from the introduction of the joints of the tarsi as points of division, has fewer groups than any of the earlier ones, namely, only the following six.

I. *Coleoptera.* Mandibles and hard anterior wings. They are divided into

1. Those with hard entire elytra.
2. Those with hard half elytra. And
3. Those with soft membranous elytra (the *Hemiptera* of De Geer).

Each of these groups is subdivided from the number of the joints of the tarsi, in four or five lower groups.

II. *Hemiptera.* Sucking oral organs and half hard anterior wings.

III. *Lepidoptera.* Same as Linnæus.

IV. *Tetraptera.* Four naked membranous wings.

a. Feet three jointed (*Libellula*, *Semblis*).

b. Feet four jointed (*Rhaphidia*).

c. Feet five jointed (*Ephemera*, *Phryganea*, *Hemerobius*, *Myrmecoleon*, and the *Hymenoptera* of Linnæus).

V. *Diptera.* The same as Linnæus.

VI. *Aptera.* The same as Linnæus.

From whatever point of view we regard this system, it is equally unna tural, and worse than any of his predecessors. In the second group of beetles we find the genera *Staphylinus, Forficula, Meloë*, and *Necydalis*, De Geer had already shown that the earwig does not belong to the beetles. But, indeed, if cockroaches, grasshoppers, and locusts are to be classed among the beetles, as Geoffroy has done, the earwig may very well be placed there. What a mixture is not the fourth order even! It was very necessary that an active mind should occupy itself to separate all these errors from the truth, and to raise entomology from its existing state of childhood to its age of manhood.

§ 342.

This genius was found amongst the Germans; it was John Christian Fabricius, who was born in 1748 at Tondern, in the Grand Duchy of Sleswig: he died upon the 3rd of March, 1808, as Professor at Kiel. It was indeed time that the Germans should exhibit themselves as a people that loved science and knew how to promote it, for all their neighbours had preceded them with celebrated examples; but it soon displayed itself in a manner superior to any of the rest, as the most comprehensive, active, profoundest, and most zealous for science.

His division, which was first published in the year 1775, in his Systema Entomologiæ, followed quite a new path, the groups of it being founded upon organs which had never yet been used by authors as the principles of subdivision. These were the oral organs. Fabricius defined the orders (which he incorrectly called classes) by their differences, and in the course of his progressive investigation he established thirteen equivalent groups. Both his first and last subdivisions we will here subjoin.

His first classification was given in 1775, in the Systema Entomologiæ.

I. Insects with biting oral organs.

1. Four or six palpi at the *maxillæ* and *labium*.

a. Maxillæ free, uncovered. 1. *Eleutherata* (*Coleoptera* of Linnæus).

b. Maxillæ covered. 2. *Ulonata* (*Hemiptera* of De Geer; a portion of the *Hemiptera* of Linnæus).

c. Maxillæ connate with the *labium*. 3. *Synistata* (*Neuroptera, Hymenoptera,* and some *Aptera* [*Monocul. Onisc. Lepisma, Podura*] of Linnæus).

d. No *maxillæ*. 4. *Agonata* (lobsters and scorpions).

2. Only two *palpi*, and indeed upon the *maxillæ*. 5. *Unogata* (*Libellulæ*, centipedes, and spiders).

II. Insects with suctorial mouths.

a. With a spiral tongue. 6. *Glossata* (Linnæus's *Lepidoptera*).

b. With valvular proboscis consisting of *setæ*. 6. *Rhyngota* (the remaining *Hemiptera* of Linnæus).

c. With fleshy setiferous proboscis. 7. *Antliata* (Linnæus's *Diptera*).

Howsoever meritorious the undertaking of Fabricius was to discover a new principle of subdivision, whereby all groups of insects could be determined, yet this first division by no means answers the requisitions that a strict classification is justified in making. It therefore at first found but little favour, and the difficulty of the investigation also impeded it, and in many cases indeed doubt was entertained of the possibility of the process. In fact, this work was but the first essay of a new method, and, as such, certainly praiseworthy, in as far as the attention of entomologists was drawn to parts which had not previously been regarded, and which, however, as was evident from this representation, were of the greatest importance for the distinction of groups, and especially of genera. Fabricius has not therefore acquired an immortal name in science so much by the establishment of his system, as exactly like Linnæus, by the path he pursued. All that was distorted and false that originated with him, time in the progress of the science has removed, and his system is put aside; but he is the founder of this mode of arrangement, for which he will never be forgotten, for this he stands forth as a model to succeeding generations.

The changes to which he gradually subjected his system are manifold. New orders were established, old ones more correctly restricted, and the whole was raised to a superior scientific completion. Thus almost in the evening of his days he proposed the following division in the supplementary volume to the second edition of his System of Insects.

I. Insects with biting mouths.

A. Two pairs of mandibles.

a. The lower ones having *palpi*.

1. Free without covering.	1. Class. *Eleutherata* (beetles).
2. Covered.	2. — *Ulonata* (*Orthoptera*).
3. Connate with the *labium*.	3. — *Synistata* (*Neuroptera*).
4. Distended, thin, coriaceous.	4. — *Piegata* (*Hymenoptera*).

5. Horny, strongly toothed, *labium* without *palpi*.	5. Class. *Odonata* (*Libellulæ*).
b. All without *palpi*.	6. — *Mitosata* (*Scolopendra*).
B. A pair of *maxillæ* resembling scissors.	7. — *Unogata* (scorpions and spiders).
C. More than two pair of *maxillæ*.	
1. Within the *labium*.	8. — *Polygonata* (*Isopoda*).
2. Outside the lip closing the mouth.	9. — *Kleistagnatha* (short-tailed crabs).
3. Outside the lip, but covered by the *palpi*.	10. — *Exochnata* (long-tailed crabs).

II. Insects with suctorial mouths.

1. In the mouth a spiral tongue.	11. — *Glossata* (*Lepidoptera*).
2. In the mouth a horny proboscis, surrounded by jointed sheaths.	12. — *Rhyngota* (*Hemiptera*).
3. In the mouth a soft unjointed proboscis.	13. — *Antliata* (*Diptera*).

We perceive from this division that Fabricius had no idea of a natural grouping, but that he separated from solitary characters when he could. Thus forms the most allied were torn from each other, and very different genera were forced into the divisions from one-sided views; thus for instance, the flea stands among the *Rhyngota*, with which it has nothing in common but its suctorial mouth, whereas we find the lice among the *Antliata*, although they pass through no metamorphosis. The character of the *Odonata* is erroneous, for the *Libellulæ* have one jointed labial palpi, and the character of the *Synistata* does not agree with all, but merely with some genera.

§ 343.

Nevertheless, the system of Fabricius had many followers, especially because by means of it the genera were more correctly determined than had previously been the case; yet its being so unnatural and artificial displeased many, and, therefore, Illiger * proposed uniting both systems, that of Linnæus with the latter, a proposition which he himself executed in the following manner:—

* In the Appendix to his Käfer Preussens, vol. i. Halle, 1798. 8vo.

1. *Coleoptera*, Lin., without *Forficula*	—	*Eleutherata*, Fab.
2. *Hemiptera*, Lin. . . .	—	*a. Ulonota*, F. *b. Rhyngota*, F.
3. *Lepidoptera*, Lin. . .	—	*Glossata*, F.
4. *Neuroptera*, Lin. (to which *Termes*, *Lepisma*, and *Podura* are added)	—	*a. Odonata*, F. *b. Synistata*, F.
5. *Hymenoptera*, Lin. . . .	—	*Piezata*, F.
6. *Diptera*, Lin. (with *Pediculus* and *Acarus*)	—	*Antliata*, F.
7. *Aptera*, Lin. (without the above-named apterous genera) . .	—	*a. Unogata*, F. *b. Agonata*, F. *c. Mitosata*, F. *d. Kleistagnatha*, F. *e. Exochnata*, F.

According to this grouping, which, indeed, removes several of the deficiencies of that of Fabricius, the large Helwig-Hoffmannseggian collection was to be arranged, and thus made the basis of a detailed elaboration of entomology, but its execution was prevented by political events.

Clairville * published almost contemporaneously with this essay of Illiger's a subdivision of insects, which, although it had no influence upon the progress of the science, yet merits a short notice. It was the following:

I. Insects with wings. *Pterophora*.

A. With mandibulate oral organs.

1. Anterior wings horny.	1. Ord. *Elytroptera* (beetles).
2. . . coriaceous.	2. — *Deratoptera* (*Orthoptera*).
3. Wings with reticulated nervures.	3. — *Dictyoptera* (*Neuroptera*).
4. Wings with ramose nervures.	4. — *Phleboptera* (*Hymenoptera*).

B. With haustellate oral organs.

1. Wings and halteres.	5. — *Halteriptera* (*Diptera*).
2. . . covered with scales.	6. — *Lepidoptera*.
3. . . variously constructed.	7. — *Hemimeroptera* (*Hemiptera*).

II. Insects without wings.

1. With suctorial oral organs.	8. — *Rhophotera*.
2. With mandibulate oral organs.	9. — *Pododunera*.

* Entomologie Helvetique. Zur. 1798—1806, 2 vol. 8vo.

§ 344.

These were the systems of the preceding century. But the whole science of zoology, and consequently, therefore, entomology, was involved in a great and advantageous revolution, promoted by the general impulse towards a natural system, and which was especially stimulated by anatomical studies. Blumenbach, by the publication of his comparative anatomy, had conducted naturalists to this we may almost say new field, and its elaboration was now commenced with zeal. Hence was developed the zootomical tendency of zoology, and which possessed in Cuvier its most distinguished and universally revered representative. It took, lastly, a physiological direction, which did not, like the former, merely regard form, but inspected the entire essence of which form is merely the expression. The latter consequently reposes upon the zootomical, and without which it cannot be brought to bear, but its tendency to secure us from one-sidedness, to which the latter so easily leads, is its very greatest advantage. It is also called the philosophical system, and justly, for the path it pursues is more philosophical, in as far as it seeks to explain the composite from the simple, and endeavours to refer the former back to this. But its foundation being physiology, it justly merits its first name. Oken and his system are the representatives of this method.

§ 345.

The first new division of animals was proposed about this time by Cuvier (George Leopold Christian Frederick Dagobert, born 1769 at Mümpelgarde, in Alsatia, died at Paris in 1832), and actually executed in his 'Traité Elementaire'. Insects are here still treated according to the system of Linnæus, but yet the subsequent divisions are indicated in the grouping of the orders. The first of these divisions, namely, the separation of insects into two equivalent classes, was executed some years later in the Tables appended to his Comparative Anatomy, where he separated those with distinct blood-vessels as *Crustacea*, but left all the rest united as *Insecta*.

In the interim, another French naturalist, who afterwards acquired the highest fame in entomology, namely, P. A. Latreille (born 1762 at Brives) published a new division of insects*, which differs from

* Precis des Caractères Génériques des Insectes. Brives, 1796. 8vo.

the Linnæan merely in establishing the *Orthoptera* as an order, and the separation of the *Aptera* into seven equivalent orders. The following are the seven new orders:

1. *Suctoria* (the genus *Pulex*).
2. *Thysanura* (the genera *Lepisma* and *Podura*).
3. *Parasita* (the lice, with *Ricinus*, De Geer).
4. *Acephala* (*Unogata*, F., spiders, scorpions, and *Acari*).
5. *Entomostraca* (the genera *Cypris*, *Daphina*, &c.).
6. *Crustacea* (*Kleistagnatha* and *Exochnata*, F.).
7. *Myriapoda* (*Mitosata*, F., the genera *Scolopendra*, *Iulus*, *Oniscus*, and allies).

The author professes to have sought their natural arrangement, and to have founded his divisions less upon a single character than the general expression of the whole; but the mode in which he has formed his system scarcely supports his proposition, for many unnatural separations still remain. He, however, claims the positive merit of having introduced the natural families.

The next arrangement published by Latreille we find in his 'Genera Crustaceorum et Insectorum,' Paris, 1806, 4 vols. 8vo. He here divides, with Cuvier, Linnæus's *Insecta* into two equivalent groups, *Crustacea* and *Insecta*, the former of which he characterises by the possession of a heart and bronchial respiration, and the latter by respiring through tracheæ. The class of insects which alone here concerns us is divided in the following manner:

I. Insects without wings. *Aptera*.			
A. With segments bearing seven or more pairs of legs.			
a. Head separated from the thorax.			
a. a. Four antennæ. Last segments of the body without legs.	1.	Legion.	*Tetracera*.
b. b. Two antennæ. All the segments except the last with legs.	2.	—	*Myriapoda*.
b. Head connected with the thorax. No antennæ.	3.	—	*Acera*.
B. With three segments bearing legs.	4.	—	*Apterodicera*.
II. Insects with wings.	5.	—	*Pterodicera*.
A. With elytra and wings. *Elytroptera*.			
a. With mandibles. *Odontata*.			

a.a. Wings folded transversely. 1. Ord. *Coleoptera.*
b.b. . . . longitudinally, 2. — *Orthoptera.*
b. With haustellate mouth. *Sipho-nostomata.* 3. — *Hemiptera.*

B. Without elytra, with wings. *Gymnoptera.*
a. With mandibles. *Odontata.*
a.a. Nervures reticulated. 4. — *Neuroptera.*
b.b. . . ramose. 5. — *Hymenoptera.*
b. With haustellate mouth. *Siphonostoma.*
a.a. Four wings covered with scales. 6. — *Lepidoptera.*
b.b. Two wings and two halteres. 7. — *Diptera.*
c.c. No wings or halteres. 8. — *Suctoria.*

We may oppose to this arrangement, which, as it does not regard the entire being of insects, is still merely artificial, that it is not sufficiently strict, for the order of the *Suctoria* is as an apterous group, not in its right place among the *Insecta pterodicera.* And also the groups which are here considered as equivalent to the *Tetracera, Myriapoda, Apterodicera,* and *Pterodicera,* are by no means of equal value, but the two first and two last are most closely allied; the former are the subordinate members of a higher group, and the latter also could at most be placed as equivalent to the orders of the *Insecta pterodicera.* Latreille published shortly afterwards a new grouping of insects in his 'Considerations Générales,' &c. (Paris, 1810), his attention having been aroused by Lamarck's division of invertebrate animals; and he here differed from his former work, by subdividing Linnæus' insects into three equivalent groups. The first of these, the *Crustacea,* remained as before; the second, the *Arachnides,* comprised all the *Insecta aptera* of the former system; the third, the *Insecta,* included the earlier *Insecta pterodicera,* containing the same orders in the same series, whereas the second had received some alteration by the separation of the *Insecta apterodicera* into two orders, the *Thysanura* and the *Parasita.* Later alterations, which Latreille repeatedly made, convince us that, even this arrangement, which is so far superior to the former, neither satisfied the author nor the demands of judicious criticism. In his own discontent with the result, and his endeavours to correct it where possible, and to take advantage of everybody's views, which, indeed, he has nowhere expressed, yet which is but too apparent from all his subsequent works, he evinces a deficiency of all the principles which should have guided him in his systematic labours, and he thereby exposes their being untenable. Thus we find in his next grouping, published in Cuvier's Règne Animal (Paris, 1817, 4 vol. 8vo.), the *Insecta* of Linnæus again divided into three groups, but these differently limited. The first, the *Crustacea*, has received an addition in the order *Tetracera*, whereas the second, *Arachnides*, is made to sacrifice not only this, but also the *Myriapoda*, *Thysanura*, and *Parasita*, which are placed in the third group among the *Insecta*. This also received a new order in the *Strepsistera*, discovered and established by Kirby, so that it now consisted of twelve orders. His next division (Familles Naturelles du Règne Animal, Paris, 1825, 8vo.) raises the *Myriapoda*, after Leach, to a distinct class, and divides the *Insecta* into eleven orders, which remain as before established: the *Annulata* collectively, which form Linnæus' *Insecta*, are here first called *Condylopa*. In the new edition of Cuvier's Règne Animal (Paris, 1829, 5 vols. 8vo.) the class *Myriapoda* is again reduced to an order among the insects, and their number again raised to twelve orders, whereas in his latest system (Cours d'Entomologie, Paris, 1832, 8vo.) they are again made into a class and placed between the *Arachnides* and insects, the loss of which in the number of the orders is made up by the establishment of *Forficula* as a distinct one. The following is this system, which is the last published by its author:

I. *Apiropoda*. *Condylopes* with more than six legs.
  1. Class. *Crustacea*.
  2. — *Arachnides*.
  3. — *Myriapoda*.
II. *Hexapoda*. *Condylopes* with six legs.
  4. Class. *Insecta*.
    A. Insects without wings.
      a. Without metamorphosis.
        * With mandibulate organs. 1. Order. *Thysanura*.
        ** With suctorial mouths. 2. — *Parasita*.
      b. With a perfect metamorphosis. 3. — *Siphonoptera*.
    B. Insects with wings.
      a. *Elytroptera*. The anterior wing covers the posterior like a sheath.

* Mandibulate mouth.

Cases horny. Perfect metamorphosis. 4. Order. *Coleoptera.*

Cases horny. Imperfect metamorphosis. 5. — *Dermaptera*, the genus *Forficula.*

Cases coriaceous. Imperfect metamorphosis. 6. — *Orthoptera.*

** Suctorial mouth. 7. — *Hemiptera.*

b. Gymnoptera. Wings alike.

* Four wings.

† Mandibulate oral organs, at least distinct mandibles.

Wings with reticulated nervures. 8. — *Neuroptera.*

Wings with ramose nervures. 9. — *Hymenoptera.*

†† Suctorial mouth, mandibles abortive. 10. — *Lepidoptera.*

** Two wings.

† Two distorted moveable processes on the prothorax. 11. — *Strepsiptera.*

†† Poisers behind the wings. 12. — *Diptera.*

We have not space here to enter into the merits of this system, and we can only remark that the author has made divisions upon mere external characters, and that, therefore, the naturalness of his grouping, which he chiefly aimed at, was necessarily lost. This may be asserted also of the families within the orders; they are also frequently deficient in a natural connexion and a natural arrangement.

§ 346.

Whilst Latreille was elaborating the natural system during a space of thirty-six years, other countrymen of his were busied with the same subject. Lamarck is the first among these. He first proposed the separation of the *Arachnides* as a class, and he separated the *Insecta* of Linnæus into the three equivalent groups, *Crustacea, Arachnides, Insecta.* The *Insecta* he subdivided into eight orders, as follows:

I. Insects with suctorial mouths.

1. Order. *Aptera* (merely the genus *Pulex, Suctoria*, Lat.).
2. — *Diptera* (besides the *Diptera*, the order *Rhiphiptera*, Lat., also belongs here, but which differs by a mandibulate mouth).
3. — *Hemiptera* (the same as Latreille).
4. — *Lepidoptera* (the same as Linnæus).

II. Insects with mandibulate mouths.

5. — *Hymenoptera* (like Linnæus and Latreille).
6. — *Neuroptera* (do. do.).
7. — *Orthoptera* (like Latreille, but with the addition of the order *Dermaptera*).
8. — *Coleoptera* (like Linnæus and Latreille).

All other apterous insects Lamarck places among the *Arachnides* and *Crustacea*. Then the *Thysanura*, (*Lepisma, Podura*,) *Myriapoda*, (*Scolopendra*,) *Julus* and the parasites (*Pediculus*, *Ricinus*) among the *Arachnides*, with the scorpions, spiders, and *Acari*; the *Crustacea* are the same in Cuvier and Latreille.

§ 347.

Another French naturalist, Dumeril, to whom we are indebted for a, in some degree, peculiar division of insects, in so far differs from the opinion of his compatriots, that he places insects in the series of animals above the *Mollusca*; his arrangement, with this exception, is but a slight modification of the Linnæan. He forms two classes of Linnæus' insects, namely, *Crustacea* and *Insecta*, the former of which comprises all the crabs, and the latter, on the contrary, all the six-legged insects, spiders, scorpions, wood-lice, and *Myriapoda*. They are thus brought into eight orders

I. Insects with wings.

A. Four wings.

a. Mouth with mandibles.

a. a. Wings unequal, the anterior horny.

* The posterior transversely folded.	1. Order. *Coleoptera*.
** The posterior longitudinally folded.	2. — *Orthoptera*.

b. b. Wings equal.

* With reticulated nervures.	3. — *Neuroptera*.
** With ramose nervures.	4. — *Hymenoptera*.

b. Mouth without mandibles.
a. a. Without a bent proboscis. 5. Order. *Hemiptera.*
b. b. A spirally rolled proboscis. 6. — *Lepidoptera.*
B. Two wings. 7. — *Diptera.*
II. Insects without wings. 8. — *Aptera.*
a. Six legs.
a. a. Mouth a proboscis. 1. Family. *Rhinaptera* (lice and six-legged *Acari*).
b. b. Mouth with mandibles, abdominal apex without setæ and appendages. 2. Family. *Ornithomyzæ* (genus *Ricinus*, De Geer.
Mouth with various appendages. 3. Family. *Nematuræ* (*Lepisma, Podura*).
b. Eight legs. No antennæ. 4. Family. *Acera.*
c. More than eight legs.
a. a. Body with many segments, each bearing a pair of legs. 5. — *Myriapoda.*
b. b. Body with fewer segments, fourteen pairs of legs. 6. — *Polygnatha* (*Oniscus* & *Armadillo*).

The author, besides, endeavoured to reunite more naturally, and by other principles, the families that had been so monstrously subdivided. and to reduce, especially, the host of genera, which, as his work was to serve as a general introduction to the natural history of insects*, is very much to be praised.

§ 348.

The whilst these systems were being sketched by the French, English naturalists likewise occupied themselves with entomology. Among these there are especially three which well merit mention, namely, Leach, Kirby, and Macleay. The system of the last is founded upon philosophical principles, and which we will therefore examine last. Leach sketched the following system †.

I. Insects without a metamorphosis. *Ametabola.*
A. Abdominal apex with setæ. 1. Order. *Thysanura.*
B. . . . without setæ. 2. — *Anoplura* (*Parasita*, Lat.).

* Considerations Générales sur la Classe des Insectes. Paris, 1823. 8vo. av. fig.

† Zoological Miscellany, vol. iii. p. 57—60.

II. Insects with metamorphosis. *Metabola.*

A. With mandibles and wing cases.

a. Metamorphosis imperfect (perfect).

Wings folded transversely. — 3. Order. *Coleoptera.*

b. Metamorphosis half perfect.

Wings folded longitudinally and transversely. — 4. — *Dermaptera* (*Forficula*).

Wings folded longitudinally.

With a straight suture. — 5. — *Orthoptera.*

Crossed at the apex. — 6. — *Dictyoptera* (*Blattaria*).

B. With setiform mandibles for puncturing.

Wings crossing at the apex. — 7. — *Hemiptera* (bugs).

Wings straight, contiguous. — 8. — *Omoptera* (*Cicada*).

C. With setiform mandibles and without wings. — 9. — *Aptera* (*Suctoria*, Lat.).

D. With indistinct mandibles, connate at the base.

Wings covered with scales. — 10. — *Lepidoptera.*

Wings generally hairy. — 11. — *Trichoptera* (*Phryganea*).

E. With mandibulate mouths, but without wing cases.

a. With simple foot claws. — 15. — *Diptera.*

b. With divided foot claws. — 16. — *Omaloptera* (*Diptera pupipara*).

The subdivision of insects into many orders, which the English are especially fond of, certainly merits no recognition; only where nature has set true limits let them be divided, and let us not wilfully destroy the beautiful picture of harmony she everywhere presents us with. How, for instance, will the author justify the separation of the *Orthoptera* into three orders; and how the separation of the *Trichoptera* and *Neuroptera* by these principles; and how the division of the

Omaloptera from the *Diptera*? What business has the genus *Nycteribia*, which forms for him a separate order, *Notostoma*, in this company, and which should be among the *Acari* with the *Arachnides*?

§ 349.

William Kirby, who, together with William Spence, has earned an immortal fame in entomology, by their Introduction to this science, has inserted in their fourth volume the following system.

I. Insects with mandibles. *Mandibulata.*

1. Order. *Coleoptera* (like Linnæus and Latreille. *Eleutherata*, Fab.).
2. — *Strepsiptera*, Kirb. (*Rhiphiptera*, Latr.).
3. — *Dermaptera*, Leach (Family *Forficula*, Latr.).
4. — *Orthoptera* (like Latreille, but without *Forficula*).
5. — *Neuroptera* (like Linnæus and Latreille, but without the *Trichoptera*).
6. — *Hymenoptera* (like Linnæus and Latreille).

II. Insects with suctorial mouths. *Haustellata.*

7. Order. *Hemiptera* (like Linnæus and Latreille).
8. — *Trichoptera* (Leach).
9. — *Lepidoptera* (Linnæus and Latreille).
10. — *Diptera* (like Linnæus and Latreille).
11. — *Aphaniptera*, Kirby (*Suctoria*, Latr.).
12. — *Aptera* (all apterous insects breathing through tracheæ).

* *Hexapoda* (*Ametabola*, Leach, *Thysanura* and *Parasita*, Latr.).

** *Octopoda* (*Arachnides*, *Tracheales*, Latr.).

*** *Polypoda* (*Myriapoda*, Leach, Latr.).

That many of the orders here partly adopted from Leach cannot be justified upon principle, must be speedily discovered by every one upon a close inspection. To separate the earwigs from the *Orthoptera*, on account of the structure of their wings, is as wrong as it would be to raise those beetles which have but half elytra into a distinct order. Both principles of division are merely family characters. The same may be said of the order *Trichoptera*, which has been equally capriciously separated from the *Neuroptera*. If even the *Phryganea* imbibe their food, yet are their oral organs formed upon the type of mandibulate mouths, and by the same right the beetles and *Hymenoptera,* which suck the juices of flowers and plants, for example, the *Lucani,* many *Lamellicorns,* and the wasps and bees, should be removed among insects with suctorial organs.

§ 350.

Upon now passing to the physiological or philosophical systems, we find their originators to have consisted chiefly of Germans. Proceeding from the view that organic nature is to be considered as one great whole, which exhibits in its several members progressive grades of development up to its very fullest perfection and evolution, the philosophical system endeavours to characterise these grades of development as classes, and then further strives to prove their gradual perfection in the order of each class. After this idea had been started hypothetically in Schelling's school, Oken sought to transfer it to natural history, and there practically to apply it. He thence obtained thirteen classes among animals, each of which is represented by a successively added organ. Insects occupy the ninth of these classes, and are characterised as lung-animals. The following * is their division:

I. Order. Germ flies (Keimfliegen).

Insects with imperfect metamorphosis.

1. Tribe. Bugs (*Hemiptera,* Latr.).
2. — 'Schricken' (*Orthoptera* and *Dermaptera,* Latr.).
3. — 'Bolde' (*Neuroptera,* Latr.).

II. Order. Sexual flies.

Insects with perfect metamorphosis and equal wings.

4. Tribe. 'Mücken' (*Diptera* and *Suctoria,* Latr.).
5. — 'Immen' (*Hymenoptera,* Latr.).
6. — 'Falter' (*Lepidoptera,* Latr.).

III. Order. Lung-flies. Beetles (*Coleoptera,* Latr.).

Insects with perfect metamorphosis, elytra, and wings.

7. Tribe. 'Kirner' (*Coleopt. tetramera,* Latr.).
8. — 'Schruppe' (*Coleopt. heteromera,* Latr.).
9. — 'Runke' (*Coleopt. pentamera,* Latr.).

We may object to this arrangement, which tolerably distinctly exhibits the gradual development of the insect world, that the three

* Naturgeschichte für Schulen. Leipzig. 1821. 8vo.

chief groups of beetles, which are here made equivalent to the other tribes, are much more closely allied together, and should properly form but one tribe; besides that in the tribe *Neuroptera* there are insects with perfect and imperfect metamorphoses, which is opposed to the principles of the system. Many objections might also be made to the arrangement of the families within each group, but this would lead us too far.

The systems of other German naturalists, which are founded upon philosophical principles, merely diverge from that of Linnæus in the consecutive arrangement of the orders: we will therefore no longer dwell upon them, but only cite Goldfuss and Wilbrand as their projectors.

§ 351.

We now come to the system of M'Leay *. The following are the principles which guided him in the distribution.

1. All natural groups of the kingdom of nature return within themselves, and, consequently, present themselves in the form of circles.

2. Each of these circles contains five other circles, which are connected together in the same way.

3. Where these circles join, there are intermediate groups by means of which they are still more closely connected.

4. The members of each circle, which are at the points where the circles meet, exhibit analogies.

According to these principles, organic nature is divided into two large circles, one of which comprises the vegetables and the other the animals. Each consists of five circles, which, in the animal kingdom, are the following: *Acrita* (*Infusories* and *Polypes*), which are bordered on the one side by the *Mollusca*, and on the other by the *Radiata* (*Medusa* and *Echinodernia*); next to the *Radiata* stand the *Annulosa* (*Crustacea*, insects), and to the *Mollusca* the *Vertebrata*, which pass over to insects by means of the fishes, and to the *Mollusca* by the *amphibia*. The *Annulosa*, which chiefly concern us here, again consist of five principal groups, which have the following characters and boundaries.

* See his Horæ Entomologicæ. Lond. 1821. 2 vol. 8vo., and Linnean Transactions, vol. xiv. p. 46, &c.

1. *Crustacea.* (According to Cuvier, Latreille, &c.) they are contiguous to the *Radiata,* and especially the *Echini.* Upon one side they join the

2. *Arachnida.* (The spider-like annulosa, according to Latreille, Lamarck, &c.) On the other side the *Crustacea* border upon the

3. *Ametabola.* Insects without a metamorphosis, namely, the *Myriapoda, Thysanura,* and *Parasita* of Latreille.

4. *Haustellata.* Six-legged insects with wings and suctorial mouths. They join the *Arachnida,* metamorphose, and therefore form with the following group the true insects.

5. *Mandibulata.* Six-legged insects with wings and mandibulate mouths. Their place is between the *Haustellata* and *Ametabola;* the latter form the transition to the fishes.

Here, therefore, only three orders will occupy us, namely, the *Ametabola, Mandibulata,* and *Haustellata.*

Hitherto but three groups of the *Ametabola* have been found, viz., the *Myriapoda,* which join the *Crustacea;* the *Thysanura* and the *Anoplura* (*Anopl.,* Leach, *Parasita,* Lat.), which approach the *Mandibulata.*

The division and affinities of the *Mandibulata* and *Haustellata,* which are called *Insecta ptilota,* in contradistinction to the *Ametabola,* as apterous insects, is represented in the following table:—

Ptilota.

Mandibulata.	*Haustellata.*
Larvæ with feet, pupæ obtectæ.	
Trichoptera. (*Semblodes, Phryganea,* &c.)	*Lepidoptera.*
Larvæ apods, pupæ exaratæ.	
Hymenoptera.	*Diptera.*
Larvæ varying, pupæ free and quiet.	
Coleoptera.	*Aptera.* (*Suctoria,* Lat.)
Metamorphosis semi-complete, larva resembles the imago.	
Orthoptera.	*Hemiptera.* (*Hemip. Heteroptera,* Lat.)
Larvæ with six feet, metamorphosis varying.	
Neuroptera.	*Homoptera.* (*Hemip., Homopt.,* Latr.)

These circles, which the *Mandibulata* and *Haustellata* form, are contiguous to each other in the *Trichoptera* and *Lepidoptera*, especially the genus *Mystacides*, Latr., of the former, makes the transition to the genus *Aglossa*, Latr., in the latter. M'Leay considered the following families as the connecting links between the two orders of

Mandibulata and *Haustellata*.

Bomboptera.
(*Tenthrenodea*, stand between the *Trichoptera* and *Hymenoptera*.

Strepsiptera, Kirb.
(Between *Hymenoptera* and *Coleoptera*.

Dermaptera, Leach.
(Between *Coleoptera* and *Orthoptera*.

Dictyoptera, Lea., Kirb.
(Between *Orthoptera* and *Neutera*.

Megaloptera.
(*Semblodes* between *Neuroptera* and *Trichoptera*.

Genus *Psychoda*.
(Between *Lepidoptera* and *Diptera*.

Homaloptera.
(*Diptera pupipara*, Lat., between *Diptera* and *Aptera*.

Genus *Aphis*.
(Between *Aptera* and *Hemiptera*.

Family *Hydrocorides*, Latr.
(Between *Hemiptera* and *Homoptera*.

Genus *Aleyrodes*, Latr.
(Between *Homoptera* and *Lepidoptera*.

It is not to be denied that in this arrangement there are many affinities, but just as many appear forced and unnatural. The opinion that has also been expressed by Goldfuss and other German naturalists appears indeed true, that animals in general, and consequently insects, do not ascend in a consecutive series from the most simple to the most perfect, but the several groups touch each other in different parts, thereby receiving other forms, and are frequently interlinked by true groups of transition. If, now, the determinate adoption of five chief groups appears forced, and without a sufficient reason, if also we cannot detect in what relation the osculant groups stand in the system of the author to the chief ones, whether they are equivalent or subordinate, and if, lastly, the *Hemiptera* are incorrectly divided into two orders, and the entire order of the *Trichoptera* must be considered as artificial, as the *Phryganeæ*, *Semblodes*, and *Tenthredonodea* are united, we must yet admit that the author has exhibited considerable skill, correct judgment and knowledge of the whole, and that his system as an essay to arrange the animal world from this point of view, must not be considered as without its use, or wholly unsuccessful, although his propositions are not fully solved.

§ 352.

We have still to explain the system which we have ourselves sketched, and which we communicated partially in the introduction. To do this we refer to the chapter upon the metamorphoses, where we gave our arrangement of the entire animal kingdom, and the relation of insects to other animals. We there discovered that its physiological character was its organisation as a motive animal, that is, its division into segments and joints, but which were, however, collected into three chief divisions. We do not find this division into three parts in any other annulose animal; and as we again find a similar separation in the most perfect of the *Vertebrata*, we may conclude that insects are the most perfect of all the *Annulosa*. To attain this most perfect grade insects require a gradual development, which displays itself in their transition through the earlier animal forms and organisations. This we denominate their transformation, or metamorphosis. The more marked the transformation the more heterogeneous is the individual in the several stages of its existence; and as all insects proceed from the same point, those, necessarily, whose metamorphosis we call complete must attain a higher grade than the rest, which transform themselves incompletely. We thus obtain two chief groups among insects, which we distinguish as *Insecta ametabola* and *Insecta metabola*, but in a different sense to that understood by Leach. Both commence a new development in the organisation of the mouth, as they at first exhibit to us abortive setiform oral organs, only adapted to suction, but in the higher grades these suctorial organs develope themselves into free mandibles, with a lip covering them. Thus each group has *Insecta haustellata* and *Insecta mandibulata*. Each of these groups may then be further subdivided according to the form of the larva, the structure of the wings, and the entire internal organisation and these divisions constitute their orders. We thus obtain an arrangement, the principles of which are deduced from the idea of the entire insect, and which, as this idea becomes separated according to its several characters and constituents, it consequently necessarily and spontaneously forms itself by the philosophical laws of thought. It is the following:—

I. *Insecta ametabola.*

The larva resembles the perfect insect, yet it wants wings if the perfect insect be winged; the pupa in this case have their rudiments; it runs about and eats.

a. With sucking mouths, which consist of four fine setæ, lying in a sheath; palpi are wanting; four biliary vessels, and generally a free prothorax.

1. Order *Hemiptera.*

b. With mandibulate mouths: mandibles and maxillæ distinct, the latter having palpi, and generally distinct large superior lip.

a. Four unequal wings; the anterior ones leathery or parchmenty, the posterior ones folded longitudinally and also once transversely; prothorax always free; many biliary vessels.

2. Order *Orthoptera.*

β. Four, generally equal, more rarely unequal wings, never folded, or sometimes none at all: in the first case the nervures are usually reticulated, and generally many biliary vessels; in the last case four biliary vessels, attached to the intestine; prothorax sometimes free, sometimes not.

3. Order *Dictyotoptera.*

II. *Insecta metabola.*

The larva is a worm, consisting of thirteen segments, either with or without legs; the pupa is quiet, or if it moves it does not eat.

a. Four equally large or equally long wings, with reticulated nervures; mandibulate mouths; few, four or eight, biliary vessels, rarely more; prothorax always free.

4. Order *Neuroptera.*

b. Wings always unequal, the posterior ones sometimes wanting, rarely all.

a. Mouths adapted to sucking.

a. a. Instead of posterior wings there are pediculated knobs, yet the wings are sometimes wholly wanting; four biliary vessels; larvæ apods; a soft proboscis in the mouth, with several setæ and a pair of palpi; prothorax not free.

5. Order *Diptera.*

b. b. Four wings, generally covered with scales; six biliary vessels; larvæ with feet and a distinct head; the maxillæ forming a spiral tongue; prothorax not free, but small, and closely connected with the mesothorax.

6. Order *Lepidoptera*.

β. Mouths with distinct, biting mandibles.

a. a. Four naked wings traversed by ramose nervures; larvæ generally without head and feet, but sometimes with both; many biliary vessels; prothorax not free.

7. Order *Hymenoptera*.

b. b. Anterior wings, horny elytra; larvæ with head, with or without feet; four or six biliary vessels; prothorax always free.

8. Order *Coleoptera*.

Our system is not acquainted with an order *Aptera*, which we have found in the majority of the others, as in every case it is artificial, and must embrace insects of the most dissimilar orders. The most distinct proof in support of this assertion is furnished by the circumstance that we find in the same family winged and apterous genera, contiguous together, and, indeed, in many genera which we have before enumerated, the males winged, and the females apterous. From the principles of the system we might expect a group containing insects without any metamorphoses, but there cannot be such an one, as the idea of an insect would be thereby annulled. All true insects whose metamorphosis has been denied by other entomologists belong to the group with an imperfect metamorphosis, and were only considered as deficient in it, because in them the organ is wanting in which we detect the imperfect metamorphosis. If, for instance, an insect remains apterous throughout its whole life, it loses the organ by which we distinguish the imperfect metamorphosis, but in other respects its development is conformable to those with an imperfect metamorphosis. We have therefore applied the name given by Leach to those apterous insects, to all with an imperfect metamorphosis, for in fact there is no difference in the processes of development in each. This is the guide to the correct estimation of our system.

A difference of opinion may exist upon the application of the Linnæan names to our orders, as many orders contain entire families to which those names do not apply, for instance, apterous insects. But I think it better to retain an old characteristic name, than by means of new ones, formed upon new principles, to increase the already innumerable host of names. Groups that are so multiform as are the higher ones of a natural system can scarcely be distinguished by one name, and composed of many, as would be requisite in the present instance; as, for instance, *Insecta ametabola haustellata* or *Insecta metabola mandibulata elytroptera* appear still less appropriate; we have therefore retained Linnæus, as the most ancient, but have applied them to differently determined groups.

THIRD CHAPTER.

OF NOMENCLATURE.

§ 353.

System has not only to attend to the division, but also to the naming of natural bodies; this is important, as names serve us as the means of distinguishing groups which differ from the rest by certain characters and qualities. Thus the names of insects are as important to the entomologist as the words of his mother tongue to man in general; were there no words there could be no communication of ideas, for they are the means to express and characterise them. Without the groups being named, naturalists could not communicate together, and without a distinction of the known and discovered all would speedily return to its former obscurity: there is, consequently, in natural history a distinct chapter, which treats of the doctrine of naming, and which is technically called the nomenclature. Nomenclature propounds the laws whereby names must be formed, and investigates the correctness of existing ones, by the principles of grammar and language. Linnæus is the originator of this division of natural history; he was the first to introduce systematic names into natural history: before him it was customary to call animals according to their vulgar name, or by that imposed by the ancients. By the introduction of these scientific, fixed, and universally valid names Linnæus has doubtlessly acquired his greatest merit in science, and if everything else should be forgotten that he has done, this, which is wholly his work, will secure his name from forgetfulness.

§ 354.

The groups to be distinguished by separate names are those of which we have treated in the first chapter of this section; for every species, genus, and higher group has its distinct name. With respect to the form of these names, Linnæus determined that the names of genera, and of all the higher groups should be substantives, whereas those of species must be adjectives which should refer to the substantive name of the genus. This mode of distinction has the advantage of requiring fewer substantives than if all the species were to be named by them; and also the same distinguishing adjective can be applied in many genera, which would not be the case if substantives were used. It is indeed also allowed to use substantives as the names of species, but then they are proper names, and are not to be understood without the addition of the genus. Thus Linnæus distinguished most of the butterflies by giving them mythological or historical names, for example, *Papilio Priamus, P. Hector, P. Hecuba,* &c.

§ 355.

The structure of the generic name, as the chief word for the distinction of the lowest groups, will first occupy us. The most appropriate name for a genus would certainly be that which at the same time characterises it. Fabricius, indeed, maintained *optima nomina, quæ omnino nil significant,* but we do not participate in this opinion; a name that expresses a character is in every case better than an absolutely foreign and unmeaning one. But every one in this may follow his own opinion, and he who has discovered a genus has the privilege of naming it, be it by cities (*Edessa*), rivers (*Halys*), or heroes (*Polyphemus*), and maidens (*Daphnia, Cypris*). If, however, the name expresses the character, and is formed for this purpose by composition, this must follow the laws of grammar and language, and is not allowed the same caprice as the choice of the name itself; here choice can make but the first step, all the rest are subject to immutable laws. By not following these laws compound words have been recently formed, which scarcely bear the least trace of what they should properly be, and words have been made which neither Greeks nor Romans would admit to be theirs, although they have been published as derived from the Greek and Latin. Fortunately, entomology is less encumbered with these monstrosities than other portions of zoology, for instance, ornithology, and yet we should have to sweep long before we cleansed away all the rubbish. We must therefore be satisfied with stating some of the laws by which such names should be formed.

1. The words intended to compose the name must be of the same language. There were many delinquencies against this natural law even formerly, for instance, *Monoculus, Insectology*, &c. It would require too many innovations to remove all such hybrid words; but let no new ones be thus formed, for it is opposed to the fundamental laws of language.

2. A Latin word cannot receive a Greek termination, nor can a Greek word a Latin one, but entire Greek words may be transmuted into Latin. Grammar teaches the modifications the word undergoes in this case; its explanation would here lead us too far. *Cicindeletæ* is erroneous, for *Cicindela* is Latin, and *eta* is doubtlessly from the Greek termination ιτης; it should therefore be *Cicindelina*.

3. New words may be formed either out of two substantives or a verb and substantive, or an adjective and substantive, or a preposition and a substantive.

In every case the rule is that the chief idea stands behind, appended to the root of the first word, and generally with an inserted vowel. In Greek words this vowel is *o*, and in Latin words *i*. If the second substantive in Greek commence with a vowel, the *o* is contracted, or cut off, in Latin the *i* is omitted. But this rule does not obtain in every case; exceptions are sometimes admitted, which analogies determine, for example, *Glossotheca* is derived from γλῶσσα and θήκη; the root, after rejecting the termination, of the genitive, is γλωσσ, therefore γλωσσοθήκη in Greek. *Fissipes* comes from *fissus* and *pes*; *fiss* is the root, thence *fissipes*. Linnæus's word *Myrmeleon* is wrong, as it comes from μύρμηξ and λέων, it should therefore be called *Myrmecoleon*, for μύρμηξ is the root, and not μυρμη. Latreille incorrectly writes *Melasoma*, whereas it should be *Melanosomata*, for μέλας has in the genitive μελανος, and therefore μελαν is the root, not μελα.

In prepositions the connecting vowel remains away if they terminate in a vowel, for instance, *Metathorax* from μετὰ and θῶραξ. Even this vowel is rejected if the following word commences with a vowel.

If the second word in composition be a verb there is appended to the root, in Greek words, the terminations ος, ε, and ον, which are transformed in Latin into *us, a,* and *um.* Many verbs also in this composition transmute a vowel of the root, for instance, φέρο does not form φέρος, but φόρος, thence *Aspidiphorus.* In Latin verbs *us* is appended similarly, for example, *Carnivorus,* derived from *caro,* gen. *carnis,* root, *carn* and *vorare,* root *vor,* thence *vorus,* the *i* is the inserted vowel, whence we have *carnivorus.*

4. New generic names are formed chiefly from Greek words, partly because Greek compounds are more harmonious, and partly because the Greek is richer in words, and more flexible than the Latin.

§ 356.

The laws are the same for the composition of the names of groups. With respect to the form of the generic name itself, it can only be altered when urgent circumstances demand it, for the name is sacred, and no one dare touch it with impunity. Two circumstances only, namely, false construction and previous application, warrant its alteration. The sex of the generic name is optional, and may be left wholly to the taste of the originator, but within certain groups, wherein a certain sex has been introduced for the genera, it is as well to continue it for the sake of uniformity. The genera *Carabus, Anthia, Calosoma, Bembidium* stand together in one family, notwithstanding their difference of sex. But if a new genus be separated from an old one the sex must be left unaltered, else it may too easily occasion confusion and misunderstanding in the specific names.

Generic names consisting of two separate words, as we find them in the older writers, Fabricius justly rejects, for example, Ray's *Vespa Ichneumon* for *Ichneumon,* or Petiver's *Musca apiformis* for *Bombylius,* &c. Whereas Fabricius goes too far when he wishes to reject words composed of two Latin substantives, as *Gryllotalpa,* Lin. Generic names that sound badly, or are too long (*nomina sesquipedalia et enuntiatu difficillima*) must also be avoided, as well as such as have objectionable double meanings *.

If a new genus be separated from an old one, the best known and commonest species must be left with the old name, and a new one must be invented for the rarer ones: hence Linnæus's *Scarabæus stercorarius,*

* Fabricius, Philosophia Entomologica, p. 115. § 32.

is more appropriately called in Fabricius *Scarabæus*, than in Latreille *Geotrupes*, for, next to the cockchafer, it is the commonest of all Linnæus' *Scarabei*.

§ 357.

Family groups were deficient in the older systems, and therefore also family names; but as the families have been chiefly formed from the external resemblance of their individuals, it appears appropriate to express this conformity in the name, and they are therefore called after the best known genus. Thus Jussieu proceeded when he devised names for his natural families of plants. They took the form of an adjective, as the substantive *planta* was tacitly understood; all therefore required the feminine gender, for example, *Malvaceæ*, *Gramineæ*, &c.

Latreille, the first founder of families among insects, selected also generally the adjective form, but he did not consider that the word *insectum* was to be understood, and that, consequently, they should be neuter. The gender of these names appeared to him indifferent, and we thence find in the same order every possible form, for example, *Cicindeletæ*, *Carabici*, *Malacodermi*, *Pimeliariæ*, *Melosomæ*, *Bruchelæ*, *Rhyncostoma*, &c. But all adjectives must necessarily, even when they stand alone, refer to an understood substantive, which in this case can be no other than *insectum* or *insecta*, and therefore all generic names must, according to the first grammatical rule that the predicate shall agree with its subject in gender, number, and case, be in the neuter. Latreille's family names must therefore be corrected by this and the previously instituted laws. Let us examine more closely the way in which he and others have constructed the names of families.

§ 358.

Four different paths have been followed in the structure of family names.

The first is that pursued by Jussieu in botany, namely, to form an adjective name from the chief genus of a family for its distinction, and by means of this name to indicate its resemblance with a known form. This process appears to be the best, in the first place, because we can never be at a loss for a family name, and secondly, because these adjectives are easily formed, and merely the knowledge of the derivation of the generic name, whether it be from the Latin or the Greek, is required. But then regard must be had to the form of the termination of the adjective, as this is always determinate for certain purposes. The termination of adjectives derived from animals is always εως in Greek, and in Latin *inus;* it is, consequently, with these terminations that generic names must be formed into family names. Thus, for instance, from *Syrphus* we must form the family name *Syrphea,* because the ει in its transit into Latin becomes long *e,* as in *Pythagoreus,* derived from Πυθαγόρειος. From the Latin word *Cicindela* we should make, according to this rule, *Cicindilina,* and not with Latreille, *Cicindeletæ.* The terminations *aceus, a, um,* which Jussieu introduced into the families of plants, express the resemblance to the object of the root of the word, and could therefore be perfectly correctly applied also in Latin generic names, yet the termination *inus* should be preferred, as it is the most usual and common to indicate a derivation from animals, as *Asininus, Equinus, Ovinus,* &c.

§ 359.

A second adjective termination for family names is that which has originated from the composition with εἶδὸς, which the Greek termination οείδης or ώδης gives. It also expresses a resemblance with the idea of the root, but can only be united with such words as originate from the Greek. We nevertheless find in Linnæus errors against this rule, for example, *Curculionides* derived from *Curculio.* Error has frequently happened from appending this termination to the nominative, as it, which is the case in all compounds, should be added to the root, consequently to the genitive upon the rejection of the genitive termination. The Romans, as far as I know, have received no Greek word thus formed into their language, and we can therefore merely decide by analogy upon the transmutation that must take place upon this transition. In Greek they are of the common gender, and are declined by the third contracted declension, consequently, upon their transition into Latin, they would most appropriately follow the third declension also, and their inflexions be made analogous to original Greek words. I have thus treated these names, but have left the uncontracted Greek form always in the neuter, for the sake of distinction, as *Carabodea* instead of *Caraboda.* It is still doubtful whether we should use *oides* or *odes,* as both forms exist in the classics, for instance, in Aristotle καραβοειδής and καραβωδής. Buttman gives the form *oides* as the most correct, because ειδος has in the ancient language the digamma; but I have chosen the contracted form, as it is shorter, and because it is more frequent in Aristotle.

§ 360.

Besides these adjective forms substantives have been used to distinguish families; latterly, namely, Greek patronymics have been applied to the construction of family names, but these also can only be formed of true Greek words. If in the Latin poets forms such as *Romulidæ* exist, prose absolutely rejects them, and the language of naturalists is no poetry, but a scientific and consequently pure prose. If, on the contrary, they be applied to Greek names, they must be declined according to the first declension; upon transition into Latin all are then true masculines.

Other substantives originate by the compounding of two words, according to the above rules. Names like the following are false, *Melosoma, Taxicornes, Myrmeleonides;* they should be *Melanosomata, Taxocera* (for *cornu* is Latin and τάξις Greek), *Myrmecoleontoides.*

The substantive termination *ites*, which Latreille so frequently applies to family names, is Greek, and therefore can be appended only to such words as are of Greek origin. It is always of the masculine gender, and distinguishes some relation, and therefore a resemblance with the object represented by the root. It may therefore be unquestionably used for the structure of substantive family names; but names like *Curculionites, Crabronites,* are erroneous, as *Curculio* and *Crabro* are of Latin origin.

§ 361.

The names of the higher groups of the tribes and orders are in general formed of two words, generally substantives, compounded according to the above rules. It is seldom requisite to form new names for such groups, as those existing are sufficient, and, at least in insects, the orders were determined very naturally even by Linnæus. Although our system proceeds from different views to the Linnæan, we have yet retained the names of his orders, as they are everywhere known, and everybody already connects an idea with them. The names of classes als have been already correctly distinguished by early naturalists, and even by the common man in his mother-tongue, so that we scarcely require them; but it is only among the lower animals that new ones are necessary, yet those already existing well enough suffice to distinguish even them. But if new ones are to be formed they must be constructed by the above rules. It is also endeavoured, even in the higher groups, to express their character in their names.

§ 362.

Specific names (*nomina trivialia*) are formed in three ways: they are either pure adjectives or substantives, in apposition to the generic name, or the genitive of the predicate, which expresses a relation to the thing whence the name is derived.

The adjectives are usually deduced from the most remarkable and striking quality of the insect, and refer to form, colour, general clothing, sculpture, size, &c. &c. It is scarcely possible to give general rules for their imposition, it must be left to the tact of every one who names species to select appropriate names. This is a subject in which the naturalist can exhibit much skill, and we cannot in this respect sufficiently admire the talent of the immortal Linnæus: Fabricius has also in general invented good names. Comparative names, however, are not adapted as specific names, as we do not always know whether the species which we distinguish as the smallest is actually the smallest; but when once applied we must leave them where we find them, if they do not become incorrect by the discovery of one surpassing them. Fabricius endeavours also to discountenance specific names derived from the time of appearance, &c., but in this he probably goes too far; if the field be too much contracted we shall ultimately find no adjectives for specific names. Some insects likewise frequent very determinate places, and why then should they not be named after it? It however sometimes happens that animals have names that are not at all appropriate to them, for instance, the genus *Euphone* among the birds, the species of which, travellers say, do not sing at all.

§ 363.

Specific names formed of substantives refer either to the resemblance which insects have to the object represented by its name, be this expressed in form, colour, or any other quality; thus is *Amphicoma vulpes* rough, like a fox, and of the same yellowish colour. Or they express a significant comparison, and are the sports of the fancy of the namer, for instance, *Cerambyx heros*, *Geotrupes Hercules*, &c.

Thus Linnæus has wished to indicate the beauty of the butterflies by giving them names from the mythology and the mythic history of the Greeks, and restored the heroes and gods of the infancy of the human race in them ; we here again find Apollo and the Muses, Jason and his companions, and the vigorous warriors of the plains of Troy.

The genitive of the predicate is also of a double kind. In the one case it exhibits the locality of the insect, either in its larva or perfect state. In this case the substantive is either the name of the plant or animal upon which the insect lives as a parasite, or parts of them, when they dwell only on certain parts, for example, *Apion Ulicis, Ceutorhynchus Echii Balaninus nucum, Œstrus ovis, Gastrus equi, Pediculus capitis,* &c. The second kind of genitives of the predicate consists of the names insects have received in honour of meritorious entomologists, the person imposing the name wishing thereby to express his estimation for such individuals, for their scientific exertions. Thus we have *Carabus Linnei, C. Fabricii, C. Germari, C. Schönherri,* &c. But latterly there has been too much liberality in thus naming after individuals, for mere collectors, known to nobody but the namer himself, have been thus immortalised. In these instances the idea spontaneously suggests itself, that the namer has thereby wished to raise his friend to the rank of those entomologists who have promoted the science by their study and industry, and consequently thus express the esteem in which he holds their works. But he who cannot distinguish between the merits of a naturalist and a collector had better be silent, lest, by uttering a word, he should betray himself.

THE END.

BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

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DESCRIPTIONS OF PLATES.

FRONTISPIECE. 1, *Carabus nitens*, F. 2, *Euceros crassicornis*, Grav. 3, *Hemerobius concinnus*, Steph. 4, *Polyommatus Adonis*, Lat. 5, *Anomoia Gaedii*, Walk. 6, *Blatta Germanica*, L. 7, *Acrida varia*, Kirb. 8, *Corizus Hyoscyami*, Fall.

[*All the above insects are British, and all but No.* 3 *in my own collection.*—TR.]

*** All the figures to which no authority is placed are from the author's drawings.

Plate I. Figure 1, Hemispherical egg of *Gastropacha dumeti* (Knoch). Fig. 2, Conical egg of *Pontia Napi* (Sepp.) Fig. 3, Cylindrical egg of *Gastropacha everia* (Knoch). Fig. 4, Hairy egg of the same, *a*, spot where the hair is removed, and the eggs exposed to view. Fig. 5, Tun-shaped egg of *Vanessa Urticæ* (Sepp.). Fig. 6, Lenticular egg of *Noctua psi* (Sepp.). Fig. 7, Convex and ribbed egg of *Hipparchia Tithous* (Sepp.). Fig. 8, Flat lenticular ribbed egg of *Noctua Orion* (Sepp.). Fig. 9, The egg of *Phalena prunata*, with an apparent cover (Sepp.). Fig. 10, Cup-shaped egg of *Orgyia antiqua* (Sepp.). Fig. 11, Turban-shaped egg of *Lycæna Betulæ* (Sepp.). Fig. 12, Flask-shaped egg of *Culex pipiens* (Reaumur). Fig. 13, Thumbstall-shaped egg of *Argynnis Lathonia* (Sepp.). Fig. 14, Petiolated eggs of *Hemerobius perla* (Reaumur). A, Natural size. B, One enlarged. Fig. 15, Contiguous eggs of *Gastropacha Neustria* (*ib.*). Fig. 16, Petiolated egg of *Ophion luteus* (Kirby and Spence). Fig. 17, Eared egg of *Scatophaga putris* (Reaumur). A, From the front. B, From the side. Fig. 18, Tailed egg of *Ranatra linearis* (Geoffroy). Fig. 19, Crowned egg of *Nepa cinerea*. A, Two eggs as they hang together (Kirby and Spence). B, One with the distended crown (Rösel). Fig. 20, Cylindrical, pointed egg of *Sialis lutarius* (Suckow). Fig. 21, Elliptical egg, with the larva seen through, of *Sphinx Ligustri* (Sepp.). Fig. 22, Globose egg, with the larva shining through, of a *Noctua* (Sepp.). Fig. 23, Egg shell of the egg of *Gastropacha Pini* (Suckow). Fig. 24, Embryo with the membranes of *Gastropacha Pini* (Suckow). A, Head of the embryo, with the already visible eye points. B, Its body. C, Space in which the amnion is contained. *a a a*, The amnion. *b b b*, The chorion. *c c*, Tracheæ, which distribute themselves upon the superior surface of the amnion. *d*, Main stem of the trachea, which lies beneath the germen.

Pl. II. Fig. 1, Headless maggot of *Musca vomitoria*. A, *a*, The hook-shaped setæ projecting from the mouth. B, The flat tail. *a a*, The two stigmata. *b b*, The coronet of fringe surrounding them. *c c*, The pedal warts. Fig. 2, The caterpillar, with anal feet only, of *Œcophora Rajella* (De Geer). Fig. 3, Maggot with a head of *Vespa vulgaris* (*ib.*). Fig. 4, Larva of *Lixus paraplecticus*. *a*, Head. *b*, Setiform feet. *c*, Anal propellers (*ib.*). Fig. 5, Pseudo-caterpillar with five pair of ventral feet, and one anal proleg of an *Hylotoma* (*ib.*). Fig. 6, Larva of *Cetonia aurata* (*ib.*). Fig. 7, Pseudo-caterpillar of *Cimbex* (*ib.*). Fig. 8, Rat-tailed maggot of *Eristalis tenax*. *a a*, Anterior air tubes. *b*, Anus. *c*, External sheath of the tail. *d*, Internal tube. *e*, Setiform crown at the apex. *f*, Mouth with furcate mandibles. Fig. 9, Caterpillar of *Pieris Machaon* with the tentaculæ of the neck extended. Fig. 10, Caterpillar of *Plusia gamma* (Sepp.). Fig. 11, Geometer caterpillar of *Phalæna betularia* (De Geer). Fig. 12, Caterpillar without anal proleg of *Harpyia vinula* (Sepp.). Fig. 13, Caterpillar's head with its organs. *a*, Upper lip. *b b*, Upper mandibles. *c c*, Lower maxillæ. *d*, Under lip with the spinneret. *f f*, Antennæ. *g g*, Eyes. Fig. 14, Under lip of the caterpillar of *Cossus ligniperda* seen externally (Lyonet). *a*, Spinneret. *b b*, Sheath surrounding the base of the spinneret. *c c*, Maxillary palpi. *d d*, Labium. Fig. 15, Head of the caterpillar of *Vanessa prorsa*. Fig. 16, Head of the caterpillar of *Apatura iris*. Fig. 17, Feet of the caterpillar of *Cossus ligniperda* (Lyonet). *a*, Part of the ventral membrane. *b*, Coxa. *c*, Trochanter. *d*, Femur. *e*, Tibia. *f*, Tarsus. *g*, Claw. Fig. 18, Ventral or proleg of the same caterpillar with a double coronet of hooklets (*ib.*). Fig. 19, Pupa of *Sphinx Ligustri*. *a*, Head-case. *b*, Eye-case. *c*, Tongue-case. *d d*, Leg-cases. *e*, Antenna-case. *f*, Case of the prothorax. *g*, Case of the mesothorax. *d*, Of the metathorax. *i i*, Of the ventral segments. *k k*, Spiracles. *l l*, Kirby and Spence's *adminicula*. *m*, Case of the superior wings. *n*, Of the under wings. *p*, Cremaster. Fig. 20, Pendent pupa of *Hipparchia Egeria* (Sepp.). Fig. 21, Enclosed pupa of *Musca vomitoria*. Fig. 22, Cremaster of the pupa of *Noctua dissimilis* (Knoch). Fig. 23, Cremaster of the pupa of *Noctua lucipara* (*ib.*). Fig. 24, Pupa of neuter bee (Swam.). Fig. 25, *a*, Cremaster of the pupa of *Harpya Fagi* (Knoch). *b*, Cremaster of the pupa of *Euprepia mendica* (*ib.*). Fig. 26, Bound pupa of *Pontia Cratægi*. Fig. 27, Larva case of *Stratiomys chameleon* (Swamm.). *a*, Head. *b*, Coronet of setæ around the spiracle at the tail. *c c*, The pupa shining through.

Pl. III. Fig. 1, Larva of *Phryganea*, with the case in which it dwells (De Geer). Fig. 2, Larva of *Ephemera*. *a a*, Lateral branchial leaves. *b b*, Rudiments of wings (*ib.*). Fig. 3, Larva of *Culex*. *a*, Air tube. *b*, Anal tube (Swamm.). Fig. 4, Pupa of *Culex*. *a a*, Air tube (*ib.*). Fig. 5, Larva of *Chironomus*. *a a*, Air tubes at tail. *b*, Air tubes at breast (Reaumur). Fig. 6, Pupa of *Chironomus*. *a a*, Branchial fasciculus on the thorax (*ib.*). Fig. 7, Larva of *Corethra*. *a*, Branchial fasciculus at tail. *b*, First, and *c*, Second pair of bladders, which stand in connexion with the intestine *f*. *d*, Mandible. *e*, Antennæ. Fig. 8, Pupa of *Corethra*. *a a*, Air tubes. *b b*, Anal leaves (*ib.*). Fig. 9, Larva of *Simulia*. *a a*, Fasciculi on the head, which are perhaps palpi. *b b*, Antennæ. *c*, Air tube in the thorax. *d d*, Indicated spiracles. *e e*, Anal air tubes (Verdet). Fig. 10, Pupa of *Simulia*. *a a*, Branchial fasciculi. *b b*, Wing sheaths. *c*, Head. *d*, Thorax from the back. *e*, Abdomen (*ib.*). Fig. 11, View from above of the head of *Carabus glabratus*. A, Skull. *a*, vertex. B, Frons. *b*, Sinciput. *c*, Clypeus. I, Labrum. O O, Mandibles. *γ γ*, First joints of the antennæ. *a a*, Eyes. Fig. 12, Under view of the same. D, Gula. *d*, Swollen margin of the same. G, Occiput. Q, Mentum. O O, Mandibles. P P, Maxillæ. *a a*, Eyes. Fig. 13, Lateral view. S, Facies. E, Cheek. F, Temples. *γ*, Socket of the antennæ. The other letters as before. Fig. 14, Lateral view of the head of *Myopa testacea*. B, Frons. *a*, Vertex. E, Cheek. F, Temples. G, Occiput. M, Mouth. *c*, clypeus (*hypostoma*, Meig.). *d*, proboscis. *e*, Whisker. *γ*, Antennæ. Fig. 15, Labium of *Vespa vulgaris*. *a a*, Glandular points of the four-lobed tongue. *b*, Chin. *c c*, Palpi (Treviranus). Fig. 16, Maxilla of *Cychrus rostratus*, from above. 1, Cardo. 2, Stipes. 3, Squama. 4, Mando. 5, Palpus maxillæ internus, or galea. *a*, Basal joint. *b*, Apical joint. A, palpus maxillaris. *e*, The groove. Fig. 17, The same from beneath. Fig. 18, Maxilla of *Spondyla buprestoides*, with the same lettering. Fig. 19, Maxilla of *Melolontha vulgaris*, with the same lettering.

Pl. IV. Fig. 1, Anterior view of the head of *Myopa testacea*. *a a*, Eyes. *γ γ*, Antennæ. *c c*, Hypostoma. *d*, Proboscis. Fig. 2, Maxilla of *Copris lunaris*, with the lettering as in fig. 16 of preceding plate. Fig. 3, Labium of *Cychrus rostratus*. A, Mentum. B, Ligula. C C, Palpi. Fig. 4, The same from within. A, Mentum. B, The bilobed tongue. Fig. 5, Lateral view of the labium of *Locusta viridissima*. *a*, Superior lobe of the mentum, forming the true mentum. *b*, Basal joint of the left palpus. *c*, Basal portion of the mentum. *d*, The loose tongue. Fig. 6, Head of *Ateuchus sacer*. *a a*, The eyes (Sturm). Fig. 7, Head of *Truxalis nasutus*. *a*, Root of antenna. *b*, Eye. *c*, Labrum. *d d*, Maxillary palpi. *e e*, Labial palpi. *f*, Labium. Fig. 8, Mandible of *Hydrophilus piceus*. *a*, Incisor teeth. *b*, Molar process. *c*, Lower joint ball. *d*, Superior bent joint ball. *e*, Situation of the third internal process, where the flexor muscle is inserted. Fig. 9, Maxilla of *Lucanus cervus*. 1, Cardo. 2, Stipes. 3, Squama. 4, Mando. 5, Penicillate lobe. A, Palpus (Sturm). Fig. 10, Maxilla of *Cicindela campestris*. As far as 4 the same as above, the latter internally beset with teeth, and with a superior moveable tooth, *c*. 5, Internal maxillary palpus. *a*, Basal joint. *b*, Apical joint. A, External maxillary palpi. Fig. 11, Labium of *Libellula*. *a*, The true labium. *b b*, The lateral lobes, which appear to be modified labial palpi, 2 2. These would then be the second joints of the labial palpus. Fig. 12, Maxilla of *Sphex* (*Ammophila*) *arenaria*. 1, Cardo. 2, Stipes. 3, Squama. 4, Mando, here forming the membranous sheath of the tongue and labium. *a*, Filiform palpus. Fig. 13, Maxilla of *Barynotus obscurus*. *a*, Conical palpus. *b*, The maxilla, with four teeth on its inner edge (Germar). Fig. 14, Maxillary palpus of *Melandrya*. Fig. 15, Labial palpus of *Oxyporus*. *a*, The groove which exhibits after the death of the insect the palpal surface. Fig. 16, Maxillary palpus of *Lymexylon navale*. Fig. 17, Maxillary palpus of *Atractocerus necydaloides* (Kirby and Spence). Fig. 18, Maxillary palpus of *Bembidion* (Sturm). Fig. 19, Ditto of *Trechus* (*ib.*). Fig. 20, Ditto of *Trox sabulosus*. Fig. 21, Maxilla of *Hydrophilus piceus*. 1, Cardo. 2, Stipes. 3, Squama. 4, Mando. 5, External lobes, consisting of *a*, the basal joint, and *b*, the hooked, hairy, apical joint. A, Palpus, Fig. 22, Maxillary palpus of *Gryllotalpa vulgaris*. *a*, The swollen palpal surface. Fig. 23, Terminal joint of the same palpus with the dried up surface, *a*. Fig. 24, Labial palpus of *Noctua libatrix* (Savigny). Fig. 25, Ditto of *Lithosia pulchella* (*ib*). Fig. 26, Maxilla of *Banchus falcator*. The figures the same as in fig. 21.

Pl. V. Fig. 1, Proboscis of a *Musca*. A, The fleshy lip. *a*, The peduncle. *β*, A portion beyond the knee. *γ*, The knob. B, The seta within the channelled excavation of the lip. C C, The one-jointed palpus. Fig. 2, Setæ which lie in the fleshy lip of *Tabanus*. *a*, Labrum. *b b*, Mandibles. *c c*, Maxillæ. *d*, Tongue. C C, Two-jointed maxillary palpi. Fig. 3, Proboscis of *Tabanus* seen from above; the letters as before. Fig. 4, The same from beneath. *d d*, The halves of the knobs of the labium. C C, Palpi of the maxillæ. Fig. 5, Labrum from beneath (Savigny). Fig. 6, Mandible (*ib.*). Fig. 7, Maxilla (*ib.*). *c*, Maxilla. C, Two-jointed palpus. Fig. 8, Head of *Cimex rufipes* seen from beneath. A A, Eyes. B B, First joints of antennæ. *a*, Labrum. *b b*, Four-jointed sheath of the proboscis produced by the growing together of the labial palpi. Fig. 9, Clypeus of the same, with the rostral seta extended. *a*, Labrum. *c*, Mandible still united. *d d*, Maxillæ (Savigny). Fig. 10, Head of *Cimex rufipes*, in which the upper integument is removed. A A, The eyes. *c c*, The mandibles, with the muscle which affixes each to the occiput. *d d*, Maxillæ attached by muscles to the tongue. *e*, Tongue. Fig. 11, Head of *Nepa cinerea* seen from above. A A, Eyes. *a*, Labrum. *b b*, Sheath of the proboscis or labium. Fig. 12, The three-jointed sheath of the proboscis seen from beneath. Fig. 13, Proboscis of *Nepa cinerea* separated (Savigny). *b*, Proboscideal sheath. *c c*, Mandibles. *d d*, Maxillæ. *e*, Tongue, at the base of which is the entrance to the œsophagus. Fig. 14, Labrum of *Nepa cinerea* seen from beneath (Savigny). *g*, Clypeus from within. *h*, Reflexed margin of the labrum. *f*, Internal passage for the reception of the maxillary setæ. Fig. 15, Head and oral organs of *Noctua libatrix* (Savigny). AA, Eyes. *a*, Labrum. *b b*, Mandibles. *c*, The maxillæ partially united and forming the proboscis. *d d*, Maxillary palpi. *e e*, Articulating cavities for the labial palpi in the reflexed labium. Fig. 16, Labrum of the same moth separate (*ib.*). Fig. 17, Both of the mandibles of the same moth (*ib.*). Fig. 18, Labium of the same moth (*ib.*). *c*, Labium. *d d*, Labial palpi divested of their hair and scales.

Pl. VI. Fig. 1, Maxilla of the same moth (*ib.*). *a*, The filiform portion. *b*, The palpus. 1, The cardo. 2, The stipes. 3, The squama. 4, The mando. Fig. 2, Section of the proboscis (*ib.*). *a a*, Ridges which close the central canal of the proboscis above. *o*, The central canal. *p p*, The canals in each half of the proboscis. Fig. 3, Head of *Galleria cereana* (*ib.*). A, Eye. B, Antenna. *d*, Labial palpus. *e*, Projecting proboscis. Fig. 4, Parts of the mouth of the same moth. *f*, The proboscis, consisting of two halves. *g g*, Palpi of the proboscis. *d d*, Labial palpi. *e*, The labium. Fig. 5, Head of a neuter *Apis mellifica* seen from beneath. *a*, Mentum. A, Fulcrum. *b*, Tongue (a pierced sucking tube). *g g*, Paraglossæ. *c c*, Four-jointed labial palpi attached to the tongue close to the fulcrum. *d d*, Pergamentaceous maxillæ. *h h*, One-jointed maxillary palpi. *f f*, Mandibles. *n n*, Horny ridges in the articulating membrane of the parts of the mouth. *m*. Occipital aperture. Fig. 6, Mouth of the same insect similarly marked. *e*, The valve of the œsophagus, the second tongue according to Treviranus. 1, 2, 3, 4, 5, The several horny bones which lie in the articulating membrane. Fig. 7, Lower portion of the proboscis (tongue). *b*, With the paraglossæ *a a*, (Brandt). Fig. 8, Anterior view of the head of *Apis mellifica*. A A, Eyes. B, Stemmata. C C, Antennæ. D, Clypeus. E, Labrum. *f f*, Mandibles. *d d*, Maxillæ. *c c*, Labial palpi. *b*, Proboscis or tongue. Fig. 9, Head of *Phryganea grandis* seen in front. A A, Eyes. *a a*, Mandibles. *b*, Labrum. *c c*, Maxillæ. *d d*, Maxillary palpi. *e e*, Labial palpi. *f*, Spoon-shaped Labium. Fig. 10, Labium seen from above. *c c*, Maxillæ. *e e*, Maxillary palpi. *d*, The channel of the under lip which leads to the orifice, *g*, of the œsophagus. Fig. 30, Labium from beneath. *f f*, Labial palpi. *e e*, Basal joints of the maxillary palpi. *g*, Fulcrum.

Pl. VII. Fig. 1, Setiform antenna of *Locusta*. Fig. 2, Ditto ditto of *Cicada*. Fig. 3, Bodkin-shaped ditto of *Leptis*. Fig. 4, Filiform ditto of *Carabus*. Fig. 5, Moniliform ditto of *Tenebrio*. Fig. 6, Sword-shaped ditto of *Truxalis*. Fig. 7, Sickle-shaped ditto (Kirby and Spence). Fig. 8, Dentate ditto of *Stenochorus*. Fig. 9, Serrate ditto of *Elater*. Fig. 10, Imbricate ditto of *Prionus coriarius*, male. Fig. 11, Pectinated ditto of *Ctenocerus*. Fig. 12, Doubly-pectinated ditto of *Ctenophora* (Meigen). Fig. 13, Curled antenna (Kirby and Spence). Fig. 14, Fan-shaped ditto of *Psygmatocerus* (Perty). Fig. 15 Ramose ditto of *Cladius difformis*. Fig. 16, Furcate ditto of *Schizocerus*. Fig. 17, Geniculated ditto of *Apis mellifica*. *a*, Scapus. *b*, Flagellum. Fig. 18, Clavate ditto of *Silpha*. Fig. 19, Capitate ditto of *Necrophorus*. Fig. 20, Ditto of *Hydrophilus*. Fig. 21, Lamellate ditto of *Melolontha fullo*, male.

Pl. VIII. Fig. 1, Tunicate antenna of *Lethrus*. Fig. 2, Inflated antenna of *Paussus* (Sturm). Fig. 3, Fissate antenna of *Lucanus*. Fig. 4, Uncinate ditto of *Odynerus*, male. Fig. 5, Nodose antenna of a *Curculio* (Kirby and Spence). Fig. 6, Angustate ditto of *Asilus* (Meig). Fig. 7, Setigerous ditto of *Sargus* (*ib.*). Fig. 8, Plumose ditto of *Volucella* (*ib.*). Fig. 9, Both of *Ceria conopsoides* seated on a process of the frons (*ib.*). Fig. 10, Antenna of *Chrysotoxum* (*ib.*). Fig. 11—13, Ditto of *Bombylius* (*ib.*) Fig. 14, Of *Lophosia* (*ib.*). Fig. 15, Of *Rhaphium* (*ib.*). Fig. 16, Of *Sybistroma* (*ib.*) Fig. 17, Of *Gonia* (*ib.*). Fig. 18, Mucronate ditto of *Empis* (*ib.*). Fig. 19 and 20, Auriculate ditto of *Parnus* and *Gyrinus*. Fig. 21, Ramose ditto of *Nepa*. Fig. 22, Irregular ditto of *Cerocoma*. Fig. 23, Ditto of *Psychoda* (Meig.). Fig. 24, A portion of the antenna of *Gastropacha trifolii*. *b*, A portion of the branch to exhibit the fine ramose hairs which form the fringe, the one strongly, the other slightly magnified. Fig. 25, Fasciculate antenna of *Callichroma alpinum*. Fig. 26, Antenna of a small Brazilian *Saperda*. Fig. 27 and 28, Feathery antennæ of *Ceratopogon* and *Tanypus* (Meig.). Fig. 29, Portion of an antenna with kidney-shaped joints of *Nephrotoma* (*ib.*). Fig. 30, Irregular clavate antenna of *Agaon paradoxum* (Dalman).

Pl. IX. N. B. In Plates IX.—XIV., which explain the composition of the thorax in the different orders, for the sake of distinction the prothorax is coloured *red*, the mesothorax *blue*, the metathorax *yellow*, and the coxæ *green*. In all the figures, A indicates the pronotum, B the prosternum, *b* the omium, C the mesonotum, D the scapula of anterior wing, D* of posterior wing, E the mesosternum, F the metanotum, G the metasternum, H the parapleura, I the pleura, K the coxæ (generally of the posterior legs). All the figures are original, and from drawings by the author.

[No. 1] exhibits parts of the thorax of *Carabus glabratus*. Fig. 1, Prothorax from above. Fig. 2, Ditto from beneath. Fig. 3, Prosternum from the inner surface, to exhibit the situation of the two weak internal processes. Fig. 4, The omium. *b*, The external surface. *b**, The reflexed margin which is attached to the inner surface of the pronotum. Fig. 5, Lateral view of the prosternum. *c c*, Its two internal scale-shaped processes, between which the nervous cord lies. Fig. 6, Meso- and Metathorax seen from above. R R, The rudimentary wings. *b*, The same from beneath. S S, The first abdominal segment. S* S*, The second ditto. K K, Coxæ of the posterior legs T T, Trochanters. Fig. 7, Anterior view of the mesosternum to exhibit the two processes *f*, which form the fork, and between which the nervous cord lies Fig. 8, Anterior wings of the scapula seen from the surface. *b*, The reflexed margin which lies against the posterior wings. Fig. 9, Posterior wings of the scapula seen from the surface. *b**, The reflexed margin which lies against the margin of the anterior wing, and forms the suture in which both meet together.

[No. 2,] Parts of the skeleton of *Dyticus*. Fig. 1, View of the internal portion of the head after the removal of the upper integument. *a a*, The two ridges which proceed from the throat and enclose the cerebellum between them. *c*, The tentorium or the transverse band of connexion between the two ridges. *d*, A second deeper-seated band, consisting of two halves, upon which the anterior portion of the cerebellum rests. *e e*, Two hooked processes, which proceed from the superior margin of the bands, and encompass the œsophagus in front of the cerebrum. They serve for the insertion of small muscles which retain the œsophagus. *f f*, A horny ridge which runs beneath the frons from one side of the head to the other, and to which the labrum is attached. *g*, The labium, or, rather, its superior fleshy part, the tongue. *h*, A horny semicircular bone, to which the tongue is attached; it lies free in the flesh, and does not come in contact with the integument of the head. *b b*, The orbits. Fig. 2, The prothorax seen from beneath. *b b*, The omia. Fig. 3, The prosternum from behind. *a a*, The jugularia which lie in the membrane of the neck, and upon which the head revolves. *b b*, Internal processes of the prosternum which encompass the nervous cord. Fig. 4, The omium seen from the surface. *b*, The external surface. *b**, The reflexed margin which lies against the surface of the pronotum. Fig. 5, Prosternum from the side. *b*, The internal processes. Fig. 6, Coxæ, trochanters and femur of the intermediate leg, to show the free articulating process. *a*, Audouin's trochantinus. Fig. 7, Meso- and metathorax from above. Fig. 8, The same from beneath. Fig. 9, Mesosternum separated from the parapleura, with its internal processes. This gives the most perfect representation of the vertebra of an insect. E is the body of the vertebra whence the arches proceed which encompass the nervous cord. *b b* are the transverse processes. *a* forms the processus spinosus, consisting of two halves. At the superior transverse process of the body the scapulæ articulate; they correspond to the articulating surfaces of the ribs in the vertebræ. Fig. 10, Anterior wing of the scapula (D). Fig. 11, Posterior wing of the scapula (D*). *b*, The reflexed margin which forms the suture with that of the anterior wing. Fig. 12, The connate coxæ seen from the front to exhibit the process springing from them. It ascends in a forwardly inclined direction from the suture of both coxæ, and then divides into four processes, the two posterior of which again furcate. *b b*, The anterior processes. *a a*, The posterior with their furcate branches **.

[No. 3,] Portions of the skeleton of *Buprestis mariana*. Fig. 1, Prothorax from beneath. A A, Reflexed margin of the pronotum. B, Prosternum. *b b*, The small round plates which correspond to the anterior wings of the scapulæ in *Carabus* and *Dyticus*. Fig. 2, The same from the front. *a a*, The jugularia which lies in the membrane of the neck. Fig. 3, Prosternum from the side. The internal processes are small, and stand forwards. *g*, The same from within, *a a*, these processes. Fig. 4, Upper view of the meso- and metathorax. Fig. 5, The same from beneath. Fig. 6—8, Mesosternum and scapulæ in their natural situation. *b*, Mesosternum (E E). Fig. 7, Anterior wings of the scapulæ (D D). Fig. 10, Metathorax from within to exhibit the quadridentate process. *b b*, The anterior teeth. *a a*, The posterior. Fig. 11, The same from the side. Fig. 12, Meso- and metathorax of *Hister cadaverinus* seen from beneath. S, First abdominal segment. Fig. 13, The same from above.

Pl. X. [No. 1,] Fig. 1, Parts of the skeleton of *Geotrupes nasicornis*. Fig. 1, Pronotum from beneath, the prosternum is removed. *a a*, The reflexed margin. Fig. 2, Prosternum from beneath. Fig. 3, The same from the side. *a*, The internal processes. Fig. 4, Meso- and metathorax from above. Fig. 5, Mesosternum with the scapulæ. E, Mesosternum. D D, Ala anterior scapulæ. D* D*, Ejusd. ala posterior. Fig. 6, Meso- and metathorax from below. Meso- and metasternum are here connate. Fig. 7, Mesosternum from within. *a a a*, The three points of the processus internus. Fig. 8, The internal process from the side. *a a a*, The three points. [No. 2,] Skeleton of *Cetonia aurata*. Fig. 1, Meso- and metathorax from above. Fig. 2, The same from beneath. Fig. 3, Prosternum and scapulæ seen from the front. Fig. 4, The connate sternum from within. *a a*, Proc. intern. mesosterni. *b*, Proc. intern. metast., each consisting of two divaricating lamellæ, between which the nervous cord lies. [No. 3,] Skeleton of *Hydrophilus piceus*. Fig. 1, Pronotum from beneath. Fig. 2, Prosternum ditto. Fig. 3, Mesonotum from above (the letter G is here wrong). Fig. 4, Metanotum from above. Fig. 5, Sternum from without. Fig. 6, The same from within. *a*, The internal processes of the mesosternum which ascend to the scapulæ. *b b*, Wings of the processus internus metasterni. Fig. 7, The same from the side. *a a*, The pro. int. mesost. ascending as far as the scapulæ. *b b*, Both wings of the processus internus metast. *d*, This process itself. *e*, A thin horny lamella which lies beneath the proc. *g*, An externally visible aperture which indicates the point of division between the two parts of the connate sternum. Fig. 8, Parapleuræ from the inner surface, with the tendon of the large extensor of the wing. *a*, The plate-shaped distension.

b, The central petiole which is affixed to the anterior main nervure of the wing.

Pl. XI. [No. 1,] Skeleton of *Gryllotalpa vulgaris*. Fig. 1, Pronotum from above. Fig. 2, Prothorax from beneath. *a a*, The two stigmata which lie in the membrane behind the prothorax. *b*, Aperture of the neck, being the entrance to the prothorax. *c*, Posterior aperture. *d d*, Cavities for the coxæ. Fig. 3, Internal skeleton of the prothorax. A, Pronotum. B, Prosternum. C, Descending keel of the pronotum, which divides into two furcating lamellæ, the anterior and posterior points of which are at E E and F F. With the anterior ones, the T-shaped anterior distension of the sternum articulates, and with the posterior ones, which again unite, the posterior apex articulates at *. Besides which, two processes, D D, spring from the sides of the pronotum, which meet at the anterior angles of the central carina near E E. A process, G, springs on each side backwards from the posterior angles of the central carina, both of which are retained by a bone upon which the crop rests, and which is connected by muscles at * * with them. Fig. 4, Meso- and metathorax from above. Fig. 5, Mesosternum from the side, lying free internally upon the external plate E, the point bending backwards. Fig. 6, The same from beneath with the backwards directed processes, the points are cut off. Fig. 7, The mesonotum seen from the front to exhibit the prophragma, in which, at *a*, the aperture to the aorta is found. Fig. 8, Lateral view of the meso- and metathorax. *β*, Stigma upon the limits of the meso- and metathorax. [No. 2,] Skeleton of *Gryllus migratorius*. Fig. 1, Head from beneath, with the aperture of the mouth distended anteriorly to exhibit the radiating tentorium (*c c c*). *a a*, Basal joints of the antennæ. *b b*, The eyes. Fig. 2, Prothorax from front, natural size. *a a*, The horny arch springing from the sides, which bow over the acetabulæ of the coxæ. Fig. 3, Meso- and metathorax from above, with distended but cut-off wings. *c c*, Prophragma. Fig. 4, The same from the side. *a a*, Rudiments of the base of the wings. *c*, Prophragma. *β*, Second spiracle of the thorax. Fig. 5, The same from beneath. Fig. 6, Mesothorax alone seen from behind. C, Mesonotum. D D, Scapulæ. E, Mesosternum. *a a*, Remains of the wing. *c*, Mesophragma with the aperture *p* for the aorta. *d d*, Internal ridges, which indicate the suture of the wings of the scapulæ. *e e*, Horny arch spanned over the acetabulæ. [No. 3,] Skeleton of *Libellula*. Fig. 1, Entire thorax from above, with the remains of the wings. Fig. 2, The same from the side. *c*, The free prophragma. *β*, Second thoracic spiracle. Fig. 3, The same from beneath. Fig. 4, Prehensile organ upon the second and third ventral segments of the male *Libellula*. *a a*, Two moveable hooks which encompass the points * * of the processes *b b*. *c c*, Processes of the second division of the prehensile organ, between which the hook *d* lies. *e*, Third division of that organ. Fig. 5, The same from the side. Fig. 6, Third division of the prehensile organ, consisting of a large swollen knob, *a*, which at *d* is excavated, and at the anterior ridge of which the hook *b* hangs by two joints. Fig. 7, Central division of the prehensile organ. *a a*, The processes. *b*, The hook between them raised. Fig. 8, First division of the same organ, consisting of the anterior pieces, *a a*, which articulate at *d d* with the posterior ones, *b b*, and the hooks *c c*. Fig. 9, Apex of the abdomen of a male *Libellula*. Fig. 8, 9, 10, The same ordinal joints of the abdomen. *a*, The aperture to the sexual organs.

Pl. XII. [No. 1,] Skeleton of *Cimbex variabilis*. Fig. 1, Lateral view of the thorax. *a*, Tegula which covers the first thoracic spiracle. *d*, Patagium analogous to the anterior wing of the scapula. *c*, Scutellum. *β*, Second spiracle. Fig. 2, View of the thorax from above. *γγ*, Cenchri. Fig. 3, Mesonotum alone. *a*, Prophragma. *d d*, Patagia. *c*, Scutellum. Fig. 4, Prosternum seen from behind, to show the internal processes *a a*. *b b*, Cavities of the coxæ. Fig. 5, The same from the side. Fig. 6, Mesosternum with its lateral ascending wings. *a a*, Internal process divided into two points. *b b*, Cavities of the coxæ. *c*, Hook-shaped process, which originates from the side of the sternum, and serves the muscles of the coxæ for insertion. [No. 2,] Skeleton of *Scolia flavifrons*. Fig. 1, Thorax from above. *d d*, Patagia. *c*, Scutellum. *β β*, Second spiracles. Fig. 2, The same from the side. *a*, First spiracle. *β*, Second. *d*, Patagium. *c*, Scutellum. Fig. 3, The same from beneath. * Aperture through which the tendon passes which holds the abdomen. Fig. 4, Metanotum with the process to which the muscle is attached, which, with the tendon proceeding from it, holds the abdomen. Fig. 5, The same from the side. Fig. 6, Prosternum from behind. *a a*, Acetabulæ of the coxæ. *b b*, Internal processes. Fig. 7, Cavity, A, in the metathorax, for the reception of the apex of the abdomen. *a*, Hole through which the tendon passes. *b b*, Ball joints. Fig. 8, Cavity in the base of the abdomen, which inserts itself in the cavity of the metathorax. *a a*, Sockets. *b b*, Ball joints. *c*, Process to which the tendon is attached. Fig. 9, First segment of the abdomen seen from the side. *a*, Process to which the tendon is affixed. *b*, Socket for the reception of the ball joint of the metaphragma. *c*, Ball joint which is inserted in the socket of the metaphragma.

Pl. XIII. [No. 1,] Thorax of *Methoca ichneumonides*, Lat. Fig. 1, Thorax seen from above. A, Pronotum. *c*, Scutellum. F, Metanotum. Fig. 2, The same from the side. B, Prosternum. E, Mesosternum. G, Metasternum. *β*, Second spiracle. [No. 2,] Thorax of *Myrmosa melanocephala*, male. Fig. 1, From above. Fig. 2, From the side, marked as above. [No. 3,] Superior view of the thorax of *Chrysis ignita*. A, Pronotum. C, Mesonotum divided by two furrows into three fields. *c*, Scutellum. *d d*, Patagia. F, Metanotum. [No. 4,] Thorax of *Cossus ligniperda*. Fig. 1, View from above. *e*, Mesonotum. D*, Patagium. *d d*, Frenum. *c*, Scutellum. F F, Metanotum. K K, Coxæ of the posterior legs. Fig. 2, Lateral view. A, Scale-shaped pronotum. B, Prosternum. *a*, Cavity in which the first spiracle lies. C, Mesonotum. *c*, Scutellum. D*, Patagium. D, Scapula. E, Mesosternum. *β*, Cavity of the second spiracle. F, Metanotum. G, Metasternum. K K K, Coxæ. [No. 5,] Thorax of *Cicada Fraxini*. Fig. 1, View from above. A, Pronotum. C, Mesonotum. *c*, Scutellum. *d d*, Frenum. F F, Metanotum. Fig. 2, View from beneath. B, Prosternum. E, Mesosternum. G, Metasternum. *β β*, Scales beneath each of which the second spiracle of the thorax lies. [No. 6,] Thorax of *Lygæus equestris*. Fig. 1, Prothorax from above. Fig. 2, The same from beneath. Fig. 3, Meso- and metathorax from above. C, Mesonotum. *c*, Scutellum. Fig. 4, The same from beneath. E, Mesosternum. *β β*, Cavities covered by scales, beneath which the spiracles lie. G G, Metasternum.

Pl. XIV. [No. 1,] Thorax of *Tabanus bovinus*. Fig. 1, View from above. *d d*, Protrusions which take the place of the patagia. Fig. 2, View from the side. *a*, First spiracle, indicating the boundary of the prothorax. B, Situation of the prosternum. C, Mesonotum. *c*, Scutellum. *d*, The patagium. E, Mesosternum. R, Base of the wing. S, Scale. F, Metanotum. G, Metasternum. T, Poiser. *β*, Second spiracle. H, Metaphragma K K K, Coxæ. [No. 2,] Thorax of *Myopa testacea*. Fig. 1, View from above. A A, Protrusions which indicate the prothorax (humeri of entomologists). C C, Mesonotum. *c*, Scutellum. S S, Scales. T T, Poisers. F, Metanotum. Fig. 2, Lateral view. A, Humerus. *a*, First spiracle. C, Mesonotum. *c*, Scutellum. E, Mesosternum. S, Scale. F, Metanotum. G, Metasternum. T, Poisers. *β*, Second spiracle. H, Metaphragma. [No. 3,] Thorax of *Semblis bicaudata*. Fig. 1, Prothorax from above. Fig. 2, The same from beneath. B, Prosternum. *a a*, Place of the first spiracle. K K, Acetabulæ. Fig. 3, Meso- and metathorax from above. C, Mesonotum. F, Metanotum. Fig. 4, The same from the side, with the same indications. Fig. 8, Pincers of a *Forficula* (De G.). Fig. 9, A *Smynthurus* seen from beneath (De G.). *a*, The fork which produces the leap. *b*, Process upon the mesosternum whence the filaments proceed. Fig. 10, Apex of the abdomen of *Staphylinus erythropterus*. *aa*, The hairy styli. Fig. 11, Apex of the abdomen of *Blatta orientalis*. *a a*, The circi. *b b*, Two other processes which proceed from the ventral plate. *c*, The male organs withdrawn. Fig. 12, Apex of the abdomen of a male *Ephemera*. *a*, The penis. *b b*, The two fangs which are seated on the ventral plate. *c c*, The jointed fila proceeding from the dorsal plate, the half of which is cut off. Fig. 13, Apex of the abdomen of *Machilis polypoda* (Dumeril), with the hairy setæ. Fig. 14, Apex of the abdomen of *Aphis*. *a a*, The siphunculi.

Pl. XV. N. B. The two arrows at the base of the wings indicate the course of the current of the blood. Fig. 1, Wing case of *Nepa cinerea*. *a*, Clavus. *b*, Hemielytrum. *c*, Appendix. *d*, Membrana. Fig. 2, Wing case of *Gryllus migratorius*. A, Marginal cell. *b*, Vena radialis. B, Central cell. *c*, Vena cubitalis. C, Sutural cell. Fig. 3, Wing of *Dyticus*. *a*, Vena marginalis or radialis. *b*, Vena cubitalis or postcosta, also nervus internus.—The marginal space is in this and in all the following wings indicated by red, and the sutural space by yellow. The former is bounded by the vein through which the current of blood streams, and that of the latter by the one through which it returns. Fig. 4, Wing of a *Tenthredo*. *a*, Vena radialis. *b*, Vena cubitalis. *β*, Stigma, carpus. *d d*, Cellulæ radiales. *e e e*, Cellulæ cubitales. Fig. 5, Wing of a bee. *a*, Marginal vein. *b*, Discoidal vein. *d*, Marginal cell. *e e*, Cubital cells. *c c*, Discoidal cells. *f f f*, Incomplete cells. Fig. 6, Wing of a *Tipula*. Fig. 7, Wing of a *Syrphus*. Fig. 8, Wing of a *Tachina*. Fig. 9, Wing of one of the smaller *Muscidæ*. Fig. 10, Wing of a *Phora*. Fig. 11, Wing of *Hippobosca*. All these figures are marked like 5. Fig. 12, Anterior wing of *Platypterix*, ala falcata. Fig. 13, Posterior wing of *Papilio Podalirius*, ala caudata. Fig. 14, Anterior wing of *Orneodes hexadactyla*, ala digitata.

Pl. XVI. Fig. 1, Anterior leg of *Carabus*. *a*, Coxa. *b*, Trochanter *c*, Femur. *d*, Tibia. *ꝺ ꝺ*, Calcaria. *e*, Tarsus. Fig. 2, Anterior leg of *Ateuchus sacer*. *e*, The terminal spine supplying the place of a tarsus. Fig. 3, *a*, Intermediate leg of a butterfly. *b*, Abortive leg of the same. Fig. 4, Swimming leg of *Dyticus dispar*. Fig. 5, Leaping leg of *Haltica*. Fig. 6, *a*, Prehensile leg of *Mantis religiosa*. *b*, Prehensile leg of *Nepa cinerea*. Fig. 7, Digging leg of *Gryllotalpa vulgaris*. The tarsus is three jointed. Fig. 8, Fringed femur of an *Andrena*. Fig. 9, Supporting trochanter of *Carabus*. Fig. 10, Double-jointed trochanter of a *Pimpla*. Fig. 11, Lamellate tibia of a *Lygæus*. Fig. 12, Scutellate tibia of *Crabro cribrarius*, *a*. *e*, The five-jointed tarsus. Fig. 13, Brush-like tibia of *Apis*. *e*, Planta. Fig. 14, The sole of *Carabus* fringed with spines. Fig. 15, Cordate tarsal joint of *Timarcha tenebricosa*. Fig. 16, Triangular tarsal joint of *Copris lunaris*. Fig. 17, Quadrate tarsal joint of *Buprestis mariana*. Fig. 18, Bilobate tarsal joint of *Callidium violaceum*. Fig. 19, Furcate tarsus of *Xya*. *a*, Spines on the tibia. *e e*, The furcate tarsus, consisting each of one joint. Fig. 20, Tarsus with three distended joints of *Cicindela campestris*. Fig. 21, Tarsus with four distended joints of *Calosoma sycophanta*. Fig. 22, Tarsus with one distended joint of *Hydrophilus piceus*. Fig. 23, Anterior tarsus of *Dyticus dispar*, *a*, from above, *b*, from beneath. *p p*, The large patellulæ. Fig. 24, Claw joint of *Carabus*, equal claws. Fig. 25, Claw joint of *Anisoplia fructicola*. Fig. 26, Claw joint with very large unequal claws of *Rutila*. Fig. 27, *b*, Furcate claw of *Meloë* divided near the surface. *a*, Furcate claw of *Anisoplia horticola*, divided near the ridge.

N. B. It is only the external larger claw that is thus divided, and not, as the drawing indicates, the smaller one also. Fig. 28, Dentate claw of *Melolontha.* Fig. 29, Dentate claw of *Ornithomya.* Fig. 30, Serrate claw of *Cistela.* Fig. 31, Claw joint of *Lucanus cervus.* *a a*, The large claws. *b*, The pseudo claw. Fig. 32, Claw joint of *Tachina fera.* *a a*, The serrate claws. *b b*, The plantulæ. Fig. 33, Claw joint of *Laphria flava.* *a a*, The claws. *b b*, The plantulæ. *c*, The pseudo claw. Fig. 34, Tarsus of *Xenos*, without claws, but with soft plantulæ. Fig. 35, Hairy plantula of *Lamia.* Fig. 36, Plumose plantula of *Zabrus.* Fig. 37, Spongy plantula of *Timarcha tenebricosa.* Fig. 38, Tarsus cryptopentamerus of *Cerambyx heros.* 1, First tarsal joint (metatarsus); 2, second tarsal joint (phalanx prima); 3, third bilobate tarsal joint (phalanx secunda); 4, abortive fourth tarsal joint (arthrium); 5, claw joint. Fig. 39, Tarsus cryptotetramerus of *Coccinella.* 1, First tarsal joint; 2, second deeply excavated foot joint; 3, arthrium; 4, claw joint.

Pl. XVII. Fig. 1, Internal structureless folded tunic of the ilium of *Hydrophilus piceus.* Fig. 2, Second tunic of the ilium of the same beetle beset with ridges, teeth, and stars. Fig. 3, Third or muscular tunic, with the ventral glands, which lie in a transparent case, of the same. Fig. 4, Third or muscular tunic of *Dyticus marginalis.* Fig. 5, Second tunic of the crop of the same beset with horny ridges that form regular meshes. Fig. 6, Transverse section of the membrane of the crop of the same. *a*, Internal layer beset with ridges. *b*, Muscular tunic. Fig. 7, Tunic of the œsophagus of the same with undulating horny ridges. Fig. 8, Proventriculus of the same. It is excavated in the form of a tunnel, and supplied with four teeth, which are broad above and narrow below. 3, Intestinal canal of the larva of *Vespa crabro* (Suckow). A, Œsophagus. D, Ventriculus. H, Cæcum. K K, Biliary vessels. Fig. 10, Intestinal canal of *Vespa crabro* (*ib.*). A, Œsophagus. C, Crop. D, Transversely striated ventriculus. E, Ilium with four longitudinal stripes. H, Colon with horny rings.

Pl. XVIII. Fig. 1, Intestinal canal of *Aphrophora spumaria* (*ib.*). A, Œsophagus. D, Crop. D *, First division of the ventriculus. D D * *, Second division, which returns to the crop. E, Ilium. H. Colon. K K, Biliary vessels. Fig. 2, Intestinal canal of the maggot of *Musca carnaria* (*ib.*), marked the same as above. N N are the salivary vessels with their simple outlets, O. Fig. 3, *a*, A portion of the biliary vessel much magnified. Fig. 3, Intestinal canal of the perfect fly (*ib.*). Fig. 4, Intestine of the caterpillar of *Gastropacha Pini* (Suckow), marked similarly. F is the clavate gut. O O are the spinning vessels. Fig. 5, Intestinal canal of *Pontia Brassicæ* (Herold). C, The sucking stomach. G, The cœcum. The rest as before.

Pl. XIX. Fig. 1, Intestinal canal of the larva of *Calosoma sycophanta* (original), marked as before. H is the internally longitudinally folded colon to which the last segment of the larva is still attached. Fig. 2, Intestinal canal of the perfect beetle (Suckow). D is the ventriculus, the anterior half of which is covered with the pancreas, and the posterior portion, D*, with glands. Fig. 3, Intestinal canal of the larva of *Dyticus marginalis* (orig.), marked the same. Fig. 4, That of the perfect beetle, as before, the ventriculus anteriorly covered with the pancreas.

Pl. XX. Fig. 1, Intestinal canal of *Cetonia aurata* (Ramd.). D, The pancreas covers the ventriculus with three coronets. F, The clavate gut. Fig. 2, Ditto of the perfect insect (*ib.*), as before. Fig. 3, Ditto of *Cimex rufipes* (Trevir.). *a a* and *β β* are the setæ of the proboscis whence the vessels *γ γ* originate which open into the commencement of the ventriculus. *b b*, The salivary vessels and glands. D, The first stomach with the two-folded bodies (*δ δ*) at its orifice (this supplies the place of a crop). D*, The second stomach (supplying the place of a proventriculus). D**, The third stomach, forming, as it were, a second crop in front of the true ventriculus. D***, The ventriculus, consisting of four contiguous tubes. The rest as before.

Pl. XXI. Fig. 1, Intestinal canal of *Gryllus migratorius*. Lateral view. *a a*, Four of the six blind tubular appendages at the orifice of the stomach (pancreas). *n*, Nervus sympathicus. Fig. 2, The same opened. B, The crop with the rows of teeth. **, Spot where the blind appendages open. D, Ventriculus. ****, Spot where the biliary vessels open; the rest the same as before. Fig. 3, *a b*, Two rows of teeth which are found within the crop much magnified. Fig. 4, Raised longitudinal ridges beset with teeth within the lower portion of the crop. Fig. 5, The processes, *b b*, of the internal tunic of the stomach, *a a*, which thrust into the blind appendages and their cavities, and open at C C into the intestine. Fig. 6, The portion of the intestine where the blind appendages open, *a a*, their apertures; these cut off, to show their internal volume. *c c*, V-formed horny teeth, which form the proventriculus Fig. 7, Œsophagus and crop of *Gryllotalpa vulgaris* (J. Müller). A, Œsophagus. B, Crop. C, Continuation of œsophagus. D, Proventriculus. E E, Blind bags which open into the commencement of the ventriculus. G, Ventriculus. *a*, Cerebrum. *b b*, Nervous cords which form the first ganglion, *c*, of the sympathic system. *d d*, The sympathic nerves. *e*, Branch of it for the crop. *f*, Second or connecting ganglion. *g*, Branch for the proventriculus. Fig. 8, Transverse section of the proventriculus of *Termes fatalis*. *a a*, Projecting horny plates. *b b b*, Six fasciculi of muscles which close it. Fig. 9, Lateral view. *a*, Space before the proventriculus, crop. *b*, The proventriculus seen through the contracted orifice of the ventriculus. *d*, Ventriculus. Fig. 10, Opened proventriculus of *Termes fatalis*. *a a*, Twelve horny plates, which are alternately supplied with strong fasciculi of muscles, *b b*, which unite to form the sphincter of the stomach. Fig. 11, Orifice of the stomach of *Lamia ædilis*. *a a*, Four teeth, which have two fine horny ridges. *b b*, Ridges of the crop. *c*, Ventriculus. Fig. 12, Salivary vessels of *Locusta viridissima*. *a*, Tongue from beneath. *b b*, Outlets of the glands. *c c*, Glands. Fig. 13, Mandibles and salivary vessels of the caterpillar of *Gastropacha Pini* (Suckow). *a*, Mandible. *b*, Gland, aperture of the salivary vessel. *c*, Muscle of the mandible. *d d*, Salivary vessel. Fig. 14, Urinary organ of *Dyticus marginalis*. *a a*, Secreting vessel, kidney. *b*, Urinary bladder. *c*, Evacuating duct. Fig. 15, Salivary vessels of *Reduvius personatus* (Ramd.). *a*, Œsophagus. *b*, Duct of the salivary glands. *c c*, Longitudinal glandular bodies. Fig. 16, Salivary vessel of *Pulex* (Ramd.), vesicular glands. *b*, Excretory duct.

Pl. XXII. Fig. 1, Single salivary vessel of *Nepa cinerea* (Ramd.). *a*, Duct. *b*, Glands. *c*, Glandular vessel. Fig. 2, Second salivary vessel of ditto (*ib.*). *a b*, Double duct of the auxiliary gland. *d*, Auxiliary gland. *e e*, Chief gland. Fig. 3, Salivary vessel of *Blaps* (Leon Duf.). Fig. 4, Ditto of *Tabanus* (Ramd.) Fig. 5, Ditto of *Cicada* (Leon Duf.). Fig. 6, Ventral salivary glands of *Leptis* (Ramd.). *a a*, The two glandular bags. *b*, Œsophagus. *c*, Outlet of the sucking stomach. *d*, Commencement of the ventriculus. Fig. 7, Ventral salivary glands of *Bombylius* (*ib.*), the same. Fig. 8, Ditto of *Chrysotoxum* (Ramd.), the same. Fig. 8*, Lateral view of the heart of *Melolontha vulgaris* (Straus-Durck.). *a a*, Orifices of the heart, 12. *g*, Ventriculi. B, End of the heart. C, Aorta. Fig. 9, Commencement of the heart, with the muscular wings (*ib.*). *a a*, Muscular wings. *b b*, Orifices in them, in front of each aperture of the heart. Fig. 10, Spiracle of the abdomen of *Dyticus marginalis*. Fig. 11, Portion of a trachea. *a a*, External tunic. *b b*, Spiral filament which forms the second tunic. *c c*, Third, or mucous tunic. Fig. 12, A portion of the tunic of the air-bag of *Musca vomitoria*, very much magnified.

Pl. XXIII. Fig. 1, Spiracle of *Oryctes nasicornis*, seen from the front. *a a*, The projecting margin. *b b*, Horny plates, which form its lips. *c*, Aperture. Fig. 2, The same, removed from the contiguous parts, and seen from the side. *a*, Projecting margin. *b b*, The separated integument in the vicinity of the spiracle. *c c*, Posterior projecting margin of the spiracle. *d d*, The two horny triangles, which lie on one side of the main stem of the trachea, which join at *, and are moved by the broad muscle, *e*. *f f f*, Branches of the tracheæ. Fig. 3, The same, from beneath. *a a*, External projecting margin. *b b*, Separated integument. *c*, Spot where the apex of the lower triangle articulates with the margin of the spiracle that projects inwardly. *d*, The lower horny triangle. *f f f*, Stems of the tracheæ. Fig. 4, Spiracle of the larva of *Cetonia aurata*. *a a*, The external darkly-coloured margin, which is decorated with paler elliptical spots. *b b*, The central paler horny plate. *c*, The raised margin of the true aperture. *d d*, Branches of tracheæ. Figs. 5—11, Ovipositor of *Sirex juvencus*. Fig. 5, Last abdominal segment, with the ovipositor, A. B B, Lateral margins of the last largest segment. Fig. 6, Apex of the abdomen, from the side. The ovipositor, *b*, projects from the two valves, *a*. Fig. 7, Apex of the ovipositor, seen from above. *c*, The divided dentate apex of the sheath. *d d*, The two dentate setæ within the sheath. Fig. 8, The ovipositor, from the side. *c*, The upper channel. *d*, The single lower seta. Fig. 9, From beneath. *c c*, Sheath. *d d*, Setæ. Fig. 10, One seta, to exhibit the shape of the teeth upon it. Fig. 11, Transverse section of the ovipositor. *a a*, The external valves. *c*, The sheath. *d d*, The setæ. *e*, Central free channel. Figs. 12—14, Ovipositor of *Pimpla*. Fig. 12, Apex of the organ, covered with short teeth. *a*, The upper channel. *b*, The fine seta. Fig. 13, Section of the mere ovipositor. *a*, Channel. *b*, Seta. *c*, Canal. Fig. 14, Section of the ovipositor, with the valves. *a*, Channel. *b*, Seta. *c c*, Valves. *e*, Canal. Figs. 15—18, Ovipositor of *Cynips quercifolia*. Fig. 15, Last bent segment, with the two hairy processes originating from the internal surface. Fig. 16, The ovipositor. *a a*, Valves. *b b*, External channel of the setæ. *c*, Central finer seta. Fig. 17, The external, *b b*, and the central seta, *c*, alone. Fig. 18, Section. *a a*, Valves. *b b*, External setæ. *c*, Central one.

Pl. XXIV. Figs. 1—7, Ovipositor of *Cicada Fraxini*. Fig. 1, Apex of abdomen. A, Last dorsal segment. D, Last ventral segment. B, Basal joint of the sheath of the ovipositor. C, Terminal joint. Fig. 2, Ovipositor with the valves from beneath. B B, Basal joints of the valves. C C, Terminal joints. D, The ovipositor. Fig. 3, Apex of the ovipositor from beneath. *a a*, Superior distended sheath, with teeth on the margin. *b b*, The lower setæ pushed upwards, so that they project beyond the apex of the sheath. Fig. 4, Setæ from the inner side, to show the central channel. Fig. 5, Apex of the sheath from above, toothed on the margin, furrowed in the centre, emarginate at the apex to receive the points of the setæ, which form the true apex of the ovipositor. Fig. 6, Section. *a a*, The valves. *b b*, The sheath. *c*, The setæ. Fig. 7, Section of the mere ovipositor. *a a*, Sheath. *b*, Seta. Figs. 8, 9, Ovipositor of *Cimbex variabilis*. Fig. 8, The valves opened from beneath. A A, The last dorsal segment. *a a*, External valves. *b b*, Internal valves, or saws. *c*, Central short process. Fig. 9, An internal valve, or saw, from its external surface. *b*, Furrow, by means of which the external surface is divided into two halves. *a*, Lower more finely serrated. *b*, Superior more coarsely serrated surface. Figs. 10—15, Ovipositor of *Locusta*. Fig. 10, Apex of the abdomen of *Locusta viridissima*. A, Last dorsal segment. B, Last ventral segment. C, Ovipositor. Fig. 11, One half of the sheath seen from the exterior of *Locusta ephippiger*. Fig. 12, The same from the inner surface. *a*, Superior half of the valve. *c*, Lower half. *b*, Central, smaller, inner valve of the same side. Fig. 13, External view of the apparatus of *Locusta viridissima*. *a*, Upper half. *c*, Lower half. Fig. 14, The same from within. *a*, Upper half. *c*, Lower half. *b*, Internal valve, indicated here only as a projecting ridge, Fig. 15, the jointed ovipositor of *Chryis* (Kirby and Spence).

Pl. XXV. Figs. 1—4, Male organs of *Carabus glabratus*. Fig. 1, Prepuce from above, as taken from the ventral cavity. *a*, The horny ridges which distend the bag of the prepuce. *b*, The process of the prepuce, in which the penis lies. *c*, Apex of this process, into which the vasa deferentia extends. *d*, Last dorsal segment. Fig. 2, The same from beneath. *a a*, The horny ridges of the prepuce. *b*, The horny plate which lies in the lower portion of the prepuce. *c*, Process in which the penis lies. *d*, Last dorsal segment. Fig. 3, Penis from above, with *a*, lateral moveable process, *b*, in which muscles are inserted. Fig. 4, The same from beneath. *a*, Aperture of the penis, whence the sperm flows. Figs. 5—10, Male organs of *Dyticus marginalis*. Fig. 5, View of them beneath, with the last divided ventral plate. A A, The two halves of the ventral plate. B B, Muscles whereby they are affixed to the preceding one. C C, Horny ridges, which partly serve these for insertion. D D, Muscles which unite the transverse ridge with the ventral plates. *a*, A horny ring lying beneath in the prepuce. *g g*, Muscles that move the penis. *f*, Vasa deferentia. Fig. 6, Penis and prepuce separated from the last ventral plate, seen from beneath. *a*, A horny ring that distends the prepuce. *b*, Horny plate which lies in it. *i*, Membranous portion of the prepuce. *d*, Sheath of the penis. *e*, Penis. *g g*, Muscles which move the penis. *f*, Vasa deferentia. Fig. 7. The same from above. *a a*, Horny ring of the prepuce, running at the margin, and connected with the penis by muscles, *h h*. *i*, Membranous portion of the prepuce. *k*, Horny plate lying in the upper part of the prepuce. *l*, Horny scale to which the ends of the horny arch of the prepuce are attached. *e*, Penis. *g g*, Muscles which move the penis, *f*, Vasa deferentia. Fig. 8, The same seen from the left side. *a*, Horny ring of the prepuce. *b*, Horny scale lying in the lower portion. The rest as in the preceding. Fig. 9, The penis, after the removal of the prepuce. *a a*, Membranous portion of the prepuce, which is drawn back by horny ridges, *b*, which are connected with the horny ring of the prepuce *c c*, by means of muscles, at its upper margin. *d d*, Valves of the penis. *e*, Penis. Fig. 10, Penis, quite free. *a*, Ridge which lies in the penis, and closes its aperture. *b*, Lower channel, in which the ridge or bone lies. Figs. 11—14, Male organs of *Hydrophilus piceus*. Fig. 11, Prepuce from above. M, The removed colon. *d d*, Last dorsal segment, with three fenestrations. *b b*, Horny ring which distends the prepuce. E E, Sheaths of the penis. F, Penis. *f*, Vasa deferentia, surrounded by the membranous portion of the prepuce. Fig. 12, The same, from beneath. *a*, Horny plates, which lie in the lower portion of the prepuce, whence the ridges proceed which affix themselves to the apex of the last ventral plate, *e e*. *c c*, Other horny ridges, which proceed from the horny arch. *b b*, As fig. 11. *d d*, Last dorsal segment. E E, Sheath of the penis. F, The penis. Fig. 13, The free penis, from above, more magnified than fig. 12. A A, Reflexed margins of the horny plate. A, As in fig. 14. B, Membranous portion of the penis. E E, Sheaths of the penis, consisting of horn. F. Penis, provided in the middle and on the margin with horny ridges. Fig. 14, Free penis, from beneath. A, A cordiform horny plate, to which the sheaths are attached. E E, The sheaths of the penis. F, Penis, with the aperture X, which is surrounded by a horny arch, whence a ridge proceeds.

Pl. XXVI. Figs. 1, 2, Sexual organs of *Callichroma moschatum*. Fig. 1, A, Prepuce, supported by a horny ridge, C, which distends into a horny plate, B, upon the upper surface of the prepuce. D, Penis. E, Vasa deferentia. F, Ridge, by means of which the penis is pushed forwards. G, Last ventral segment. Fig. 2, Free penis, seen from the left side. *a*, Lower horny tip of the penis. *b*, Upper ditto. *c*, Vasa deferentia. Figs. 3—7, Male organs of *Blatta orientalis*. Fig. 3, View from above. *a*, Superior horny plate covering them. *b*, Left. *c*, Right. *d*, Penis. Fig. 4, The same from beneath. *c*, Right horny plate. *b*, Left. *a*, Upper. *d*, Penis. Fig. 5, The superior covering plate, consisting of several horny pieces, and provided with a hooked process. Fig. 6, The right covering plate, composed of two pieces, *a* and *b*. Fig. 7, The left covering horny plate, with the penis. *a a*, Ridges, which enclose the penis between them. *b*, The upwards bent penis, furnished at the end with a hook. Figs. 8—10, Male organs of *Cimbex variabilis*. Fig. 8, From below. *a a*, The external sheaths, each consisting of a lower (*a*) horny and a superior (*a**) membranous portion. *b b*, The penis, likewise consisting of two valves. Fig. 9, The left half of the sexual apparatus, seen from without. *a*, Horny basal portion of the sheath. *b*, Membranous appendage. *c c*, Halves of the valvular penis. Fig. 10, The same from within, marked similarly. *d*, Outlet of the vasa deferentia. Figs. 11—13, Male organs of *Vespa Germanica*. Fig. 11, Seen from beneath. *a a*, External sheaths. *b b*, Internal sheaths of the penis. *c*, Penis. X, Aperture for the vasa deferentia. Fig. 12, Penis, from the side, distended like a spoon, anteriorly, *c*, with a barb, *a*, by which it hangs attached during copula. Fig. 13, The same, from above, marked similarly. *b*, Internal passage of the penis. Figs. 14—17, Male organs of *Deilephila Galii*. Fig. 14, Lateral view of the whole apex of the abdomen. *a a*, Horny ring to which the external sheath is affixed. *b*, External sheath of the left side, with the hooked appendage (*b**). *c*, Penis. *d*, Horny process, into which the colon passes. *e*, Anus. Fig. 15, Sheath of the right side seen from within. Fig. 16, Free penis, *a*, with the aperture *c*, and the muscles *b b*, which attach it. Fig. 17, Anterior aperture of the penis, seen from above.—Figs. 18, 19, Male organs of *Cercopis vulnerata*, Ill. Fig. 18, The sexual apparatus, enclosed in valves, seen from the left side. Fig. 19, The opened sexual apparatus, seen from above. The external valves are removed. *a a*, The internal valves. *b b*, The horny penis, consisting of two parts, bent outwards.

Pl. XXVII. Fig. 1, Ovaria of *Ephemera marginata*. Fig. 2, Of *Phasma gigas* (Müller). Fig. 3, Ditto of *Gryllus migratorius*. Fig. 4, Ditto of *Meloe proscarabeus*. Fig. 5, Ditto of *Gryllotalpa vulgaris* (*ib.*). Fig. 6, Ditto of *Lepisma* (Trev.). Fig. 7, Internal sexual organs of *Hippobosca* (L. Duf.). *a a*, Ovaries. *b*, Uterus. *c c*, Conducting vessels. Fig. 8, Ovary of *Anthidium* (Suckow). Fig. 9, Ditto of *Tinea Evonymella* (*ib.*). Fig. 10, Ditto of *Musca carnaria* (*ib.*). Fig. 11, Ditto of *Aphrophora spumaria* (*ib.*). Fig. 12, Ditto of *Lucanus parallelopipedus* (*ib.*). Fig. 13, Uterus without appendage of *Tipula crocata* (*ib.*). Fig. 14, Ditto, with an appendage of *Anthidium manicatum*. *a*, The spermatheca (*ib.*). Fig. 15. The same of *Hydrophilus piceus* (*ib.*). *a*, The spermatheca, into which the serpentine gum-vessel evacuates. Fig. 16, The same of the *Melolontha vulgaris* (*ib.*). *a*, Spermatheca. *b*, gum-vessel. The pockets are at the end of the sheath, into which the knob of the penis inserts itself. Fig. 17, The same of *Xylocopa* (*ib.*). *a*, Spermatheca. *b*, Gum-vessel. Fig. 18, The same of *Sirex* (*ib.*). *a*, Spermatheca, with the two ears. *b*, Gum-vessel. Fig. 19, The same of *Harpalus ruficornis*. *a*, Sack-shaped distended sheath. *b*, Gum-vessel.

Pl. XXVIII. Fig. 1, Uterus of *Lucanus* (Suckow). *a*, Spermatheca. *d d*, Double gum-vessel. Fig. 2, Ditto of *Gryllotalpa vulgaris* (*ib.*). *a*, Spermatheca. *b b*, Gum-vessels. Fig. 3, Ditto of *Lepisma* (Trev.). *b b*, Gum-bags. Fig. 4, Duct of the internal genitalia, with its appendages, of *Gastropacha Pini* (Suckow). *a*, Spermatheca, with its narrow duct. *b b*, Glue-vessel, forked above, beneath distended into a bladder. *c c*, Second secreting vessel, probably a urinary organ, corresponding to the poison vessel of the *Hymenoptera*. *a*, Colon and cœcum. Fig. 5, Poison-vessels of *Vespa crabro* (*ib.*). *a a*, Secreting vessels. *b*, Poison-bladder. Fig. 6, The same of *Apis mellifica* (Swamm.). *a a*, Secreting vessels. *b*, Poison-bladder.

Pl. XXIX. Fig. 1, United testes, with the two outlets, of *Pontia Brassicæ* (Herold). Fig. 2, Testes of *Libellula* (Suckow). Fig. 3, Ditto of *Aphrophora spumaria* (*ib*). Fig. 4, Ditto of *Tipula crocata* (*ib.*). Fig. 5, Ditto of *Ranatra linearis* (*ib.*). Fig. 6, Half of the poison vessel of *Apis mellifica*. Fig. 7, Testes of *Dyticus marginalis*. *a*, Large knob. *b*, Small knob of the duct. Fig. 7, *b*, Testes of *Silpha obscura* (L. Duf.). Fig. 8, Ditto of *Hydrophilus piceus* (Suck.). Fig. 9, Ditto of *Trichodes* (*ib.*). Fig. 10, Ditto of *Locusta viridissima*. Fig. 11, Ditto of *Staphylinus* (L. Duf.). Fig. 12, Ditto and duct of *Musca deviens* (Suckow). Fig. 13, Ditto of *Semblis bicaudata* (*ib.*). Fig. 14, Ditto of *Apate* (L. Duf.). Fig. 15, Ditto of *Œdemera* (*ib.*). Fig. 16, Ditto of *Pimelia* (*ib.*). Fig. 17, Ditto and duct of *Lytta vesicatoria* (Brandt). *a*, Testes. *b*, First gum-vessel. *b b*, Second ditto. *a**, Bag-shaped distension at the connecting point of the duct. Fig. 18, Testes of *Lamia ædilis.* Fig. 19, Ditto of *Prionus* (L. Duf.), Fig. 20, Ditto of *Cicada* (*ib.*).

Pl. XXX. Fig. 1, Testes of *Nepa cinerea* (Swamm.). Fig. 2, Ditto of *Melolontha vulgaris* (Suckow). Fig. 3, Auxiliary testes of *Hydroph. piceus* (*ib.*). Fig. 4, Ditto of *Locusta viridissima.* *a*, Superior fasciculus of vessels. *b*, Retainer, clothed on the surface with small processes, into which the duct, *c*, opens. *d*, Sperm bladder. Fig. 5, Ducts of the genitalia of *Donacia aquatica* (Suckow), without appendages. Fig. 6, Ditto of *Phryganea oleracea.* *a*, Vasa deferentia. *b*, Vesica seminalis. Fig. 7, The same of *Dyticus marginalis*, marked the same. Fig. 8, The same of *Apis mell.* (Brandt). *a* a**, Vesica seminalis. *b b*, Clavate gum-vessels. Fig. 9, The same of *Melolontha vulgaris* (Suckow). *a a*, Ducts of the vesica seminalis. *b b*, Gum-vessels, with their distension. Fig. 10, The same of *Hydrophilus piceus* (*ib.*). *a a*, Vasa deferentia. *a* a**, Vesica seminalis. *a a*, Ends of the auxiliary testes. *b* b**, The first furcate gum-vessel. *b b*, The second simple ones. Fig. 11, The same of *Lamia ædilis.* *a a*, Vesica seminalis. *b*, Furcate gum-vessel, with unequal branches. Fig. 12, Organs of *Vanessa Urticæ*, male (Swamm.). *a*, United testes. *a* a** Vasa deferentia, into which the gum-vessels, *b b*, open. Fig. 13, Gum-vessel of *Calosoma sycophanta* (Suckow). *a*, Vasa deferentia of one side, which opens into the gum-vessel (*b b*) of the side, that of the other side and the ductus ejaculatorius is cut off. Fig. 14, Ducts of the genitalia of *Tipula crocata* (Suckow). *a a*, Vasa deferentia. *b*, Gum-vessels.

Pl. XXXI. Fig. 1, A portion of the hard membrane of the brain of *Dyticus marginalis.* Fig. 2, Brain of the caterpillar of *Cossus ligniperda* (Lyonet). A, Cerebrum. B, Cerebellum. *a a*, Nerves of the eyes. *b b*, Of the antenna. c, Cord round the œsophagus, proceeding from the cerebrum. *d d*, Cord connecting the cerebrum and cerebellum. *e e*, Nerves of the mandibles, the branches of the second nerve of the lip (*g g*), whence a branch for a muscle, N, originates. *f f*, Nerves of the maxillæ. *g g*, Second connecting nerve of the labium, of which the nerve of the mandible is a branch. *g* g**, First nerves of the labium, which give off a branch, M, to the muscles of the maxillæ. O O, Nerves of the muscles of the mandibles and antennæ. P P, Nerves of the muscles of the mandibles. R R, Nerves that distribute themselves at the posterior portion of the skull. S S, Nerves of the muscles of the neck, which pass into the thorax. V V, Connecting cords of the cerebellum and first thoracic ganglion. D, The frontal ganglion, formed of the two branches, E E, whence the sympathic nerve, F, originates. Fig. 3, Cerebrum of the same caterpillar (*ib.*). E E, Branches to the frontal ganglion. O, Nerve of the muscles of the mandibles. *b b*, Nerves of the antennæ. *a a*, Nerves of the eyes. *c c*, Cord of the œsophagus. P P, Nerves of muscles. A A, Small ganglion of the sympathic nerve. B B, Branches to ditto. F, Nervus sympathicus (which Lyonet did not discover here). Fig. 4, Brain of *Melolontha vulgaris* (Straus). A, Cerebrum. B, Cerebellum. *a a*, Optic nerves. *b b*, Nerves of the antennæ. *d d*, First ganglion of the sympathic system. G G, Second ganglion. D, Frontal ganglion. *e e*, Nerves of the mandibles. *f f*, Nerves of the maxillæ. Fig. 5, Cerebellum alone (*ib.*). *e e*, Nerves of mandibles. *f f*, Ditto of maxillæ. *k k*, Connecting cord with the cerebrum. *h h*, Connecting cords to the first thoracic ganglia. Fig. 6, Cerebrum of *Gryllus migratorius*, with the sympathic system seen from above. A A, Optic nerves. B B, Nerves of the antennæ. *a*, Frontal ganglion. *b*, First ganglion, in which the odd (unpar.) nerve terminates. *c c*, The large ganglia. *e e*, The small ditto, whence the sympathic nerve originates by two branches, which again unite at *d** and *d**. *e e*, Small ganglia upon the œsophagus. *f f*, First ganglion upon the crop. *g g*, Second, which lies at the end of the crop. *h h*, Nerves which pass between the blind appendages. Fig. 7, Brain of *Gryllus migratorius*, seen from the front. A A, Optic nerves. *a a*, Nerves which pass to the frontal ganglion. *b b*, Nerves of the antennæ. *a* a* a**, Nerves to the ocelli. *d d*, Connecting cords between the cerebrum and cerebellum. *d**, The connecting cord of these. B, Cerebellum. *e e*, Nerves of the mandibles. *f f*, Nerves of the maxillæ.

Pl. XXXII. Fig. 1, Brain of the larva of *Calosoma sycophanta*. A, Cerebrum. *a a*, Optic nerves. *b b*, Nerves of the antennæ. *d d*, Branches to the frontal ganglion. D, Frontal ganglion. F, First ganglion of the sympathic system, the posterior one I have not discovered. B, Cerebellum. *e e*, Nerves of the mandibles. *f f*, Nerves of the maxillæ. *g g*, Nerves of the labium. Fig. 1, B, Commencement of the ganglionic ventral cord of the same larva. *k*, Cerebellum. *h h*, Auxiliary connecting cord, with the first thoracic ganglion. *n n*, Auxiliary ganglia. A A, Nerves of the anterior legs. L, First thoracic ganglion. *i i*, Auxiliary connecting cords of the first and second ganglia, forming small ganglia, *m m*. *k k*, Auxiliary connecting cords between the second and third ganglia. M, Second thoracic ganglion. N, Third. O, Fourth. *p p*, *q q*, *r r*, *s s*, Nerves of muscles. B B, Nerves of the intermediate legs. C C, Nerves of the posterior legs. Fig. 2, The ventral cord of *Dyticus marginalis*. A A, Nerves of the anterior legs. B B, The intermediate ones. C C, The posterior ones. Fig. 3, Ventral cord of the larva of *Eristalis tenax*. Fig. 4, Ventral cord of the fly *Erist. tenax*. *a a*, Connecting cords with the cerebellum. A A, Nerves of the anterior legs. B B, Of the intermediate. C C, Of the posterior. *b b*, Branches of the muscles which pass into the abdomen. *d*, First abdominal ganglion. *c c*, Branches of it. *e*, Second abdominal ganglion. *f f*, *h h*, *g g*, Branches of it to the genitalia and other internal organs. Fig. 5, Cerebrum of *Vespa Germanica*. *a a a*, Nerves to the ocelli. A A, Optic nerves. B B, Nerves of the antennæ, cut off. *c*, Branch to the cerebellum. Fig. 6, Cerebrum and sympathic system of the caterpillar of *Liparis Mori* (Brandt). A A, Nerves of the eyes. B B, Nerves of the antennæ. C C, Hemispheres of the cerebrum. *a a aa*, Nerves which originate from the frontal ganglion and its branches. *b* b**, First ganglion of the œsophagus. *b** b***, Second ganglion of the œsophagus. *f*, Nervus sympathicus. *d*, Its first ganglion. *e*, Its second ganglion. Fig. 7, The same in the developed moth, similarly marked. Fig. 8, The same of *Meloë proscarabeus* (Brandt), similarly marked.

THE END.

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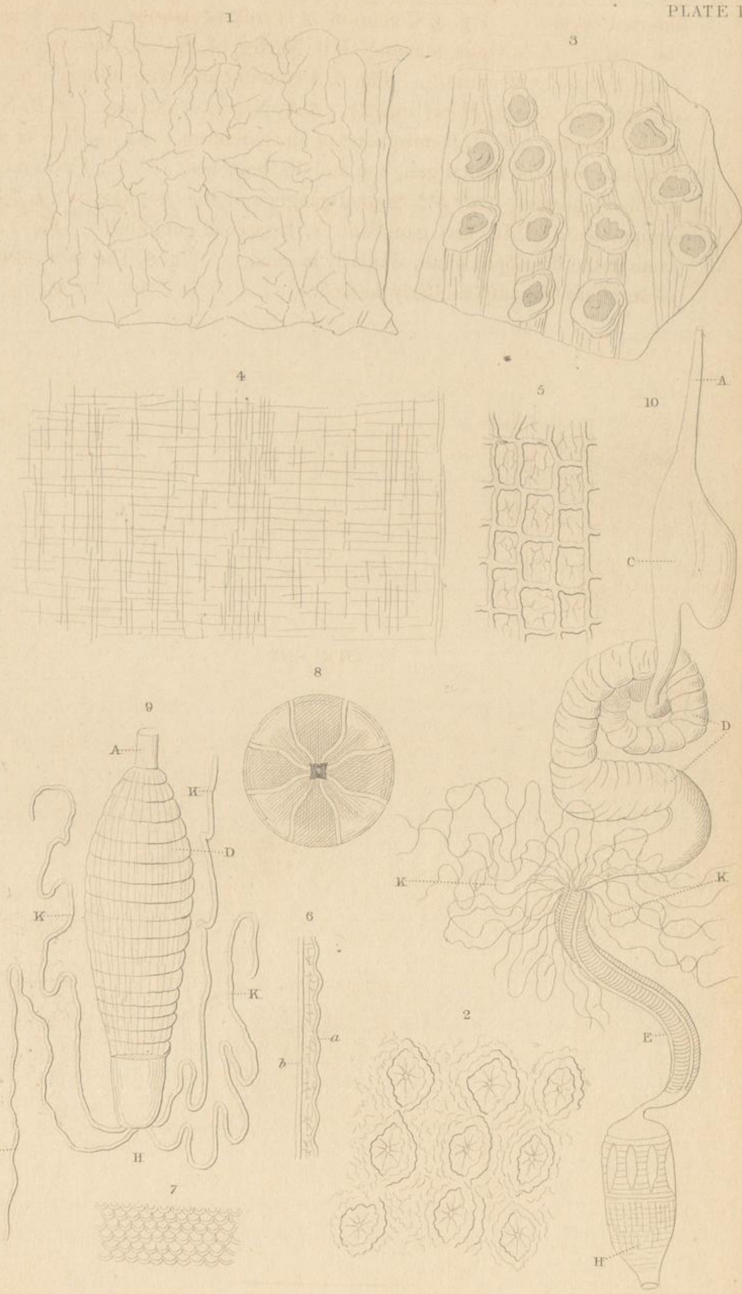
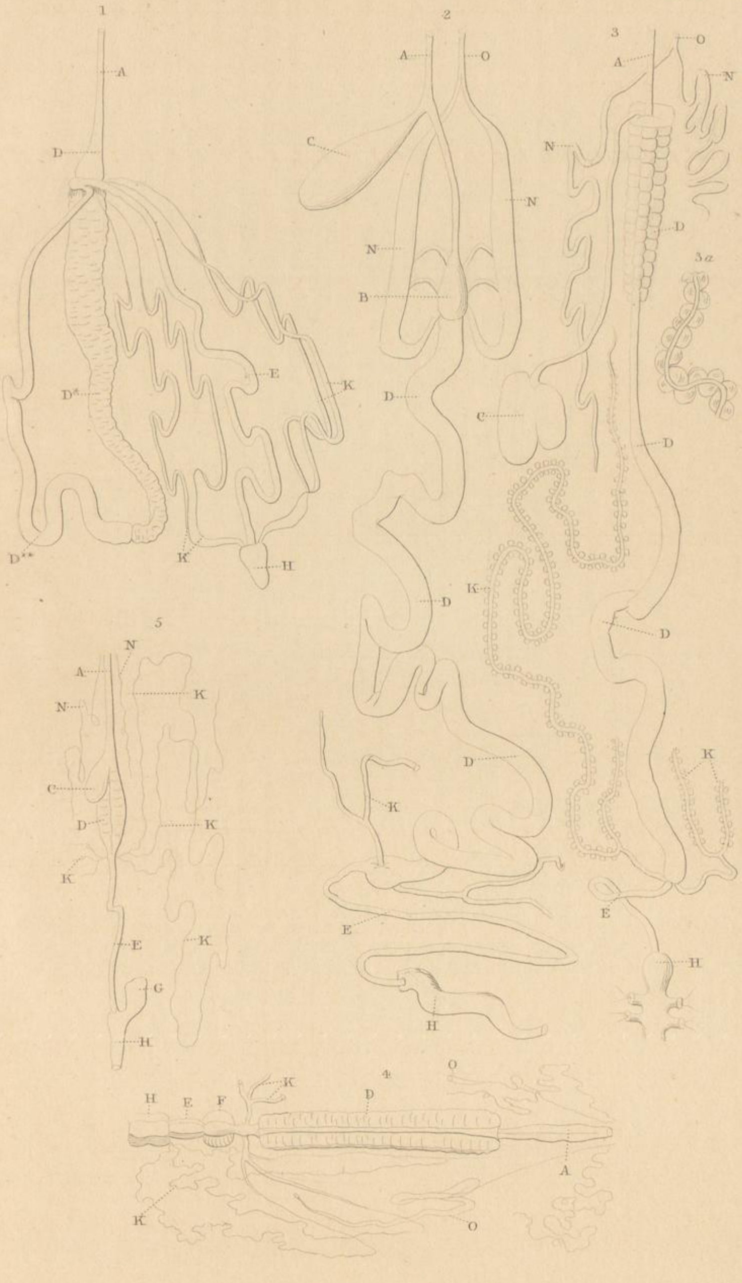
PLATE 17.

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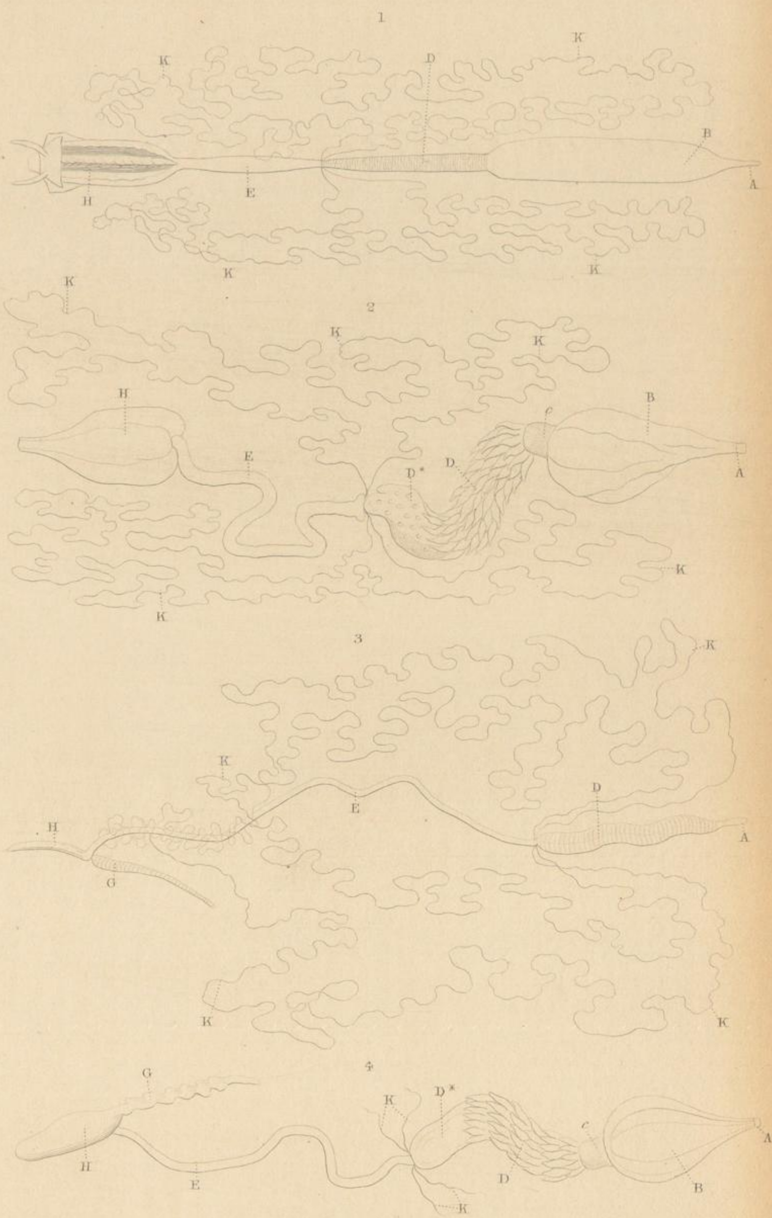
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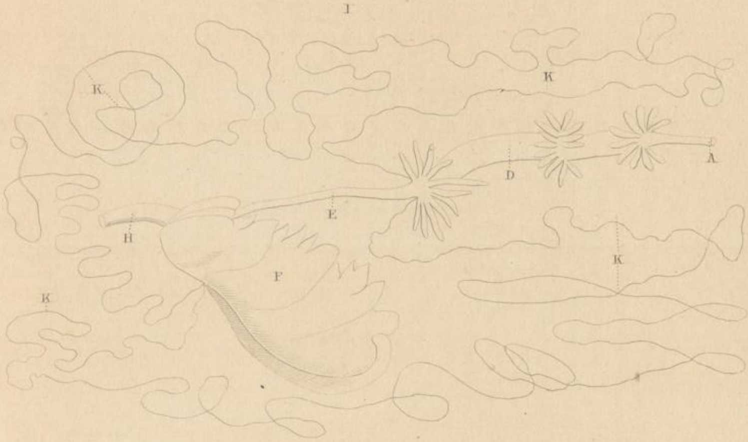

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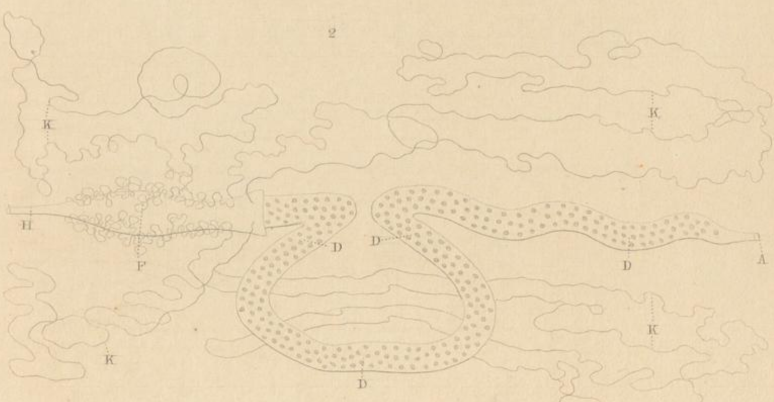

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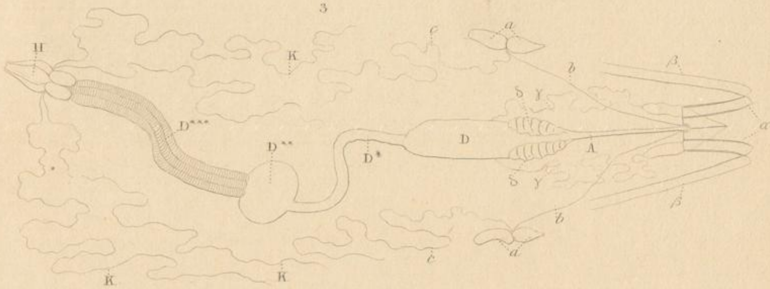

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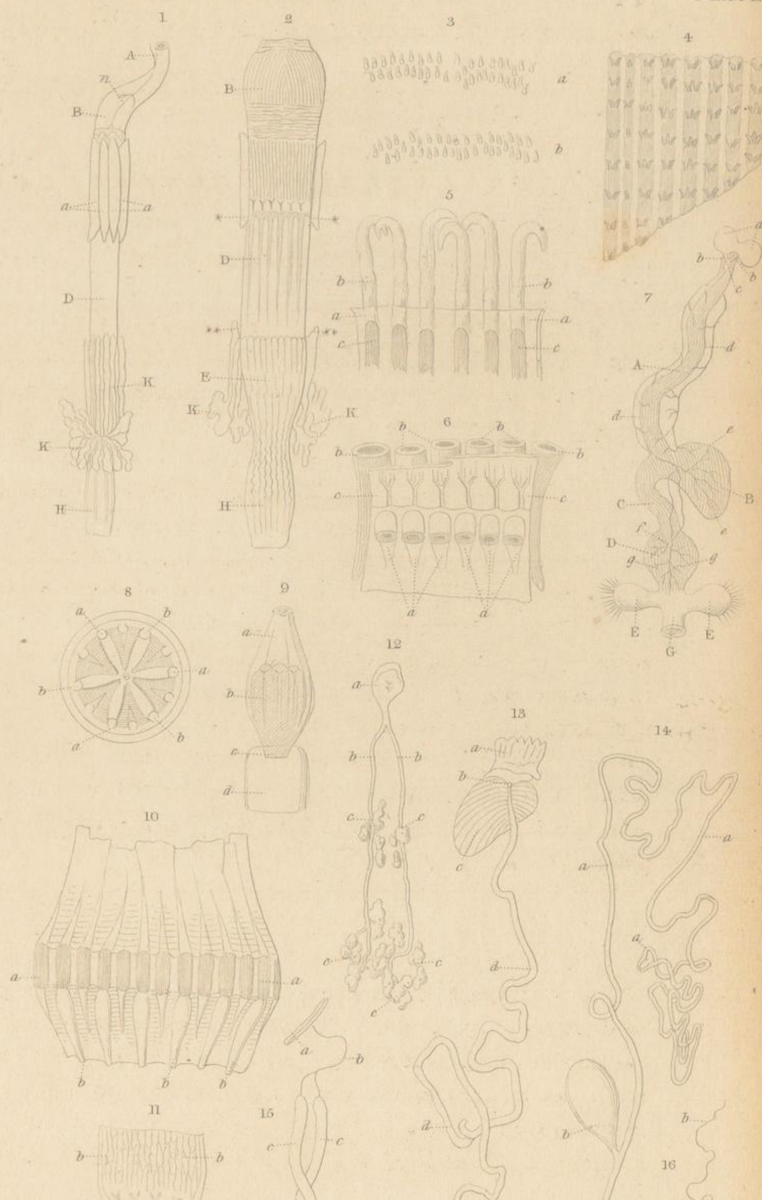

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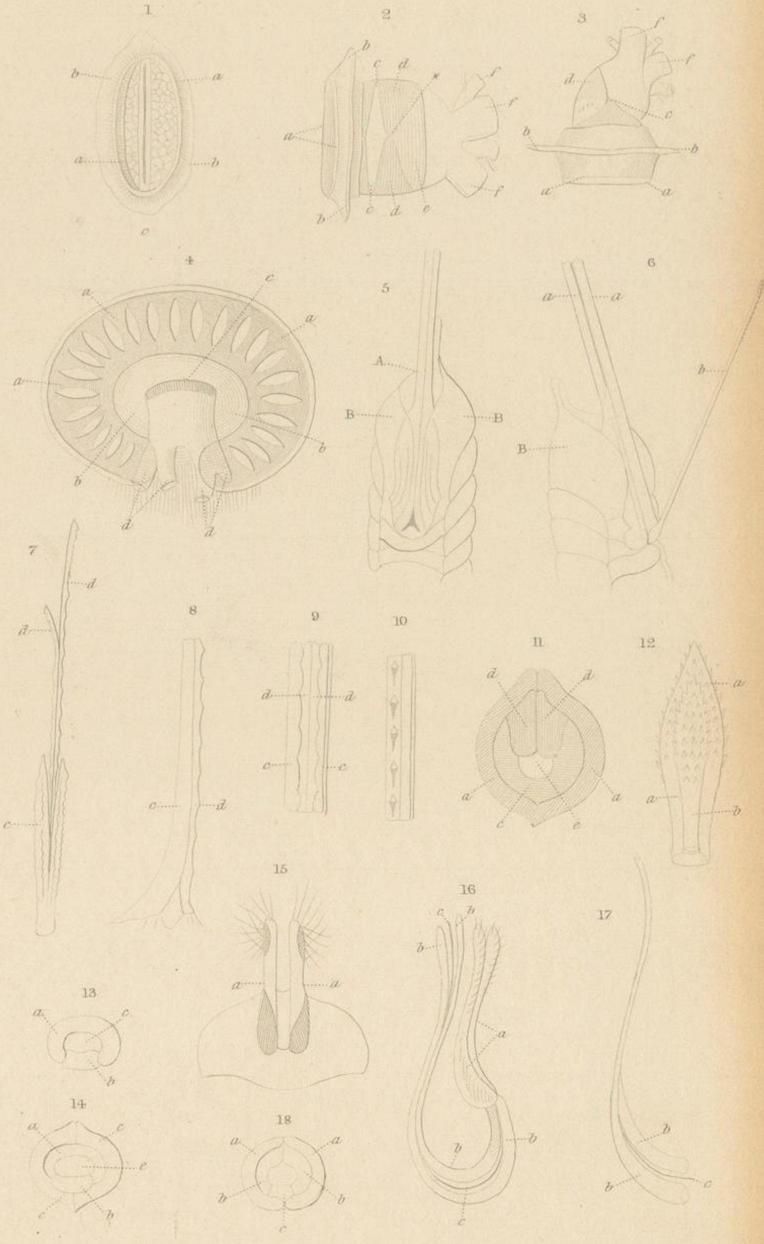

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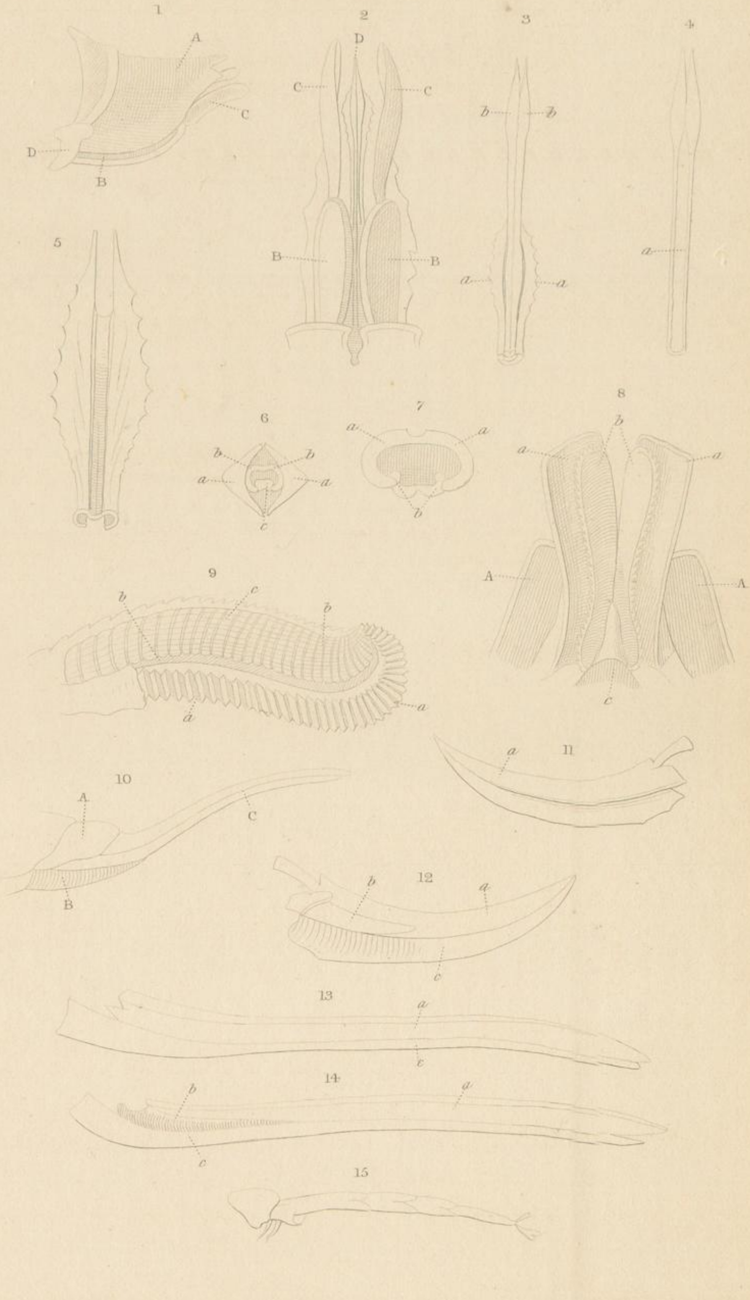
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PLATE 25.

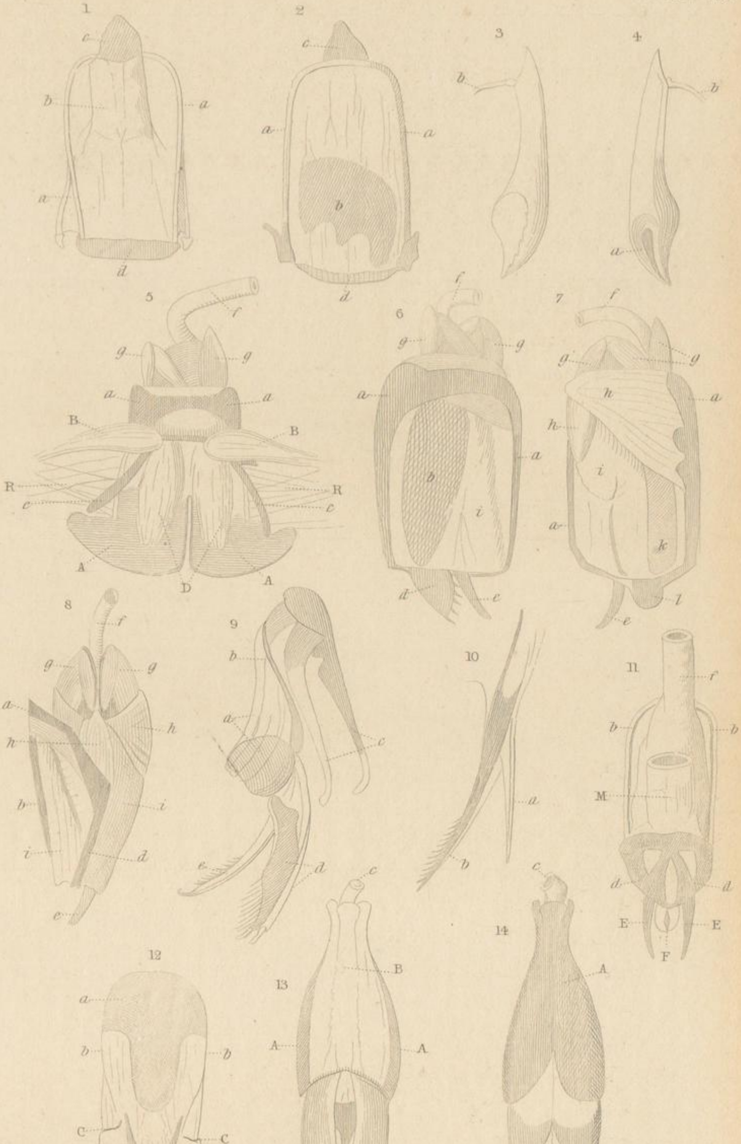

PLATE 26.

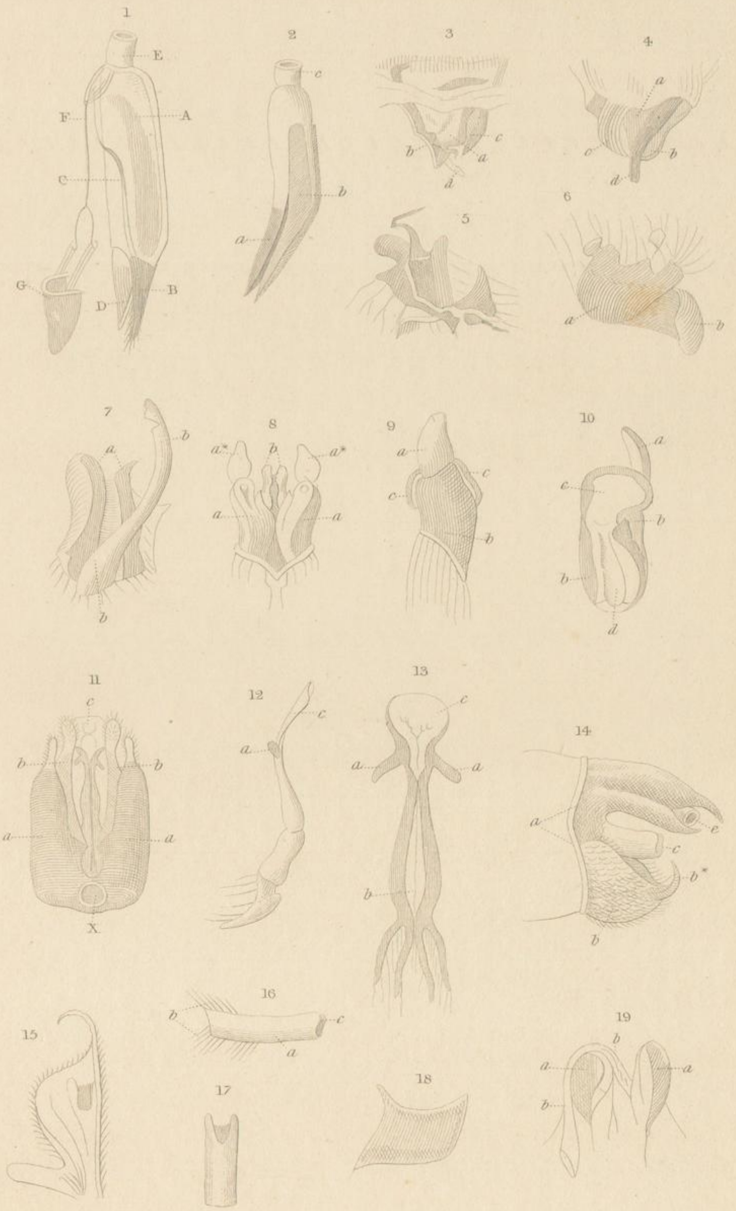
1 E F A C G D B
2 c b a
3 c b a d
4 a c b d
5
6 a b
7 a b b
8 a* b a* a a
9 a c c b
10 a c b b d
11 c b b a a X
12 c a
13 c a a b
14 a e c b* b
15
16 b c a
17
18
19 b a a b

PLATE 27.

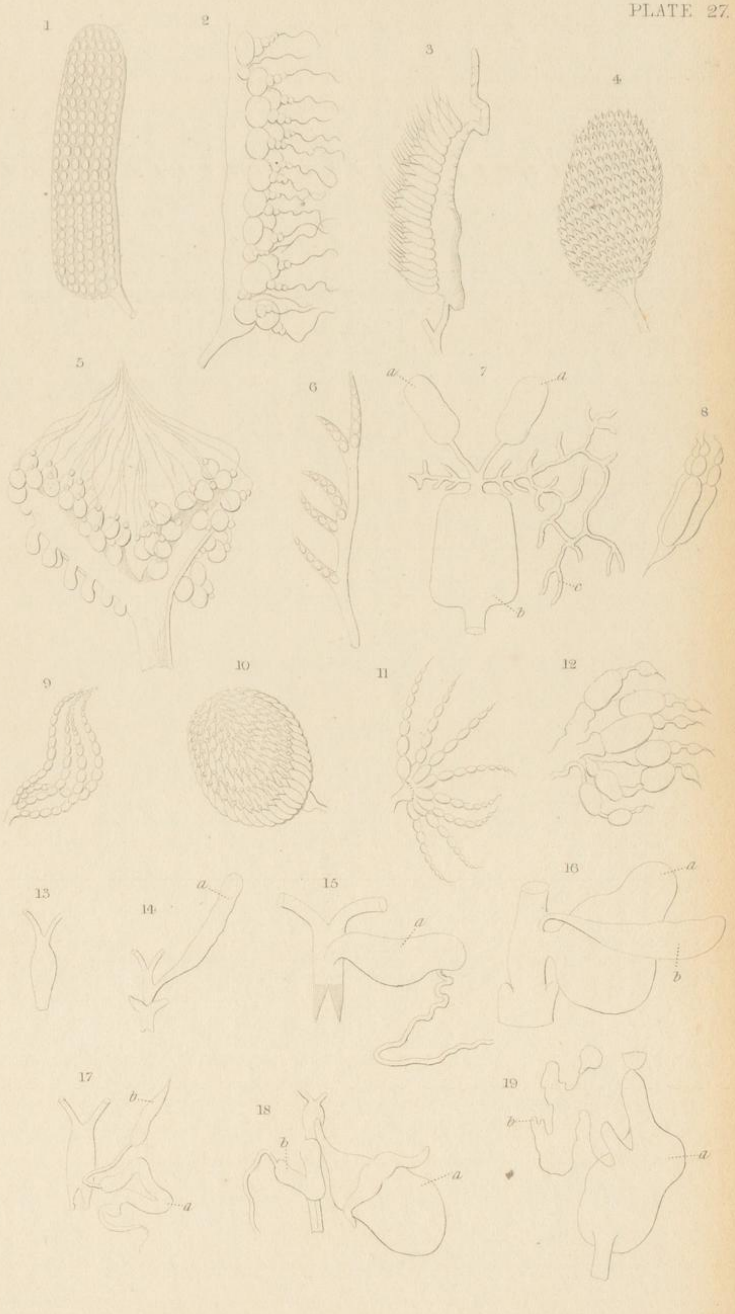

PLATE 28

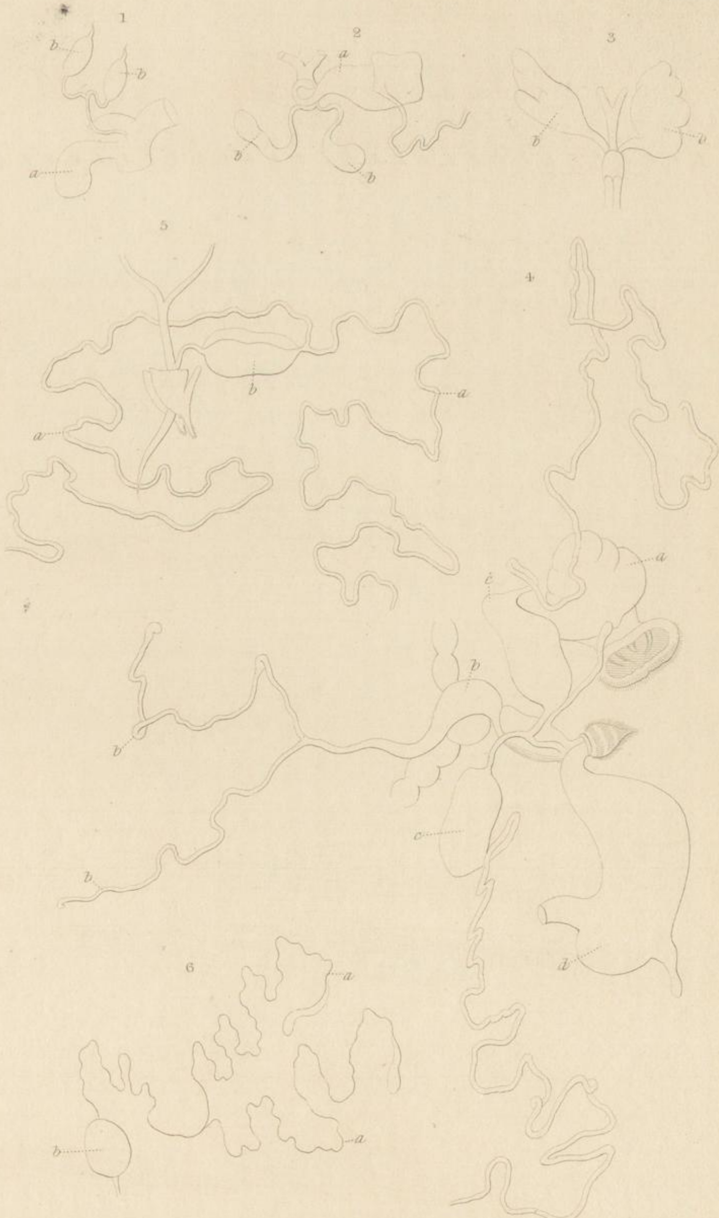

PLATE 29.

PLATE 30.

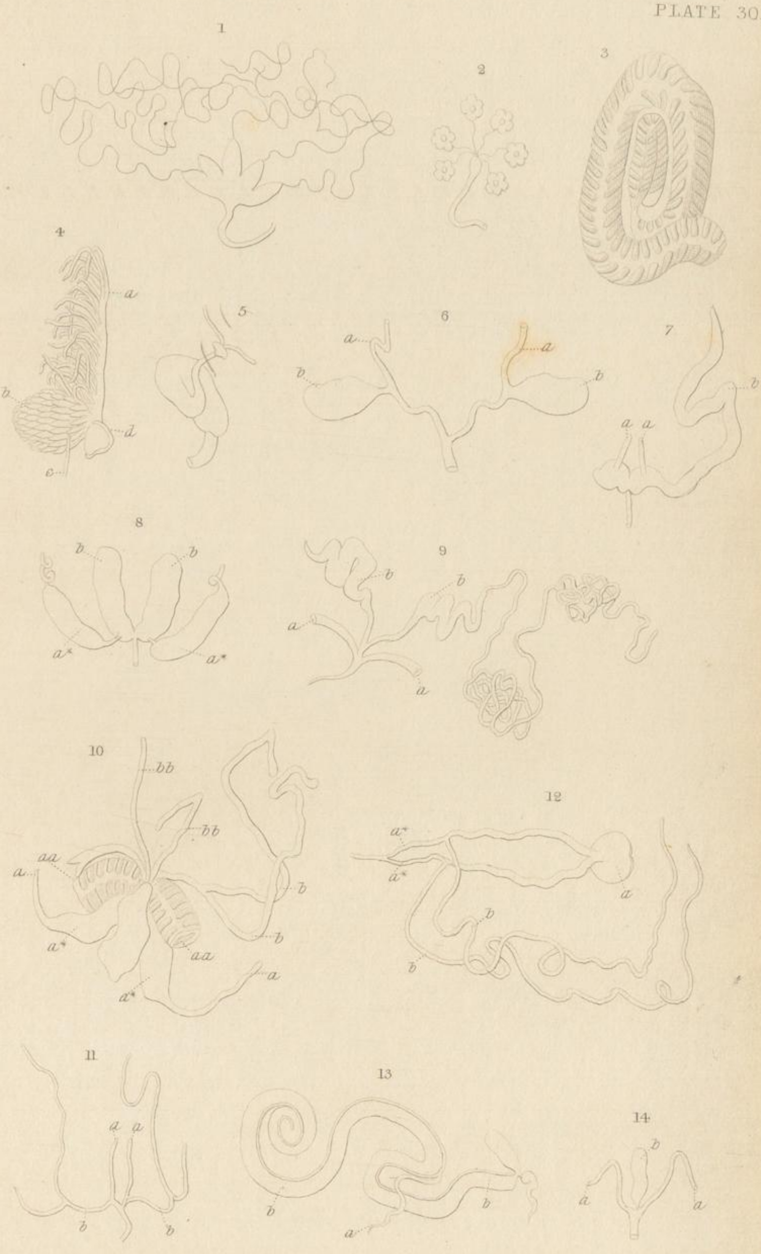

PLATE 31.

PLATE 32.