

II. *On the Distribution of the Tracheæ in Insects.*By JOHN LUBBOCK, *Esq., F.R.S., F.L.S., &c.*

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DEAN SWIFT, in the ‘Tale of a Tub,’ asserts that in the world generally, and in animals in particular, the outside is generally more beautiful than the inside. “Last week,” he says, “I saw a woman flayed; and you will hardly believe how much it altered her person for the worse.” The Dean, however, does Nature an injustice. We constantly find the most lovely things where we should least expect to meet with them. Many insects are very beautiful externally; but there is nothing, I think, more pleasing to the eye than some parts of their internal anatomy; and no one, I am sure, can see the tracheæ branching over the different organs, like trees of shining quicksilver, without being both astonished and gratified.

Although Lyonet, Straus-Dürkheim, and many other entomologists have described and figured the arrangement of the larger tracheal branches, no one has yet studied the distribution of the finer branchlets. This is, no doubt, mainly owing to the fact that, more or less quickly after death, fluid penetrates into them, and that they then become very difficult to distinguish from the surrounding tissues. It is indeed true that there are a few scattered observations on this subject; but no one has yet compared together the finer tracheæ attached to the different organs of various insects, or attempted to arrive at the laws regulating their distribution,—to determine, for instance, whether the type is the same throughout each insect, or different in the various organs, and to compare with one another insects of various families and orders.

I ought perhaps to apologise for presenting to the Linnean Society a memoir so imperfect; but if the marvellous number of insects be remembered, and if it be borne in mind that each one contains at least from fifteen to twenty different organs to be examined separately, it will be evident that no one man could hope to exhaust the subject.

Having, therefore, to deal with a subject so vast in itself, I have confined myself strictly to it. Without intending to express any opinion of my own as to their homologies and functions, I allude to the various organs by the names under which they generally pass, even when the generally received opinion seems to me doubtful or incorrect.

I wish, however, to say a few words respecting the homologies of the intestine of *Pentatoma*. It seems to be pretty generally admitted that in this group of Hemiptera, the biliary vessels, either directly or through the “vésicule biliaire” of Léon Dufour, pour their contents into the rectum, below the ileum. Léon Dufour*, indeed, while

* *Mém. des Savants Etrangers*, vol. iv. p. 153.

admitting that this is apparently the case, seems to think that it must be an illusion, and that there cannot really be any such communication.

There is however, I believe, no other group of insects known in which the biliary vessels open elsewhere than at the anterior end of the ileum (excepting perhaps the Homoptera); and we find in certain Hemiptera that the posterior part of the stomach is much elongated, and that the Malpighian vessels open at the end of it. I am therefore inclined to believe that in *Pentatoma*, *Scutellera*, &c., the so-called "cordons valvulaires" represent the posterior part of the stomach, and that if the chamber into which the Malpighian vessels fall is really the "colon," we may infer that the ileum is not developed.

In examining any given organ or membrane, it is of course necessary to have before one a surface sufficiently large to give a good idea of the type of distribution, in order to feel sure that the arrangement of the tracheæ which is seen is really characteristic of the organ. I have therefore chosen the largest insects I could obtain, because in them we see the same type of distribution repeated over and over again in the field of view; and I have also compared different specimens together.

The mode of branching is in many respects comparable to that of trees. As we find, for instance, no two oaks exactly alike in their mode of branching, while yet the species possesses a well-marked type of its own, so in the tracheæ, though no two branchlets divide in exactly the same manner, still they possess a well-marked character. And though in numerous insects many organs are alike in this respect, there are others in which any fragment of an organ could at once be recognized if it were large enough to show the mode of branching of the tracheæ.

In the different species of one genus we generally find the tracheæ very similar. In comparing together, however, insects belonging to different families of the same order, this is by no means the case. In the ovarian tracheæ, for instance, *Musca* (Pl. III. fig. 2) much resembles *Bombus*; while *Tipula* (Pl. III. figs. 4 & 5) and *Tenthredo* are quite different from either, but resemble one another. A third genus of Hymenoptera, *Ophion* (Pl. III. fig. 7), again, is dissimilar from either *Bombus* or *Tenthredo*, and agrees very nearly with *Acheta* (Pl. III. fig. 12), which, for its part, differs entirely from *Locusta*. It would seem, therefore, that the distribution of the finer tracheæ cannot have any bearing on the question of ordinal, or even of family affinities.

In some cases tracheæ, which at first sight are very dissimilar, present in reality no difference. Thus, in Pl. III, the figures 4 & 5 represent the tracheæ on the ovary of *Tipula*: in fig. 5, the tracheæ are represented as they appear when expanded by the egg; while on the parts of the tube which lie between the eggs, and are much narrower, they resemble fig. 4. It may probably be stated, as a general rule, that the waved course of many tracheæ is a provision to allow for the expansion and movements of the organ to which they are attached.

There seems to be some special tendency in the ovarian tracheæ to arrange themselves in tufts, perhaps because in this way they are better able to adapt themselves to the alterations which occur in the diameter of the egg-tubes during the rapid growth and passage of the eggs. In *Necrophorus*, *Locusta*, *Chrysopa*, *Tipula*, &c., the ovaries present more decided tufts of tubules than most of the other organs; and in *Musca* and

Bombus, where tufts are present in most of the organs, the tubules are particularly numerous on the ovary. On the other hand, this rule is not without numerous exceptions—as, for instance, *Ophion* (Pl. III. fig. 7), *Acheta* (Pl. III. fig. 12), *Aphrophora* (Pl. III. fig. 1); and it would perhaps not be safe to generalize on the subject.

In every insect which I have examined, the ganglia were well supplied with tracheæ, and the type was very uniform, showing, I think, that the minute structure of these organs is very similar, not only in different parts of the nervous column, but also in different insects.

As regards the commissures, the case is quite the reverse: not only does the distribution of the tracheæ differ much in different groups, but in some, as, for instance, in the Neuroptera and Lepidoptera, they are, at least in the perfect insects, almost entirely absent. This difference probably arises from the difference in the respective properties and functions of the ganglia and commissures. It is an interesting fact, that while in butterflies and moths I have generally found the commissures free from tracheæ, in the larvæ they are richly supplied. Is this to be accounted for by supposing that the relative functions and structures of the different parts belonging to the nervous system are not so completely differentiated in the larva as they afterwards become in the perfect insect?

The presence of tracheæ on the commissures is not, however, always a sign of low development, since they are present in many Coleoptera.

Both the larva and perfect insect of *Acheta* have tracheæ on the thoracic, but hardly any on the abdominal commissures. The presence of a few tracheæ cannot, however, be of any great functional importance, since in insects with double commissures I have more than once seen instances in which one only was so provided.

Dr. Williams*, in a paper on the respiration of insects, enunciates very confidently the following propositions, which he considers to be true without any exception, and which he has since reiterated†:—

1st. That the larger tracheæ never anastomose; that “in the *spiral* tracheæ no plexiform union of the branches ever anywhere occurs.”

2ndly. “That the ‘spiralled’ or larger tracheæ are mere conduits, like arteries or veins, and have nothing to do with, take no part in, the ultimate act of respiration.”

3rdly. “That the peripheric or extreme distribution of the tracheal system is conformable in plan to that of a blood-vascular system; that is, the capillary or membranous tracheæ are always placed intermediately between larger trunks, the branches of which they serve to connect,—standing to the larger trunks in the same relation as the capillaries of a blood-vascular system do to arteries and veins.”

4thly. “That the tracheæ can be discovered in no single instance to end in cæcal terminations—always in mutual inosculations.”

I might have passed over the first assertion as a mere momentary slip of the memory if it were not repeated more than once in 1854, and again reaffirmed in 1856. Several of the figures given by Straus-Dürckheim, Léon Dufour, and other writers, show inosculations of the tracheæ; and there is hardly a single insect in which they do not

* Annals and Mag. of Nat. Hist. 1854, vol. xiii. p. 194.

† Ib. 1856, vol. xvii. p. 347.

occur in certain organs. It will be sufficient here to mention the dorsal tracheæ in certain Coleopterous larvæ; the ganglia, anterior part of the stomach, oviduct, and heart of *Bombus*; the crop and ganglia of *Carabus*; the cæca and stomach of *Acheta*; the stomach of *Tenthredo*, *Athalia*, and *Libellula*.

These instances, and many others which might be given, show that inosculations of the larger tracheæ, so far from never occurring, are, on the contrary, by no means uncommon.

The second principle enunciated by Dr. Williams, viz. that the spiral tracheæ are mere conduit pipes and have nothing to do with the act of respiration, is less easily disproved, though I believe quite as erroneous as the preceding. Of course I do not mean to deny that the absorption of air is probably more rapid at the thin ends of the tracheæ, where the spiral is absent or rudimentary and the tracheal walls thinner. Still upon this Dr. Williams probably relies, since he scarcely gives any reason for the statement.

On the ovary of *Aphrophora* a few large tracheæ are given to the posterior end, and there divide into about 200 branches. These branches (Pl. III. fig. 1) run the whole length of the egg-tubes, a distance of $\frac{1}{10}$ th of an inch, without giving off a single branchlet. They are $\frac{1}{8000}$ th of an inch in diameter at the base, and gradually taper until they become excessively fine. At the base the spiral filament is very distinct; gradually it becomes less and less so, but it does not cease suddenly, and it can be traced for a considerable distance up the branch. If, therefore, Dr. Williams's view were correct, no respiration could take place in the ovary, except at its anterior end.

Moreover, while I readily admit that in all probability very little respiration can take place through the spiral filament itself, still it must be remembered that the coils of the spiral leave between them a considerable space, which is occupied by a delicate membrane. Why Dr. Williams should suppose that no interchange of gases can take place through this membrane, I know not; and until some reason is given, I shall think myself justified in concluding that the spiralled tracheæ are not mere conduit pipes, and that, although respiration may proceed more rapidly at the fine extremities of the branchlets, still it is not confined to these parts, but is carried on also in the larger vessels. It is true (as Dr. Williams was, I believe, the first to observe) that in some cases the spiral rib ends suddenly; this is generally the case where a trachea gives off at one point several small tubules, as for instance in Pl. I. fig. 8; but the sudden change does not occur in all insects, which led me for some time to think that there must be some error in Dr. Williams's observations.

We now come to Dr. Williams's third proposition, that the capillary or membranous tracheæ are always placed intermediately between larger trunks, standing to them in the same relation as the capillaries of a blood-vascular system do to arteries and veins.

I must confess that I am unable in any way to confirm this statement. I have never seen the minute tubules gradually collect into efferent branches, nor have I been able to find any evidence that there are two sorts of large branches—one afferent, and the other efferent—as there ought to be according to Dr. Williams's hypothesis. In the blood-vascular system we have arteries, capillaries, and veins; in the aeriferous system of insects we have only air-tubes, becoming, as a general rule, gradually smaller and smaller as they proceed further from their origin.

In most cases also, each trachea supplies a definite area, which receives no branchlets

from any other source; and it seems evident therefore that in these cases the air must pass to and fro in the same channel.

Dr. Williams's fourth assertion seems to me as little tenable as any of the three preceding. I do not, of course, deny that in some organs the tubules may inosculate, or, in other words, that the tracheæ may end in loops; but certainly this does not seem to me to be universally or even generally the case. Referring again to the tracheæ belonging to the ovary of *Aphrophora*, we see that each branch tapers from $\frac{1}{60000}$ th down to $\frac{1}{200000}$ th of an inch without giving off a single branchlet. Does, then, the fine end run into the similar termination of some similar branch, and thus form an elongated ellipse? if so, we should have expected to find the calibre nearly equal throughout; but the ends were so excessively delicate that any such inosculation could be of little importance.

A glance at the tracheæ of the Malpighian vessels in *Æschna* seems to me to be almost equally conclusive, as the tracheæ there run nearly half an inch, becoming very fine, and yet sometimes only give out a single branchlet. I readily admit that these long blind tubes seem at first sight but little fitted to ensure a constant supply of fresh air to the organs along their whole course: on the other hand, it must be remembered that the interchange of gases is very rapid; and as we do not find among the larger tracheæ any separate afferent and efferent branches, we ought not hastily to conclude that they must certainly exist among the branchlets.

It occurred to me, in reflecting upon this subject, that the removal of the carbonic acid from the tracheæ, and the continual supply of oxygen, were probably effected in consequence of the diffusion of gases. Prof. Huxley also suggested to me that in fact the same is the case in man and the higher animals generally. Upon mentioning this to Prof. Graham, he referred me to his paper in the 'Philosophical Magazine' for 1833, where he has expressed the very same opinion.

As his suggestions appear to have been almost, if not altogether, overlooked by physiologists, I may perhaps be permitted to quote a few of his remarks. He says, "I may be allowed to mention an application of the law of diffusion in explanation of the mechanism of respiration. The cavity into which air enters during respiration consists, first, of a large tube, the windpipe; secondly, of smaller tubes, into which the windpipe diverges; and thirdly, of a series of still smaller tubes, diverging from the last, themselves ramifying to an indeterminate extent, till at last the tubes cease to be of sensible magnitude, but are believed to terminate in shut sacs. The capacity of the whole cavity cannot easily be determined; but we may estimate it at 300 cubic inches. In a natural expiration, about 20 cubic inches or $\frac{1}{15}$ th of the contents are thrown out, from the application of a general pressure to the whole; but it is evident that these 20 cubic inches will be the 20 cubic inches nearest the outlet, or the contents of the larger tubes. The contents of the second-sized tubes will advance at the same time into the largest tubes, but no further, and will recede again into their original depositories on the next inspiration, which will fill the larger tubes with fresh air, which identical quantity will again be expelled in the next expiration.

"This illustration is perhaps too strongly stated; but it is evident, that, in ordinary respiration, the slight mechanical compression will have little or no effect in emptying

the most distant tubes, or the ultimate air-cells, of their contents. The bulk of the air, also, is not altered during respiration, although, for a quantity of oxygen, carbonic acid gas is substituted. This substitution, which is the great end of respiration, undoubtedly takes place most abundantly in the minute and distant air-cells, which present the largest surface to the blood; and the carbonic acid there produced must be moved along the smaller tubes by the diffusion-process (which we know to be extremely energetic and also inevitable), till it is thrown into the larger tubes, from which it can be expelled by the ordinary action of respiration. But the action of diffusion is always twofold: at the same time that carbonic acid is being carried outward from the air-cells, oxygen is carried inward in exchange; and thus the necessary circulation is kept up throughout the whole lungs.

“There can be no doubt that much of this quantity occupies constantly and permanently the most minute tubes and air-cells; for it can scarcely be withdrawn by means of the air pump. Now the question has arisen, how these ultimate tubes and air-cells are so powerfully inflated; for they are not distended by the action of muscular fibre, of which they are known to be destitute. This state of distension must be highly useful by exposing surface; and the law of diffusion enables us to account for it. The heavy carbonic acid which these minute cells may contain, is not merely exchanged for oxygen, but for a larger volume of oxygen, in the proportion of the diffusion-volumes of carbonic acid and oxygen; namely, 81 carbonic acid are replaced by 95 oxygen. The resistance to passage through the most minute tubes is overcome by the diffusion-action, as in the case of the pores of the stucco plug; and there follows a tendency to accumulation on the side originally occupied by the carbonic acid. This accumulation is limited by the increased facility with which the air-vessels can empty themselves mechanically of a portion of their contents, from their distended state.

“In the law of diffusion of gases, we have, therefore, a singular provision for the full and permanent inflation of the ultimate air-cells of the lungs. But it is in the respiration of insects that the operation of this law will be most distinctly perceived. The minute air-tubes accompanying the blood-vessels to every organ, and like them ramifying till they cease to be visible under the most powerful microscope, are kept distended during the most lively movements of the little animals, and the necessary gaseous circulation maintained wholly, we may presume, by the agency of diffusion.”

Certainly, however, in many insects the respiratory movements are as well-marked as in any of the higher animals; and even in Caterpillars and other insects* where they are absent, still the interchange of gases must be assisted by the ordinary movements of the body. Yet Prof. Graham is, no doubt, quite correct in denying the existence of any actual current of air in the smaller tracheæ; and that under these circumstances the supply of oxygen should be sufficient shows well how rapidly and forcibly the diffusion of gases takes place†; but I am still doubtful whether the superior quantity of oxygen

* *Ranatra* has no respiratory movements. In this genus, according to Newport, the whole respiration is effected through the caudal tube. It has, however, three pairs of spiracles on the under side of the abdomen; and each spiracle receives a moderate-sized trachea.

† The membrane of the spiracle well represents the plaster plug used by Prof. Graham in his experiments.

which enters, over the carbonic acid which escapes, is in all cases so necessary to expand the tracheæ as Dr. Graham suggests, because I have found the small branchlets in a larva of *Musca* still full of air after it had been drowned by immersion for some hours in water.

On putting some larvæ of *Melolontha* into water, I was surprised to see a considerable formation of bubbles on the skin, especially at a point below each spiracle, while no bubble ever appeared from the spiracles themselves. If, however, the water is first boiled, then no bubbles are produced, and the larvæ very soon, say in about a quarter of an hour, become motionless, though, if pricked, they still contract a little. Their flesh is then quite soft and flabby, while generally it is tolerably firm to the touch. I expected to have found the tracheæ free from air, or nearly so; but this was not the case. Like other insects, these larvæ readily recover from their suffocation when they are taken out of the water.

The larvæ of flies are also naked fleshy grubs; and I expected them to behave in a similar manner; this, however, is by no means the case. They live much longer in water. When they are placed in it, no bubbles form on their skin; nor does it seem to make any difference to them whether the water is boiled or not: I put four into some boiled water, and the same number into water which had not been boiled; and at the end of forty-four hours they still moved a little, gently turning their heads from one side to the other. These facts seem to me to prove that the larvæ of *Melolontha* breathe partly by means of their skin, and that those of *Musca* do not.

Yet these opposite states of the skin may be necessary for these larvæ, living as they do under such different circumstances*.

This result was quite unexpected by me; yet it throws much light on the intermediate stages which, upon the principle of natural selection, must have existed between ordinary larvæ, respiring principally through spiracles, and those which, like the larvæ of *Botys*, of Dragonflies, Ephemeræ, &c., breathe by means of foliaceous expansions of the skin.

In most insects the air will be found, after death, filling the fine ends of the tracheæ. In some cases, however, as in many parts of *Carabus*, *Melolontha*, *Acheta*, *Hipparchia*, &c., the smaller branchlets are generally, even very soon after death, filled with fluid, and can therefore scarcely be distinguished, or they even become quite invisible. This happens very frequently in Lepidoptera, Coleoptera, and Orthoptera; but I have not noticed it so often in Hymenoptera, Diptera, or Neuroptera. It is not, however, constant in the first three orders; and in *Necrophorus*, for example, the very fine tubules may be beautifully seen. The larvæ, at least of Coleoptera and Lepidoptera, do not in this respect resemble the perfect insect; but in *Acheta* all the three forms are alike.

* M. Lyonet, writing before the observations of Dr. Graham had thrown so much light upon the subject, and misled principally by the absence of special respiratory movements in many insects, doubted whether the tracheæ were organs of respiration, and suggested that one at least of their uses might be "de concourir avec les nerfs, à la contraction des muscles, pour opérer les mouvements," though I confess that I do not quite understand in what way the tracheæ were to cooperate with the nerves. In support of this view, he mentions that if the spiracles are closed by oil, or if the insect is kept under water, after a while it loses all power of movement. This experiment, however, hardly justifies the conclusion which M. Lyonet deduces from it; and it seems to me that the larvæ lose their power of movement in the same way as M. Lyonet himself would, had he been treated in a similar manner.

It might at first be supposed that the points at which the air ceases are really the ends of the tracheæ, and that where they can be traced further they are merely solid threads. In some cases, however, the air disappears slowly from the fine tubules; and a case of this is represented in Pl. III. fig. 8. Fig. 8 represents a small tracheal branchlet ramifying over two egg-tubes of *Hipparchia Janira*, examined as soon as possible (perhaps a quarter of an hour) after the death of the insect. Fifteen minutes later, the air had disappeared from the fine ends, and no more could be seen than is represented in figs. 8' & 8''. In another quarter of an hour, still more of the tracheæ had disappeared, and only the stump as it were, F, remained. In this instance all the other tracheæ on the organ ended in the same abrupt manner; but it is evident, from the preceding and many other similar observations, that the apparent ends are by no means the real terminations of the tracheæ.

This absorption or repulsion of the air from the finer tubules depends evidently, in a great measure, on the nature of the wall of the tracheæ and of the surrounding tissue, because it proceeds with different rapidity in different parts of the same insect, so that while, for instance, in *Carabus* I never found air in the finer tubules on the Malpighian vessels, on the ovaries the air may be seen for a short time after death; and in the ganglion, even after some hours, all the fine tubules still contain air.

I am unable to offer any decided opinion whether this disappearance of the air from the finer tubules is owing to its absorption by the tissues, or whether the surrounding fluid forces its way through the delicate membrane of the tracheæ. Probably, however, the latter is the case; because, if the air were simply absorbed by the surrounding tissue, a fresh quantity would, I suppose, continually be supplied by the larger tracheæ.

Moreover I never found that the manner of death made much difference in the condition of the tracheæ, whereas, if the disappearance of the air were caused by vital action of the surrounding tissue, this would hardly have been the case.

It is difficult, however, to understand why the small tracheæ fill themselves with fluid so much quicker in some insects, and in some organs, than in others. Probably, however, this is owing to some differences in the tracheal wall, which, though always permitting the absorption of air by the tissues, may be more easily permeable by fluid in some parts than in others.

The surrounding fluid must probably have the same tendency to expel the air from the finer branchlets during life as after death; so that, whilst the insect remains alive, some counteracting agency must be at work. In those insects which show no respiratory movements, Prof. Graham's suggestion, above alluded to, seems to offer the best explanation.

I have not yet paid much attention to the metamorphoses of the tracheæ during the change from the larva into the imago. The process seems, however, to be very curious; and I hope ere long to be able to devote some time to the investigation of it.

In a Lepidopterous pupa, I found, in various parts of the body, knotted spiral tracheæ invested by a common membrane, as figured by Semper*. How these knots are formed I know not.

The structure of the tracheæ has generally been described as consisting of an external

* Zeitschrift für Wiss. Zool. pl. xv. fig. 10.

and an internal membrane, enclosing between them a spiral filament. Marcel de Serres and Straus-Dürckheim deny the existence of the spiral thread in the air-vesicles, which, however, is affirmed by Suckow and Sprengel. The truth seems to be that it is certainly present in some cases, while in others it is either imperfectly developed or altogether absent. In some instances the chitinous thickening has a zigzag appearance, which Leydig also has observed.

Leydig* also appears to me to have given the best description of the structure of the tracheæ. He considers that the outer "peritoneal tunic" is a "connective-tissue, transparent, and generally colourless membrane, formed by the union of the same cells which form the fatty tissue, and with which also they remain in intimate connexion."

This description seems to me quite correct; and any one may test its accuracy by examining the fatty tissue of a caterpillar, where he will see that the external membrane here and there leaves the trachea and encloses around it a considerable space, which is occupied by the fat globules. In other words, the external membrane of the trachea is continuous with that of the fatty tissue; the trachea possesses therefore an external membrane only so long as its course is between the masses of fatty tissue, and loses it as soon as it enters one of the masses.

Burmeister† describes this membrane as structureless; but it undoubtedly consists of a union of cells, whose walls can generally be perceived without much difficulty. The nuclei also are generally visible.

Among the older writers, Sprengel appears to have had the most correct idea of the so-called spiral filament. He considers it merely as a local spiral thickening of the inner membrane,—in which view he has been followed by Burmeister and Leydig. Burmeister, however, like DeGeer, Lyonet, Bonnet, Straus-Dürckheim, Newport, and others, describes a third, inner membrane, which, like Sprengel and Leydig, I have been unable to see.

Pl. II. fig. 13 represents a fragment, which shows clearly the membrane uniting the spires of the "thread." It is, however, possible that the spirally thickened portion of the inner membrane may sometimes detach itself more or less completely from the membrane by which it is formed. Some of those naturalists who have convinced themselves of the presence of an inner membrane lining the spiral thread, appear to have arrived at this conclusion mainly on account of the inner membrane of the tracheæ being shed at each change of skin; the spiral structure, however, is shed at the same time. I have not yet been able to investigate the mode in which this exuviation takes place so carefully as I could wish; but the fact does not justify the conclusion which has been deduced from it. In the cast skin of a larva of *Dasychira pudibunda*, and in a pupa-case of *Deilephila galii*, I convinced myself that the spiral filament is cast at the time of moulting.

Nervous System.—Ganglia.—(Pl. I. figs. 1, 3, 4, 5 & 6.)

Throughout the Insecta the tracheæ of the nervous system and of the muscles vary less than those of almost any other part of the body, from which it may probably be

* Lehb. d. Histologie, p. 386.

† Handbook of Entomology, Shuckard's Transl. p. 171.

inferred that their ultimate structure also varies less than that of other parts. The ganglia are always well and often very richly supplied with tracheæ, differing in this respect from the commissures and nerves, which in many insects (as mentioned below) are entirely free from them. The tubules, excepting sometimes those which are distributed to the surface, are straight or gently curved, but not waved. They generally rise singly from the branchlets, as in Pl. I. fig. 1; but sometimes, even in the same insect, we find tufts, as in Pl. I. fig. 3.

The abdominal ganglia in *Bombus terrestris* and *B. lapidarius*, are covered over with a network of tracheæ. The meshes vary much in size, from $\frac{1}{300}$ inch in length and $\frac{1}{700}$ inch in breadth to less than $\frac{1}{20}$ th of that size. The tracheæ forming the network are of considerable breadth, averaging perhaps $\frac{1}{2500}$ inch. The short commissure between the posterior and penultimate ganglia has as rich a network of air-vessels as the ganglia themselves.

These latter are penetrated by numerous branches which end in tufts (Pl. I. fig. 3) of from five, or even six, down to two or three. The tubules branch two or three times, and resemble a fishing-rod in their general proportions and curvature, running in a gentle sweep often for $\frac{1}{100}$ inch, with a thickness at the base of only $\frac{1}{15000}$ inch.

The ganglionic tracheæ of *Panorpa*, *Libellula*, *Carabus*, and *Aphrophora* are like those of *Bombus*; and so are the tracheal tubules of *Vespa*, *Tenthredo*, *Athalia spinarum*, *Ichneumon* (probably) *extensorius*, *Ophion*, *Chrysopa*, *Tipula*, *Campæa margaritaria*, *Callimorpha jacobææ*, *Pterophorus*, and the larva of *Euplexia lucipara*; but I am not sure whether the branches end in tufts. In none of them is there a network enclosing the ganglia, as in *Bombus*.

In the larva of *Lampyrus*, *Amphimalla*, *Acheta* (both larva and imago), *Locusta*, and *Gryllus*, the tubules are larger and longer, but otherwise very similar. The branches, however, do not end in tufts.

In *Forficula* the tracheæ resemble those of *Acheta*, but are smaller.

In *Necrophorus humator*, *N. vespillo*, *Scarabæus*, and *Musca*, in *Hipparchia Janira*, *Pieris napi*, *Noctua gamma*, the larva of *Lasiocampa rubi*, of *Mamestra brassicæ*, of *Gonepteryx rhamni*; the tracheæ sometimes end like the preceding, and sometimes in tufts, a large branchlet ceasing suddenly and giving off from four to seven or more tubules. These latter divide and re-divide again, sometimes breaking into little secondary tufts.

In the larva of *Musca* the mode of branching is quite unlike that of the imago, being simple and not in tufts.

In *Hydrous piceus* the tracheæ are in tufts; but the tubules rising from them are nearly of uniform size, so that there are no secondary tufts.

In *Eristalis* the tracheæ of the ganglia break into tufts like those prevalent throughout the body. Upon the surface they are waved and resemble those of the commissures; but in the interior of the ganglion they seem to be straighter.

In *Pentatoma* large wide tracheæ go to the ganglia, and give off short thick branches. These again give off still shorter branchlets, which end in tufts consisting each of a few straight tubules (Pl. I. fig. 5).

Interganglionic Commissures. (Pl. I. figs. 2 & 7.)

It might have been expected that the tracheæ on these organs would have resembled those on the ganglia, and at any rate that tracheæ would either have been present or absent in all insects. Both suppositions, however, would have been wrong. The tubules in the ganglia are usually straight, while those on the commissures are generally waved, besides differing in other respects. Again, in *Pentatoma* and all the Lepidopterous larvæ which I have examined, the commissures are very richly supplied; in *Bombus*, the Diptera, and some Coleoptera, they are less numerous; while in some Coleoptera, the Orthoptera, Lepidoptera, and Neuroptera, the tracheæ are either rare or altogether absent. This at least holds good as far as my observations go; but the statement will no doubt be modified by further investigations.

Between two of the thoracic ganglia in the larva of *Acheta* I found one of the commissures pretty well supplied with tracheæ, while the other was quite free from them. Indeed generally throughout insects the tracheæ on the two nervous columns are not arranged in exactly the same manner.

In *Scarabeus*, *Necrophorus vespillo*, and *N. humator*, the tracheæ on the commissures and on many nerves were in tufts resembling those of the ganglion, except that they are altogether smaller, that the tubules branch oftener, and that they are more waved.

In *Cerambyx moschatus* also the commissures were well supplied with tracheæ. In *Hydrophilus piceus* the tracheæ were like those of *Necrophorus*, but in some cases I observed branchlets which did not form tufts. The tubules were numerous and very delicate indeed. In *Musca* and *Eristalis* the tracheæ were in tufts, very much like those on the ganglia, but with straighter tubules. The nerves, however, were almost entirely free from tracheæ. In *Tipula* the tracheæ were numerous. In the larva of *Lucanus* the commissures were well supplied, but in *Carabus*, the larva of *Lampyrus*, and in *Forficula*, both they and the nerves were almost entirely free from tracheæ. In *Acheta*, *Locusta*, and *Gryllus* also, the abdominal commissures had only here and there a single trachea, which seemed as it were to have strayed out of a neighbouring ganglion. In these cases I have not examined a sufficient number of specimens to prove that these single tracheæ are inconstant, but I have little doubt that this is the case. The thoracic commissures of *Acheta*, and also of its larva, were provided with decidedly more numerous tracheæ, which are a little waved and give out single branchlets which again divide once or twice.

In *Noctua* the tracheæ are like those of *Acheta*, but rather more numerous, two or three generally running nearly to the middle of the commissure. They are seldom, if ever, branched, and are almost straight. On those of *Campæa margaritaria*, *Pieris napi*, *Hipparchia janira*, *Callimorpha jacobææ*, and *Pterophorus*, I found no tracheæ. On the contrary, in the larvæ of *Euplexia lucipara* and *Gonepteryx rhamni* they were well supplied; and in the larvæ of *Lasiocampa rubi* and *Mamestra* they were very numerous both on the commissures and nerves. On the commissures of *Bombus muscorum* they are numerous, waved, and generally in tufts consisting of a few branched tubules, sometimes even of only two. On those of *Athalia spinarum*, *Tenthredo*, *Ichneumon* (probably) *extensorius*, and another small black species, I found none. On those of *Ophion* there

were hardly any. The few that I could see were almost straight and branched at intervals. In *Vespa* there was only here and there a little tuft.

On the commissures of *Chrysopa*, *Panorpa*, and *Libellula*, I found no tracheæ, and on those of *Aphrophora* only one here and there. In *Pentatoma juniperina* and *P. baccarum*, on the contrary, both the commissures and the nerves were well supplied with waved tracheæ, whose mode of branching needs no special remark.

On the nerves of Insects generally I found fewer tracheæ than on the commissures, and in most species many even of the larger nerves were without any. Whether this difference in different nerves be constant in each species, I am unable to say.

Œsophagus. (Pl. I. figs. 8 & 14.)

The œsophagus is generally very poorly, if at all, supplied with tracheæ; indeed even when they are present they are attached to the muscular bands with which the organ is provided, rather than to the organ itself.

In *Pentatoma*, *Panorpa*, the larva of *Lampyrus*, *Noctua gamma*, *Limnephilus vitratus*, *Aphrophora spumaria*, *Ichneumon*, *Ophion luteum*, *Vespa communis*, *Tenthredo viridis*, *Gryllus viridissimus*, *Tipula*, and the larva of *Mamestra*, it appeared to have no tracheæ.

In *Musca* there is a ring round the pharynx very richly supplied with tracheæ. On the upper part of the œsophagus the tracheæ are in tufts, with waved or straight tubules; on the posterior half there are a few longitudinal tracheæ; starting from the front end and running backwards, they give off waved, transverse, branchlets at intervals, and belong to the œsophageal muscles rather than to the organ itself.

In *Libellula* the œsophagus is narrow in front and swollen behind. The anterior narrow part has no tracheæ; the posterior portion is supplied as in *Musca*, only that the branches rise behind instead of in front. In *Necrophorus vespillo* the type is almost the same. In *Cerambyx moschatus* the tracheæ had more numerous transverse branchlets, but only their bases were visible. In *Lucanus cervus* and *Amphimalla solstitialis* they were similar, but with fewer branchlets; the ends were invisible. In *Carabus* the tracheæ are as in *Forficula* and *Musca*. In the larva of *Lucanus* the tracheæ resembled those of the rest of the intestinal canal, while the larva of *Lampyrus* seemed to have none. In *Bombus* they are few, waved, and simply branched. In the Orthoptera generally, the œsophagus is much swollen behind.

In *Forficula* the type is the same as in *Musca*, but the lateral branchlets are larger and more branched. In *Acheta domestica* it is accompanied by two enormous tracheæ, which are wide at each end and narrow in the middle. They give off large transverse branches, which are irregularly branched, somewhat like a system of rivers; and the ends are finely and beautifully waved. *Locusta* is also well provided with tracheæ, but the ends had become invisible. In the larva of *Acheta* the mode of termination of the tracheæ, so far as it was seen, resembled that of the imago.

In *Eristalis* the tracheæ are unlike those of *Musca*; most of them are in tufts (Pl. I. fig. 8), but are straighter and more delicate than those on the stomach. Here and there the character of tufts is almost lost, and they branch simply.

Salivary Glands.

In the larva of *Euplexia lucipara* and of one of the *Mamestræ* the salivary glands have few branchlets, which are simple and without numerous tubules. The duct was generally free from tracheæ.

In *Chrysopa* the mode of branching is similar, but the tubules are not quite so long. In *Bombus lucorum* the tracheæ on the thoracic glands were in tufts. In *Pentatoma* the tracheæ are very nearly like those of the stomach, but with perhaps rather fewer tubules. *Eristalis* has four salivary glands; two are cylindrical with circular bosses, the other two resemble in shape the ordinary long salivary glands of caterpillars. On all four the tracheæ are in tufts as on the œsophagus, and the tubules are greatly curved, but in each tuft there are very few, and even sometimes the branching scarcely seems to be in tufts at all.

In the larva of *Musca* the branching is simple, and not in tufts. It is much like the figure in Pl. IV. fig. 8.

Cæca. (Pl. I. figs. 10 & 11.)

The cæca of *Acheta* are two thick pulpy organs, one on each side of the stomach. They have some large vascular tracheæ, which divide several times and then run into the corresponding branches on the other side of the organ, as in Pl. I. fig. 10. The branchlets have a very rigid appearance, as they are broad at their origin, and taper very quickly. In the larva the tracheæ are nearly similar, but more elongated.

The character of the tracheæ is nearly the same in *Gryllus* as in *Acheta*, but the inosculations are less conspicuous, and the branchlets are rather more elongated.

In *Chrysopa* the cæcum is cylindrical, but tapering to the free end. It is divided by twelve constrictions into well-marked bosses. Large tracheæ run up the organ from its base and give off transverse branches, one of which is represented in Pl. I. fig. 12. Each boss has also a branch or more, which give off from their outer side long straight tubules (Pl. I. fig. 11). I counted 328 of these long tubules in one half of one boss, so that the total number must be very large; and as each one is about $\frac{1}{70}$ th of an inch in length, the total length of the whole must be considerable.

In the long tubes attached to the front end of the stomach in the larva of *Musca*, the mode of branching is simple, and offers no great peculiarity.

Sucking Stomach. (Pl. I. fig. 9.)

In *Bombus terrestris*, *Vespa vulgaris*, *Ophion*, *Tenthredo luteus*, *Ichneumon*, *Campæa margaritaria*, *Pieris brassicæ*, *Tipula*, and *Noctua gamma*, this organ has no tracheæ.

In *Musca*, on the contrary, it is well supplied with tracheæ in pretty little systems. The tracheæ branch simply, and the tubules have a tendency to run a little way along the parent stem, and then curve out from it in a beautiful manner. In the larva of *Musca* it appeared to be free from tracheæ.

In *Eristalis* it is poorly supplied, but the tracheæ are of the same type as those on the stomach. The duct also is supplied in a similar manner.

Crop. (Pl. I. fig. 13.)

The walls of the crop are generally strengthened by a thick chitinous layer which prevents the fine ends of the tracheæ from being well seen. It is also generally surrounded by muscular tissue. In *Acheta domestica* it is provided with twelve longitudinal tracheæ in six pairs which are joined at the base, and send off transverse branchlets at regular intervals.

In *Carabus* there are about ten longitudinal tracheæ which send out some large branches at acute angles, and many cross-branchlets (Pl. I. fig. 13). At the posterior end the great longitudinal tracheæ are connected by a transverse vessel.

In the larva of *Lampyrus* the tracheæ are as on the stomach.

In *Panorpa* they form a network, as in *Carabus*.

Stomach. (Pl. II. figs. 1 to 10.)

In *Bombus terrestris*, *B. lapidarius*, *B. muscorum*, and *B. hortorum*, the stomach is divided into two parts: along the anterior run several large longitudinal tracheæ which anastomose frequently, while on the posterior portion the tracheæ are mostly transverse. In *B. pratorum* this anterior part is shorter than in *B. terrestris*. The tracheæ give off branchlets which generally end in tufts (Pl. II. fig. 5), but the tubules themselves branch a good deal; so that often the character is almost lost, as in the right-hand tuft in the figure. Pl. II. fig. 11 represents some of the tracheæ of the larva of *B. muscorum*. The branchlets are longer than is the case in the perfect insect, and the tubules are longer, straighter, and fewer,—generally, indeed, only three in a tuft. In *Vespa* the tracheæ resembled those of *Bombus*. Often, however, instead of ending in tufts, the branchlets terminated as in Pl. II. fig. 10, the long tubules running up a muscle. *Ophion* (Pl. II. fig. 3) is characterized by very long branchlets (one-fortieth of an inch in length, without a division), which at last break up more or less dichotomously into numerous tubules. In *Tenthredo*, a genus belonging to the Ichneumonidæ, the type was much like that of *Ophion*, but altogether much smaller. The same is the case with *Cynips lignicola*. In *Athalia spinarum* and *Tenthredo*, as in *Bombus* and *Vespa*, the tracheæ anastomose frequently on the front part of the organ.

In *Ichneumon* the tubules are straight, or but little waved, long, few, and more or less at right angles with the branches from which they spring.

In the Cricket the stomach is divided into two distinct parts. The walls of the first (*f* of Léon Dufour's fig. 19*) seem to consist of large cells, round which the tracheæ run. They (Pl. II. fig. 9) are short and broad, and anastomose frequently.

On the posterior part (*h* of Léon Dufour's figure) are numerous dark glandular bodies. A great ribbon-like trachea runs along the organ and gives off transverse branches. On one side these branches much resemble trees (Pl. II. fig. 4), and the glandular bodies look like some enormous kind of fruit. On the other side of the main trachea, the mode of branching is similar, but the branches are more elongated.

* "Recherches Anat. et Phys. sur les *Orthoptères*, les *Hyménoptères*, et les *Névroptères*," 'Mém. d. Sav. Étrangers,' vol. vii.

In *Gryllus* also and *Forficula* the mode of branching has much similarity to that of a tree; but in neither did I trace the fine tubules. In the larva of *Acheta* the termination of the tracheæ, so far as it could be seen, resembled that of the perfect insect.

In *Melolontha*, *Scarabæus*, and *Lucanus* I met with the same difficulty. In the larva of *Lampyrus* and in that of *Lucanus* the distribution was much the same (Pl. II. fig. 6). In *Necrophorus vespillo* and *N. humator* the branchlets are long, waved, not very numerous, and without any special peculiarity in the mode of branching, which is generally more or less dichotomous. The organ is provided with numerous white finger-like glands, on which the waved tubules had a beautiful appearance. Generally one or two run up each gland.

The distribution of the tracheæ in *Libellula* is very peculiar. Two large tracheæ run along the stomach and give off about eight large transverse branches on each side in pairs. These lateral branches again give off branchlets at right angles, and these again others at acute angles. These last often run into one another, and thus divide the organ into numerous elongated compartments.

In *Panorpa* about ten large tracheæ go to the stomach, on which they ramify in a radiating manner. There are also a few smaller systems, but by far the greatest number of tracheæ originate from these large branches.

The tracheæ of *Chrysopa* and of *Mamestra brassicæ* (larva) resembled those of *Tenthredo* and *Cynips*, but I did not notice such long unbranched tubes. Sometimes the tracheæ were here and there in tufts. Those of *Campæa margaritaria* were still more like those of *Tenthredo* and *Cynips*, while *Hipparchia* again agreed with *Chrysopa*.

In *Musca* and *Eristalis* the tracheæ are in very pretty tufts. The ends of the tubules often run into the spaces occupied by other systems, but they very seldom inosculate. Sometimes the systems are more elongated, so as almost to lose the appearance of tufts. When magnified about 100 times, the tracheæ have a beautiful appearance.

In the larva of *Musca* the stomach is well supplied, principally by transverse branches, which, however, do not end in tufts. On the anterior part especially they are very pretty.

In *Tipula* the tracheæ are but very loosely attached to the stomach, so that they may easily be torn off in the dissection. They are not in tufts like those of *Musca* and *Eristalis*, but resemble those on the ilium.

In *Aphrophora spumaria* the tracheæ are not very numerous, and consist of long waved branchlets, with few ramifications, much, in fact, like those of *Lampyrus* and *Necrophorus*.

In *Pentatoma* the stomach is complicated. Pl. II. fig. 2 represents one of the tracheal branches magnified 60 times, and fig. 7 one of the lateral branchlets magnified 250 times, of the anterior part. The branchlets divide dichotomously, and also throw out numerous tubules from the side. The tubules often run close together for some distance. On the posterior sacculated part of the stomach are thick, broad tracheæ which send out large branches. These run principally between the sacculi, and appear to branch like those of the front part of the stomach. It is, however, difficult to follow them satisfactorily, on account of the folds. Finally, there is a broader, short chamber, into which

the Malpighian vessels fall; and on this the tracheæ resemble those of the anterior division of the stomach. I have already given my reasons for considering all these organs as being together homologous with the stomach of other insects, though the great differences in structure certainly indicate differences of function.

On the front part of the stomach two or three fine tubules rise from the large tracheæ near the base of each system, and run with only one or two branches all along the main branch of the system. What makes these tubules particularly conspicuous is, that while they are nearly as delicate as the ordinary tubules, they are much longer, and as straight as the larger branches which they accompany.

On the round sac to which the Malpighian vessels are attached the tracheæ are much like those of the front part of the stomach.

The recurrent intestine of *Aphrophora spumaria* is not very richly supplied. The tracheæ (Pl. II. fig. 16) branch more or less dichotomously, and are waved at the ends.

Malpighian Vessels. (Pl. II. fig. 15; Pl. IV. fig. 11.)

In *Bombus terrestris* the tracheæ run along the Malpighian vessels, giving off short, broad branchlets at intervals. Each of these ends abruptly, and from the termination spring from five to ten tubules. These tubules branch generally two or three times at acute angles, and are about $\frac{1}{150}$ inch long. What, however, gives a very peculiar appearance to these tracheæ, is, that the tubules of each tuft, and the branches proceeding from them, though somewhat divergent, are more or less parallel to one another.

In *B. muscorum*, *B. lapidarius*, *B. hortorum*, *Vespa vulgaris*, *Anthophora acervorum* (Pl. II. fig. 15), the tracheæ are like those of *B. terrestris*.

In *Ophion luteum* long tracheæ run along the Malpighian vessels, and give off side-branches here and there, which form little systems. In *Tenthredo* they are as in *Ophion*, but in *Athalia spinarum* they seem to have hardly any tracheæ.

In *Acheta* (larva and imago), *Gryllus*, *Locusta*, and *Forficula*, a very long trachea runs along each Malpighian vessel, from one end to the other, giving off minute branchlets at intervals. The ends of these branchlets were always filled with fluid; and I was therefore unable to determine their mode of termination.

In *Libellula* (Pl. II. fig. 19) this character was carried to an extreme, and it was only here and there that a little branchlet could be seen proceeding from the main trachea.

In *Panorpa* the Malpighian vessels were so opaque that the arrangement of the tracheæ could not be made out. In *Chrysopa* they seem to have no tracheæ. In *Aphrophora* the tracheæ were badly seen. They appeared to divide dichotomously into curved, but not waved branchlets.

In the larva of *Lampyrus* they were long, waved, and either branched dichotomously, or gave off little branchlets at intervals, very much, in fact, as on the stomach and ilium. In *Necrophorus vespillo* and *N. humator* the branchlets were more numerous, so as to have almost the appearance of being in tufts. They are less wavy than in *Lampyrus*. In *Carabus*, *Cerambyx moschatus*, *Amphimalla solstitialis*, *Melolontha vulgaris*, and *Lucanus cervus*, the ends of the tracheæ when examined were filled with fluid, and therefore could no longer be distinguished.

In *Pentatoma* the tracheæ are like those on the stomach.

In *Campæa margaritaria*, *Pieris napi*, and the larva of *Eupexia lucipara*, the ends became invisible so soon after death, that I was never able satisfactorily to see the finer branchlets. In the larva of *Mamestra* the tracheæ were long, slender, and with few branchlets, at obtuse angles.

In *Musca* and *Eristalis* they are in tufts, as is so generally the case with the tracheæ of these insects; while in the larva of *Musca* they are quite simple. A rather larger trachea runs along each Malpighian vessel in *Tipula*, and gives off little systems of branchlets at intervals (Pl. II. fig. 18).

In the larva of *Bombus muscorum* the tracheæ of the white urinary tubes resembled those of the stomach, but the branches generally ended in only two tubules.

Ilium. (Pl. II. figs. 11, 12 & 17.)

In *Bombus terrestris*, *B. muscorum*, *B. lapidarius*, and *B. hortorum* the walls of the ilium are composed of quadrangular cells, and the smaller branchlets of the tracheæ run round and between them, so that they divide the organ as it were into quadrangular spaces. This arrangement, however, I could not see well without the assistance of acetic acid. In *Vespa* the arrangement of the tracheæ is much like that on the stomach. The same is the case in *Ophion* also, though the very long branches were not so much developed, and the whole arrangement is on a smaller scale. At the front part of the organ in *Tenthredo* the tracheæ branch frequently, and finally end in tufts (Pl. II. fig. 17). At the posterior end, the tufts are less developed, or altogether absent. In parts of the organ the larger branches anastomose frequently. In *Athalia spinarum* the larger branches are like those of *Tenthredo*. The tufts have fewer tubules, and often the branchlets end without any tuft at all.

In *Ichneumon* the tracheæ resemble those of *Ophion*. In *Acheta* (imago and larva) the mode of distribution is much like that on the posterior end of the stomach, but at the lower end the tree-like branches are more elongated. In *Gryllus* also the branches are more elongated than on the stomach. In *Forficula auricularia* the branches run in a wavy course along the muscles, with short transverse branchlets.

In *Necrophorus vespillo* the ilium is very long, and covered with saccular bags. It has four longitudinal tracheæ, which send a branch to each sacculus.

In the larvæ of *Lampyrus* and *Lucanus* the tracheæ are much like those of the stomach (Pl. II. fig. 6).

In *Panorpa*, on the contrary, they are very different, but I was unable to see them satisfactorily. In *Chrysopa* again they are similar, but the branchlets are fewer. *Limnephilus vitratus* has on the ilium several large tracheæ which throw out rather numerous tubules. These latter are rather long and slightly curved, but not waved. The number of them is larger than is generally found on this organ.

Campæa margaritaria seemed to have no tracheæ on this organ, nor on the cæcum; or at least they were so loosely attached, as, in the specimen examined, to have become separated from it.

On the long ilium in the larva of *Musca* the tracheæ branch very simply, and resemble

those of the salivary glands. In *Eristalis* the tracheæ resembled those of the stomach; in *Musca* they were perhaps rather more like those of the colon. The arrangement in *Tipula* is quite different, not being in tufts. In *Aphrophora* (Pl. II. fig. 16) they are much like those of the recurrent intestine and the Malpighian vessels.

In the larva of *Bombus muscorum* the tracheæ resemble those of the stomach. The different systems cross one another a good deal. The tracheæ are stiff and wand-like, and end in small tufts of from two to four, long, straight, or gently curved tubules. These latter sometimes, though not often, branch dichotomously. In the larva of *Lampyrus* the tracheæ on the duodenum were like those on the ilium.

Colon. (Pl. IV. figs. 1 to 7.)

In *Bombus terrestris*, *B. muscorum*, and *B. lapidarius*, the colon (Pl. IV. fig. 2) was but poorly supplied, and the tracheæ were long, with only a few branchlets.

In *Vespa* the wall of the colon is divided into six parts, which have a cellular appearance, and are united to one another by their membranes. These membranes have no tracheæ, but a large branch runs along each of the divisions, and gives off numerous side branchlets, a part of one of which is represented in Pl. IV. fig. 5.

In *Ophion luteum* the rectum contains a good many round glands? which, as usual, are well supplied with tracheæ. The mode of branching is much like that in *Chrysopa* (Pl. IV. fig. 4). In *Tenthredo* and *Athalia spinarum* the colon contains six elliptical shield-like glands, which, as usual, are more richly supplied than the rest of the organ. The mode of branching is much like that of *Ophion* and *Chrysopa*. In *Ichneumon* also the rectal glands and their tracheæ are as in *Tenthredo*. In *Acheta* the walls of the organ are divided into six compartments, each of which has a double series of tracheæ, two large branches distributing themselves from near the middle, one to the front part, the other behind. The figure (Pl. IV. fig. 6) which represents the front part of one division will give a more correct idea than any description could do. The colon of *Locusta* much resembles that of *Acheta*. The type is very nearly the same in *Gryllus*; but the lateral branchlets are fewer and longer. On the colon of the larva of *Acheta* the tracheæ resemble those of the imago.

In *Forficula auricularia* the colon contains six round shield-like glands in two alternate rows. In *Carabus* it is well supplied, and the larger branches anastomose a good deal. The muscles make it somewhat difficult to follow the ramifications of the finer branches; but they seemed to be like those on the egg-tubes. In *Cerambyx* the tracheæ seemed to resemble those on the stomach, as was also the case with the larvæ of *Lampyrus* and *Lucanus*. In *Necrophorus vespillo* and *N. humator* they are almost as in *Bombus*; but the branchlets are longer. In *Libellula* there are six wide longitudinal bands, connected by a membrane without any tracheæ; each band has a large trachea, which gives off about six systems of branchlets. *Panorpa* has also six rectal glands, each with a system of tracheæ radiating from the centre. In *Limnephilus vitratus* there were at least twenty-five round glands, on which the distribution of the tracheæ was not unlike that of *Chrysopa*. *Chrysopa* has six round glands, as in *Tenthredo*, &c. The mode of tracheal distribution in the glands and surrounding membrane is represented in Pl. IV. fig. 4. In

Campæa margaritaria, *Hipparchia Janira*, *H. Tithonus*, *Pieris napi*, and *Noctua gamma*, there are many round glands, each with numerous tracheæ.

In *Eristalis* and *Musca* the tracheæ are as on the stomach, though in the latter the systems are particularly large. In both, there are several tongue-shaped glands with numerous tracheæ. In *Tipula* also are several similar glands. A large trachea enters the base of each, and there divides into four or five branches, of which about three continue nearly parallel, and give off branchlets from time to time, while the others diverge to supply the basal part of the gland. In *Pentatoma* the tracheæ resemble those of the stomach.

Male Generative Organs.—Testis. (Pl. III. figs. 13, 14, 16, 18 & 19.)

In *Bombus muscorum*, *B. terrestris*, and *B. pratorum*, the tracheæ generally divide dichotomously, but sometimes into three. The end tubules are very long,—a character which we often meet with in the testis. In *Acheta*, *Locusta*, and *Gryllus*, the air had always been removed from the fine ends, which therefore had become invisible. The branches were, however, long between the branchlets, and they tapered very little. In the pupa of *Acheta*, the tracheæ, so far as they could be seen, resembled those of the imago. In *Musca* the testis is a brown, sausage-shaped body, and the tracheæ end in small tufts (Pl. III. fig. 18). In *Eristalis* the organ is formed on a similar type. The tufts, however, though larger, are more open, and consist of fewer branchlets. In *Aphrophora* the tracheæ are almost like those of the ganglia. They end in long, gently curved tubules, which arise successively, and without forming tufts.

In the button-like testes of *Melolontha* long tracheæ run from the centre to the circumference. They divide three or four times dichotomously, and are very long. They, however, diverge but slightly, and are a good deal twisted on themselves. In *Amphimalla solstitialis* they are very similar. Pl. III. fig. 16 represents one of the least-complicated systems. In *Necrophorus mortuorum* and *N. vespillo* the tracheæ branch simply, small tubules rise from branches of considerable size, and the end tubules are straight and of great length. In *Carabus* the ends of the tracheæ had disappeared. In *Cerambyx moschatus* they were much like those of *Aphrophora spumaria*. In *Panorpa* the tracheæ were almost as in *Necrophorus*. Most of the ends had disappeared; and yet the fine tubules seemed to be very long, because they remained for a considerable distance without any great diminution of size. When one of the branchlets divided, the two tubules were each almost as thick as the branchlet from which they sprang. This character gives the tracheæ a peculiar appearance, which is very striking. In *Pentatoma* the testis is covered by broad, longitudinal, saccular tracheæ, which give off thick branches at the ends and sides.

Vas Deferens.

This organ is often without tracheæ. When they are present, they are often very like those on the testis, as for instance in *Bombus terrestris*, *B. muscorum*, *B. pratorum*, *Pentatoma prasina*, &c. In *Acheta* and *Locusta* it was thin, delicate, and apparently without tracheæ. In *Gryllus*, on the contrary, it is large and of a yellow colour. I did not ob-

serve the ends of the tracheæ; but the larger branches were like those of the testis. In *Musca*, *Aphrophora*, *Tipula*, *Forficula*, and *Panorpa* there seemed to be no tracheæ. In *Eristalis* the testes are almost sessile; and in *Necrophorus mortuorum* the vas deferens is too short to give a good view of the tracheæ.

Ductus ejaculatorius. (Pl. III. fig. 17.)

In *Bombus terrestris* and in *Panorpa* this organ has no tracheæ. In *Musca* the tracheæ are in tufts, as in so many other parts of the body. In *Necrophorus vespillo* and *Eristalis* they are like those on the testis. In *Pentatoma*, finally (Pl. III. fig. 17), the organ is pear-shaped, the vas deferens being attached to the swollen end. A number of branches start from the periphery, and soon give off several branchlets at acute angles. These branchlets run towards the posterior end, and go for almost half the length of the organ without dividing any more. They are generally straight; but some were in coils, which, however, may perhaps not be their natural position.

Epididymis. (Pl. III. fig. 20.)

Pl. III. fig. 20 represents the mode of distribution on the epididymis of *Bombus pratorum*.

Vesiculæ seminales.

In *Bombus terrestris*, *B. muscorum*, and *B. derhamellus*, the tracheæ are in tufts, the tubules often being branched again two or three times: the type is much like that on the heart; but each tuft occupies much more space. On the heart I always found the tubules waved, which is not the case in those of the vesiculæ seminales.

In *Necrophorus mortuorum* and *N. vespillo* they may be seen very well. They are large, and their manner of branching is more or less dichotomous.

In *Aphrophora spumaria* they are like those of the testis, and are therefore not very different from those of *Necrophorus*.

In *Panorpa* I did not see them well; but they seemed to be like those of *Necrophorus* and *Aphrophora*.

In *Musca* and *Eristalis* the tracheæ are in tufts, as is the case throughout these insects. In this organ the tufts are rather large.

Female Generative Organs.—Ovaries. (Pl. III. figs. 1 to 12.)

In *Bombus terrestris*, *B. muscorum*, *B. lapidarius*, *B. pratorum*, *B. hortorum*, and *Vespa*, the egg-tubes are covered by such an immense number of tracheæ, that at first sight they look almost like organs of respiration. The mode of distribution also is very different from that found in any other part of the body. In another specimen of *Vespa*, belonging perhaps to another species, the tubules were fewer, so as more to resemble those of *Tenthredo*.

The large tracheæ give off short stout branchlets at small intervals. These branchlets stop abruptly, and give off from their end a great number of fine tubules. These latter are so excessively numerous and so much twisted and interwoven together, that I was unable to trace any one to its end, or to determine whether they are branched or not.

From analogy with other tufted tracheæ, it is probable that the tubules are long, and that they branch occasionally. The impression, however, left on my mind after examining them carefully, was rather the reverse; but, as above stated, they lie so thickly together, that I cannot speak positively.

In *Tenthredo* the tracheæ were also in tufts, like Pl. III. fig. 4, which represents those of *Tipula*, consisting, however, only of from three to ten tubules. These latter branch several times. However, the tracheæ are far less numerous than in *Bombus*, and have altogether a very different aspect. In *Ophion luteum* (Pl. III. fig. 7) the contrast is still more striking. The tracheæ are few, inconspicuous, and have entirely lost the tufted character. They give off straight branchlets at acute angles; and the end tubules are long, slender, and straight. The branches do not keep each to a single egg-tube, but pass freely from one to another. In *Athalia spinarum* the tracheæ generally resembled those of *Tenthredo*, but they were not in such well-marked tufts. In a small species belonging to the Ichneumonidæ, the tracheæ resembled those of *Ophion*, but the branchlets were waved and twisted instead of straight.

In *Acheta* the tracheæ are much like those of *Ophion*, but on a larger scale. In *Gryllus* I did not get a good view of the tracheæ, and especially not of their terminations. They were more waved than in *Acheta*. In *Locusta* (Pl. III. fig. 6) they were quite different from those of *Acheta*, or, so far as I could see them, of *Gryllus*. The large branches give off short stout branchlets, almost as in *Bombus*, except that they are more waved. The branchlets end abruptly, and give off tufts of tubules, like those of *Tenthredo*. The tubules, however, are smaller in proportion to the branchlets, so as to afford a stronger contrast. Moreover they are less frequently branched. In *Forficula* (Pl. III. fig. 9) I did not see the fine ends. The tracheæ were simply branched; and the branchlets were long, much twisted, and of uniform diameter for considerable distances. In *Carabus* the tracheæ branch dichotomously towards their ends. The systems are rather large. Often two or three fine tubules spring from the side of the branchlets. In *Lucanus cervus* and *Amphimalla solstitialis* I was unable to see the fine tubules. In *Hydrophilus piceus*, *Necrophorus vespillo*, and *N. humator*, the tracheæ were generally in tufts, almost as in *Bombus*, but the tubules far less numerous. In these insects the tubules certainly divide. In *Chrysopa* (Pl. III. fig. 3) the tracheæ end in tufts. The tubules in each are few in number, straight, and divergent like a fan. They often give off one or two still smaller tubules. Except that they are in tufts, they much resemble those of *Ophion*. The tracheæ in *Panorpa*, *Limnephilus*, and I believe also in *Libellula*, resemble those of *Chrysopa*. In *Campæa margaritaria* they are in tufts, as in *Tenthredo*; but the tufts are not above a quarter as large as in that insect. In *Hipparchia* I was only once able to see the tubules. They are represented in Pl. III. fig. 8. Figs. 8' and 8'' represent all that was visible after intervals of a quarter of an hour. In *Pieris brassicæ* also I was unable to see the finer branchlets. In *Tipula* the tracheæ were like those in Pl. III. figs. 4 & 5. Unlike as are these two figures, the mode of branching is in reality very similar, and would be seen if the tracheæ of fig. 4 were extended as they are on the larger egg-germs. In *Eristalis tenax* and a large species of *Musca* (Pl. III. fig. 2), the tracheæ were intermediate in character between those of *Necrophorus* and *Bombus*.

In a smaller species of *Musca*, however, the tubules in each tuft were less numerous. In *Dioctria flavipes* the tracheæ resembled those of *Tipula* and *Tenthredo*. In *Pentatoma* a single trachea runs up the terminal chamber of each ovary, and gives off branchlets from the side, as in Pl. III. fig. 11. The trachea ends simply. In *Aphrophora spumaria* (Pl. III. fig. 1) we meet with a type quite different from any of the preceding. Large tracheæ proceed to the posterior end of the egg-tubes, where they rapidly break up into branches about $\frac{1}{8000}$ th of an inch in diameter. These branches run all up the egg-tube, and half-way along the connecting filament, gradually diminishing in size till they can be seen no longer. They are nearly one-sixth of an inch in length, and do not give off a single branchlet. On one side of an ovary I counted sixty of these branches; and there seemed to be as many on the other side.

In *Ranatra* there are five egg-tubes. One single very large trachea, about $\frac{1}{100}$ th of an inch in diameter, passes to the upper end of the egg-tubes, where they reunite to form the common connecting filament, which was first described by Müller. Here the trachea divides into about fifteen large trunks, each of which is about $\frac{1}{500}$ th of an inch in diameter. These trunks divide here and there dichotomously, and sometimes give off side branches; but the distribution of air takes place principally by means of small lateral branchlets, which give off numerous long twisted tubes, and sometimes end finally in a small tuft. This continues for about $\frac{1}{10}$ th of an inch, when all the trunks except six have exhausted themselves,—each trunk ending in the same manner as one of the lateral branchlets; but at these ends the tubules seem longer and more waved, and are not in tufts.

The six trunks just mentioned pass along the egg-tubes for about $\frac{1}{10}$ th of an inch, with a diameter, excluding the so-called outer membrane, of $\frac{3}{2000}$ ths of an inch, in which space they do not give off a single branchlet. For about half of this distance the egg-tubes are supplied by the other trunks; but for $\frac{1}{10}$ th of an inch after these have ceased, the egg-tubes are left free from tracheæ. For the last $\frac{1}{3}$ rd of an inch, the egg-tubes, and after that the oviduct and egg-canal, are supplied by the above-mentioned six trunks, and the mode of branching is the same as at the upper end of the egg-tubes. No tracheæ are given to the generative organs from any other source. The tracheæ on the oviduct are less numerous than those on the egg-tubes, and on the egg-canal they are fewer than on the oviduct.

It is very seldom that we find a whole system of organs supplied, as in this case, exclusively by one great trunk; and it is evident that here the air must pass to and fro in the same vessel.

I was surprised to find *six* large trunks running along the *five* egg-tubes. The two ovaries agreed in this respect; but I have not had an opportunity of examining other specimens, and therefore cannot say whether the number of these trunks varies or not. These six trunks run so far without a branch, and the branchlets arising from the other main trunks are so small in proportion, that the tracheæ have much the same appearance at first sight as those of *Aphrophora*; in that genus, however, the main trachea is at the posterior end, while in *Ranatra* it is at the anterior end, so that it is a case of analogy, and not of homology.

At the end of October, when I examined this insect, there were no traces of egg-germs;

so that I am therefore unable to say what relation they would bear to that part of the egg-tube which is free from tracheæ.

Oviduct.

In *Bombus terrestris* and several other species, the tracheæ of the oviduct frequently anastomose, so as to form meshes. In each mesh is one branch, ending in a tuft. The branchlets composing the tuft are waved, and branch rather often.

In *B. muscorum* the large tracheæ do not anastomose so often as in the other species I have examined.

In *Vespa* they do not anastomose, and the branchlets often ended in tufts, with, however, only a few tubules.

In *Ophion* the oviduct is thrown into folds, and the tracheæ run transversely along them. They are not very unlike those on the ovary; but the branchlets are waved, which is probably necessary on account of the movements of the organ.

In *Tenthredo*, *Locusta*, and *Carabus*, likewise, the tracheæ resemble those on the egg-tubes.

In *Cynips* the tracheæ end in tufts, consisting, however, of but few tracheæ.

In *Ichneumon* and *Forficula* I found no tracheæ on the oviduct.

In *Necrophorus vespillo* and *N. humator* the tracheæ are in tufts as on the egg-tubes, but the tubules are far less numerous and more branched. They are a good deal hidden by the irregularities of the organ, and altogether look very unlike those on the egg-tubes.

In *Libellula* I did not get a very good view of the tracheæ; but they seemed to resemble those of the ovary.

The same is the case in *Panorpa*; but I did not see the tracheæ well in this insect.

In *Eristalis* the tracheæ are, as usual, in large tufts. In *Musca* and *Tipula* also the oviduct is very short, but I saw on it several of the usual tufts.

In *Aphrophora*, on the contrary, they are quite unlike those of the ovary, being much smaller and more delicate. They are, however, long and without very many branchlets.

In *Pentatoma* the tracheæ resemble those on the stomach.

Egg-canal. (Pl. III. fig. 15.)

In *Bombus* the tracheæ do not inosculate as on the oviduct. The distribution of the smaller branchlets, however, is similar; but the tufts are fewer, more elongated, and the tubules also less numerous. In *Vespa* they are nearly the same. In *Ichneumon* it seemed to be free from tracheæ.

In *Gryllus*, *Locusta*, *Carabus*, and *Necrophorus*, the egg-canal is very short.

In *Panorpa* it seemed to have very few tracheæ. In *Eristalis* and *Musca* the tracheæ were in the usual tufts.

In *Aphrophora* and *Pentatoma* they are like those of the oviduct.

Supplementary Glands attached to the Reproductive Organs.

I have already stated that in this paper my attention is confined to the distribution of the respiratory organs. In the names applied to other parts, therefore, I have followed

simply the best authorities, without wishing thereby to express any decided opinion of my own as to their functions or homologies.

In *Bombus* we find two sorts of appendages to the reproductive organs. One is the poison-gland, and consists of two long secreting tubes falling into an oval reservoir. On the tubes the tracheæ are in tufts, but are very unlike those on the Malpighian vessels, though the tubes themselves are very like them. On the reservoir the mode of branching is simple and successive. The tubules are straight, or at least gently curved.

Between the ovaries of *Aphrophora spumaria* lies a membranous bag with tracheæ much like those of the ganglia in *Acheta*. In one specimen, however, they were waved.

On the spermatheca of *Bombus muscorum* tracheæ were few, and the mode of branching simple.

In *Hydrophilus piceus* there are certain ramified glands with swollen ends. On these glands the tracheæ resemble those of the stomach.

Heart. (Pl. I. figs. 15, 16 & 17.)

In *Bombus terrestris*, *muscorum* (Pl. I. fig. 15.), *lapidarius*, *pratorum*, and *hortorum*, *Vespa vulgaris*, and *Apis mellifica*, the larger tracheæ branch freely along the margins of this organ, and anastomose frequently with one another and with the neighbouring systems, besides sending branches which run into those of the opposite side. The branches also give out short branchlets, which do not divide nor diminish in size, but terminate suddenly and give off from their end several smaller branchlets, which, again, divide more than once, so as to end in very fine, more or less waved tubules. The branchlets into which a branch divides are often of very unequal size.

This character is, however, not common to all the Hymenoptera; for in *Ophion luteum* and in one of the Ichneumonidæ, though they had in most parts been torn off, yet in one or two places where they remained they divided into more or less waved tubules, by simple successive branching.

This is also the case in *Limnephilus vitratus*, where, however, the tubules were larger; moreover they were much obscured by the surrounding fat.

For the same reason it was difficult to see them well in *Aphrophora*, where, however (Pl. I. fig. 17.), after dividing several times, and generally dichotomously, they appeared to end in a tuft of long and apparently simple tubules.

In the specimens of *Acheta* and *Gryllus viridissimus* which I examined, I was unable to make out the arrangement of the tracheæ; and in *Locusta* I was scarcely more fortunate, but they seemed to end in tufts, almost as in *Aphrophora*.

In *Pentatoma* the distribution was almost the same as on the oviduct, but generally with fewer tubules. They were sometimes waved, sometimes nearly straight.

In *Necrophorus* they branched simply and were straight, or rather with gentle curves. After adding acetic acid, many of them were thrown into waves.

In *Lucanus cervus* they were in folds, long, and with few branches, but all the ends had disappeared, as was also the case in *Carabus* and in *Noctua gamma*.

In *Eristalis*, *Musca* (Pl. I. fig. 16), and *Tipula*, the tracheæ are in small tufts consisting of from three to six tubules. These latter give off smaller ones from their sides.

Fatty Tissue. (Pl. IV. figs. 8, 9 & 10.)

In *Tenthredo* the fatty tissue consists principally of large round cells. The tracheæ are peculiarly straight and stiff-looking; they branch occasionally, and finally end in small tufts of from two to six tubules. In *Vespa* the tracheæ resemble those of *Tenthredo*. In *Bombus muscorum* the branches of the tracheæ have the same straight, even character, and often run for some distance without branching. They end in tufts of straight tubules, which are generally not very numerous and do not branch often.

In *Hydrophilus piceus* also the tracheæ are in tufts.

In the larvæ of *Lampyrus* and *Lucanus*, and in *Scarabæus*, the fatty tissue consists of round masses, on which I did not ascertain the mode of distribution of the tracheæ.

In *Forficula* the fatty tissue is in large flakes, here and there running into one another. The tracheæ are long and rather thin in proportion. They branch seldom, and generally at obtuse angles. When the flake is broad, the trachea given to it generally emits several branchlets. When it is narrow and ribbon-like, a small branch generally runs along it, and divides only at long intervals.

In the larva of *Lasiocampa rubi* and of *Mamestra brassicae*, in *Aphrophora spumaria*, in *Tipula*, and in *Acheta domestica*, the tracheæ are nearly as in *Forficula*, and they break up gradually into a few, long, straight tubules. In *Pentatoma* the tissue consists of thimble-shaped lobules, connected by their bases. A trachea enters each, and breaks up gradually as in Pl. IV. fig. 9. In *Cynips lignicola* (Pl. IV. fig. 10) the arrangement is very peculiar. The tracheæ are shaped like rolling-pins, and scarcely taper at all, being, even at their ends, $\frac{1}{1000}$ th of an inch in breadth. From their ends and sides spring numerous fine tubules, about $\frac{1}{10000}$ th of an inch in diameter, and as much as, or even more than, $\frac{1}{20}$ th of an inch in length. The tubules scarcely ever branch, though in one or two cases I saw a dichotomous division.

Muscles. (Pl. IV. figs. 12 to 18.)

On the muscles of the abdomen in *Bombus* and *Vespa* thus end in tufts.

The thoracic muscles of these two genera have a number of large, parallel, saccular, transverse tracheæ, separated by intervals scarcely greater than their own width. They end suddenly in a number of very short, thick branchlets (Pl. IV. fig. 14); and the saccular branches give off similar little systems from their sides. In *Ophion* the system is similar, though the branchlets are more elongated.

In *Bombus* also the tracheæ of the thoracic muscles are similar; but I could follow the terminal tubules rather further. The thickness of the muscle, however, prevents them from being seen well.

In *Panorpa* (Pl. IV. fig. 12) the tracheæ on the abdominal muscles are straight, and the tubules expand like the rays of a fan. On the muscles of the thorax the tracheæ are sometimes waved; but the mode of branching may be best understood by referring to Pl. IV. fig. 18. In *Athalia spinarum* the tracheæ often end in tufts. The branchlets run across the muscles, and divide like a fan, but rather irregularly. Often the side branchlets diverge at first, and then curve round so as to become subparallel. Sometimes,

on the other hand, a side branchlet forms a separate system at right angles, or nearly so, to the first.

On the thoracic muscles of *Chrysopa* the branches end in small fan-like tufts of tubules.

In the larva of *Lasiocampa rubi* the tracheæ are numerous, simply branched, and much waved. In the larva of *Mamestra brassicæ* they are very similar, but straighter.

In *Hipparchia Janira*, *Pieris brassicæ*, and *Amphimalla solstitialis*, the tracheæ break up into straight tubules, which diverge from one another.

In *Eristalis* the thoracic muscles consist of broad ribbon-like tracheæ, which lie parallel, and near to one another, across the muscles. They end in finger-like prolongations, from the end of each of which rises a small tuft of tubules, which are apparently very short. In *Musca* the tracheæ were very similar. In *Tipula* the tubules were longer than in *Musca* or *Eristalis*. In *Necrophorus* the saccular tracheæ resemble those of *Eristalis*; but the tubules are longer.

In the Cricket they resemble those of *Panorpa* (Pl. IV. fig. 18). Some parts more resemble Pl. IV. fig. 12. *Locusta* and *Gryllus* did not apparently differ from *Acheta*.

In the larva of *Acheta* the tracheæ in some parts resemble those of the imago. In parts I found long ribbon-like tracheæ, somewhat as in *Eristalis*; only they are longer, narrower, and further apart. The tubules also which arise from them are long and only branched here and there.

Aphrophora has tracheæ of the usual type. In *Pentatoma* the parallel saccular tracheæ are narrower than in *Eristalis*, being only about $\frac{1}{7000}$ th of an inch in diameter. The terminal tubules also seemed longer; but I did not get a very good view of them.

Conclusion.

It would of course be rash to attempt to lay down general laws based on the examination of the few species which as yet I have been able to compare together; but so far as they go, my observations appear to point to the following conclusions.

First, that the same type of distribution regularly occurs in the homologous parts of different specimens belonging to the same species.

Secondly, that the same almost always holds good of homologous parts in different species belonging to the same genus.

Thirdly, that though the general type of distribution is the same in different specimens of the same species, yet the individual tracheæ differ very much,—just, in fact, as we find the general mode of branching is the same in different specimens of the Oak or Birch, though in no two oaks or birches are the various branches and twigs exactly alike.

Fourthly, that while in some insects, as for instance in *Pentatoma*, the tracheæ in many of the different organs have a different type of distribution, in others, as in *Eristalis*, one type is found in most of the different organs. Even in this case, however, the tufts (Pl. I. fig. 16) which end the branchlets, are very different in size in the different parts. A small organ has, as a general rule, more systems of tubules in a given space than a large one; but the relative proportions are, of course, not exact. Moreover, even in this case, some organs (as, for instance, the muscles) are very unlike the remainder.

Fifthly, while in the larva of Orthoptera the tracheæ very closely resemble those of the

imago, in those larvæ which undergo a perfect metamorphosis (as, for instance, in those of Coleoptera, Lepidoptera, and Hymenoptera) the tracheæ are very unlike those of the perfect insect.

Sixthly, in these latter larvæ the same type of tracheal distribution appears to be more widely distributed in the different organs. Thus, while in the imago of *Bombus* the tracheæ on the stomach, ilium, and Malpighian vessels are all three very different from one another, the tracheæ on the corresponding organs of the larva of *B. muscorum* are very similar to one another, and as in Pl. II. fig. 11. Again, in the larva of *Lucanus* the œsophagus, stomach, ilium, and colon, and in that of *Lampyrus* the stomach, ilium, colon, and Malpighian vessels, had tracheæ respectively like one another.

Seventhly, that in some cases the tracheæ of the larvæ seem to agree in species where those of the perfect insect are different; so that, comparing this with the preceding rule, it would seem that the larval tracheæ are in both respects less differentiated, and more in accordance with the original type than those of perfect insects.

DESCRIPTION OF THE PLATES.

PLATE I.

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|---|--|
| Fig. 1. Tracheæ from ganglion of <i>Acheta</i> , $\times 125$. | Fig. 10. Tracheæ from cæcum of <i>Acheta</i> , $\times 30$. |
| Fig. 2. Tracheæ from commissure of <i>Carabus</i> , $\times 125$. | Fig. 11. Tracheæ from cæcum of <i>Chrysopa</i> , $\times 125$. |
| Fig. 3. Tracheæ from ganglion of <i>Bombus</i> , $\times 125$. | Fig. 12. Tracheæ from cæcum of <i>Chrysopa</i> , $\times 125$. |
| Fig. 4. Tracheæ from commissure of <i>Acheta</i> , $\times 125$. | Fig. 13. Tracheæ from crop of <i>Carabus</i> , $\times 30$. |
| Fig. 5. Tracheæ from ganglion of <i>Pentatoma</i> , $\times 125$. | Fig. 14. Tracheæ from œsophagus of <i>Musca</i> , $\times 125$. |
| Fig. 6. Tracheæ from ganglion of <i>Carabus</i> , $\times 125$. | Fig. 15. Tracheæ from heart of <i>Bombus</i> , $\times 125$. |
| Fig. 7. Tracheæ from commissure of <i>Lasiocampa</i> , $\times 125$. | Fig. 16. Tracheæ from heart of <i>Musca</i> , $\times 125$. |
| Fig. 8. Tracheæ from œsophagus of <i>Eristalis</i> , $\times 125$. | Fig. 17. Tracheæ from heart of <i>Aphrophora</i> ,
$\times 125$. |
| Fig. 9. Tracheæ from sucking-stomach of <i>Musca</i> , $\times 125$. | |

PLATE II.

- Fig. 1. Tracheæ from the stomach of *Musca*, $\times 125$.
 Fig. 2. A few of the larger tracheæ from the stomach of *Pentatoma*, omitting the finer branches, $\times 30$.
 Fig. 3. Tracheæ from the stomach of *Ophion*, $\times 125$.
 Fig. 4. Tracheæ from the stomach of *Acheta*, $\times 60$.
 Fig. 5. Tracheæ from the stomach of *Bombus*, $\times 125$.
 Fig. 6. Tracheæ from the stomach of *Bombus*, $\times 125$.
 Fig. 7. One of the lateral branches from the above figure of *Pentatoma*, showing the fine branchlets, $\times 125$.
 Fig. 8. Tracheæ from the stomach of *Manestra*, $\times 30$.
 Fig. 9. Tracheæ from the stomach of *Acheta*, $\times 30$.
 Fig. 10. Tracheæ from the stomach of *Vespa*, $\times 125$.
 Fig. 11. Tracheæ from the ilium of the larva of *Bombus*, $\times 125$.
 Fig. 12. Tracheæ from the ilium of *Tipula*, $\times 125$.
 Fig. 13. Small part of the inner membrane of a trachea, showing the spirally thickened rib, *a a a*, $\times 125$.
 Fig. 14. Tracheæ of salivary gland of *Pentatoma*, $\times 125$.
 Fig. 15. Tracheæ of Malpighian vessel of *Anthophora*, $\times 125$.
 Fig. 16. Tracheæ of recurrent intestine of *Aphrophora*, $\times 30$.

- Fig. 17. Tracheæ of ilium of *Tenthredo*, $\times 125$.
 Fig. 18. Tracheæ of Malpighian vessel of *Tipula*, $\times 125$.
 Fig. 19. Tracheæ of Malpighian vessel of *Libellula*, $\times 30$.

PLATE III.

- Fig. 1. Tracheæ from ovary of *Aphrophora*, $\times 30$.
 Fig. 2. Tracheæ from ovary of *Musca*, $\times 125$.
 Fig. 3. Tracheæ from ovary of *Chrysopa*, $\times 50$.
 Fig. 4. Tracheæ from ovary of *Tipula*, $\times 125$.
 Fig. 5. Tracheæ from ovary of *Tipula*, $\times 125$.
 Fig. 6. Tracheæ from ovary of *Locusta*, $\times 125$.
 Fig. 7. Tracheæ from ovary of *Ophion*, $\times 30$.
 Fig. 8. Tracheæ from ovary of *Hipparchia*, $\times 125$.
 Fig. 9. Tracheæ from ovary of *Forficula*, $\times 125$.
 Fig. 10. Tracheæ from ovary of *Necrophorus*, $\times 125$.
 Fig. 11. Tracheæ from ovary of *Pentatoma*, $\times 30$.
 Fig. 12. Tracheæ from ovary of *Acheta*, $\times 30$.
 Fig. 13. Tracheæ from testis of *Necrophorus*, $\times 125$.
 Fig. 14. Tracheæ from testis of *Bombus*, $\times 125$.
 Fig. 15. Tracheæ from egg-canal of *Bombus*, $\times 125$.
 Fig. 16. Tracheæ from testis of *Melolontha*, $\times 125$.
 Fig. 17. Tracheæ from ductus ejaculatorius of *Pentatoma*, $\times 125$.
 Fig. 18. Tracheæ from testis of *Musca*, $\times 125$.
 Fig. 19. Tracheæ from testis of *Eristalis*, $\times 125$.
 Fig. 20. Tracheæ from epididymis of *Bombus*, $\times 125$.
 Fig. 21. Tracheæ on a Malpighian vessel of *Libellula*.

PLATE IV.

- Fig. 1. Tracheæ from the rectum of *Musca*, $\times 125$.
 Fig. 2. Tracheæ from the rectum of *Bombus*, $\times 125$.
 Fig. 3. Tracheæ from the rectum of *Pentatoma*, $\times 125$.
 Fig. 4. Tracheæ from the rectum of *Chrysopa*, $\times 125$.
 Fig. 5. Tracheæ from the rectum of *Vespa*, $\times 125$.
 Fig. 6. Tracheæ from the rectum of *Acheta*, $\times 30$.
 Fig. 7. Tracheæ from the rectum of *Forficula*, $\times 30$.
 Fig. 8. Tracheæ from the fatty tissue of the larva of *Mamestra*, $\times 125$.
 Fig. 9. Tracheæ from the fatty tissue of *Pentatoma*, $\times 125$.
 Fig. 10. Tracheæ from the fatty tissue of *Cynips lignicola*, $\times 30$.
 Fig. 11. Tracheæ from the Malpighian vessel of *Musca*, $\times 125$.
 Fig. 12. Tracheæ from the thoracic muscles of *Panorpa*, $\times 125$.
 Fig. 13. Tracheæ from the thoracic muscles of the larva of *Acheta*, $\times 125$.
 Fig. 14. Tracheæ from the thoracic muscles of *Vespa*, $\times 125$.
 Fig. 15. Tracheæ from the abdominal muscles of the larva of *Mamestra*, $\times 125$.
 Fig. 16. Tracheæ from the thoracic muscles of *Eristalis*, $\times 125$.
 Fig. 17. Tracheæ from the muscles of the larva of *Lasiocampa*, $\times 125$.
 Fig. 18. Tracheæ from the thoracic muscles of *Panorpa*, $\times 125$.

* * It has been found impossible to make the ends of the tracheæ as delicate as they ought to be in proportion.







