On the Anatomy and Physiology of the Tunicata.

By Albany Hancock, F.L.S.

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Having employed myself recently in the investigation of the Tunicata (their anatomical structure and physiology) with a view to a monograph of the British species, which my late lamented friend Mr. Alder and I had undertaken to prepare for the Ray Society, some very interesting anatomical facts have come to light; and I now propose to give a succinct account of the more important of these, believing that they cannot fail to be acceptable to those naturalists who may have studied these low but not by any means unattractive mollusks. I reserve, however, for some future occasion a more complete and detailed description.

When I took up this subject, I had little expectation of meeting with much that was new; for perhaps in no other group of the Molluscan subkingdom hast he anatomy been so frequently and so ably investigated as it has been in the Tunicaries; and, indeed, in them, all the leading points appear to have been fully determined; but experience proves, nevertheless, that much of interest has been left unobserved, quite sufficient to reward the labour of reexamination, and seemingly ample enough to modify some of the more important morphological determinations.

This unexpected result may, in part, be owing to the fact that, while my researches have been chiefly confined to the simple Ascidians, it is apparently to the compound, social, and pelagic forms that the greatest attention has been hitherto given. Thus it happens that numerous details have remained until now unnoticed in the former group.

There is something fresh to record in nearly all the visceral organs, but in none so much perhaps as in the vascular and respiratory systems. Before entering, however, on such new matter, it will be well to say a few words respecting the tunics, so characteristic of these animals. In all the various forms that have been examined, there is no great difficulty in determining the presence of three tunics, or envelopes—namely, the test or outer tunic, the mantle or inner tunic, and the lining membrane or inner tunic of Prof. Huxley.* The lining membrane and mantle are always, to a greater or less extent, adherent to each

* This tunic was first pointed out by M. Milne-Edwards, in his work on the Ascidies composées, p. 54.

other, and have, except where there is an abdomen developed, all the viscera and the lacunary portion of the blood-system placed between them. On the other hand, the mantle and test in *Ascidia* and *Molgula* are always free, except at the distal extremity of the respiratory tubes, where they are united; there is also an attachment at the point where the vascular trunks enter the test. But in the genus *Stycla* (Savigny's third tribe of *Cynthia*) the test is always more or less firmly attached to the mantle throughout, though at the respiratory orifices the adhesion is greatest. In all the species, however, that have been examined, with the exception of one (a small undescribed species), these two envelopes may be separated without much difficulty in specimens preserved in spirit. In the exceptional case alluded to, the mantle is exceedingly delicate; and hence probably arises the difficulty of separating it from the test. In this genus, as well as in *Ascidia* and *Molgula*, blood-vessels pass from the body to the test. It is therefore likely that vessels will be found ramifying in the outer tunic in all the simple Ascidians. In *Pelonaia* the adhesion of the mantle and test is not by any means so remarkable as was originally supposed; and, indeed, in this form they are as easily divided as they usually are in *Stycla*. Also in *Clavelina* these two tunics are slightly adherent throughout, while in *Salpa* they appear to be as free as they are in *Ascidia**.

It should be mentioned that, in a living state, unless the mantle be violently contracted, there is no actual vacant space, or space filled with fluid, as has been asserted, between it and the test; even in those species which have these tunics comparatively free the two surfaces lie in close contact. When the animal is dead, however, and preserved in spirit, the body enclosed in the mantle does not by any means occupy the entire space within the test, but lies somewhat shrivelled, and frequently quite free, just as commonly happens with the animal of the Lamellibranchs under similar circumstances.

The chief function of the test, like that of the shell in the higher mollusks, is no doubt to protect the comparatively soft and delicate portions of the animal that lie within it. But it will also act, by its resiliency, as a counterpoise to the muscular contractility of the mantle, which lines it as it were. In those species, such as *Stycla tuberosa*, in which the mantle and test are adherent throughout, this action is readily understood; it is not,

* I have examined only one species, namely *S. spinosa*; and the specimens were preserved in alcohol.

however, quite so obvious in the species which have these two tunics comparatively free, as they are universally in *Ascidia* and *Molgula*. But we have just seen that, in such instances, the inner surface of the test, and the outer surface of the mantle, lie in close contact with each other. Now, as under all ordinary circumstances, the pressure of the water inside the mantle must be as great as that of the water resting against the outer surface of the test, and as no water can possibly enter between these two tunics, it is clear enough that they will be held together with no inconsiderable force. Thus, when the muscles of the mantle contract, diminishing the bulk of that organ, the test will be drawn in after it; and so soon as the muscles of the former relax, the latter, through the elasticity of its walls, will expand, and the mantle will be constrained to do so likewise.

The most interesting matter that I have to communicate respecting the digestive system relates to the biliary apparatus. A remark or two, however, may be made, in the first place, upon the alimentary canal, which, in all the species that have come under my inspection, makes its first bend towards the dorsal region, assuming that to be the dorsal aspect where the endostyle is placed. The intestine then usually ascends and crosses over (in a more or less undulatory course, sometimes forming one or two loops) to the opposite or ventral side, where it again ascends to reach the cloaca, into which, in the Ascidians, it invariably opens. The walls, from one end of the organ to the other, are particularly firm, and do not collapse even in preserved specimens. The lower portion of the intestine is the most delicate; but even here the wall rarely shrinks. The stomach is well marked, though it is never very bulky, and is usually lined with a stout mucous membrane, which is frequently plaited or wrinkled, sometimes in a symmetrical manner, the plaits extending into the œsophagus on the one hand, and into the intestine on the other. In the latter organ this membrane is thrown up so as to form a very conspicuous groove, which extends from the stomach to that portion of the intestine which may be termed the rectum. In *Stycla tuberosa*, and some other species, however, this groove extends the whole length of the intestine.

The food of the Tunicaries is extracted from sedimentary matters; there is no power of selection in the first instance; those particles which can be, are digested; the others, chiefly composed of sand and mud, are rejected in the usual manner. This sedimentary aliment is sifted from the water in the respiratory sac, by the aid of the branchial network, and is then carried across the organ by the action of cilia; but no definite arrangement of the particles takes place until they arrive at the oral or ventral lamina, where they are formed into a cord of some tenacity, apparently through the agency of mucus, and are carried thus moulded along this lamina to the oral orifice, and so swallowed. This alimentary cord is conducted through the digestive tube, and is rejected in the same form by the anus and excurrent tube. The cord-like fæces may frequently be seen through the wall in the lower portion of the intestine, having very much the appearance of a convoluted tube lying within the canal. In some of the lower forms, however, it is broken up into elongated pellets.

All this is very similar to what takes place in connexion with the alimentation in the Lamellibranchs; but in them the lateral currents of particles are as well defined as the main or central ones.

Molgula and Savigny's first and second tribes of his genus *Cynthia* appear to be the only forms among the simple Tunicates that have hitherto been described, as possessing a well-developed liver. This organ is always sufficiently distinct in these groups, and usually presents a laminated structure, but is occasionally composed of tubular tufts or lobes, the colour being generally of a dark olive-green. I find, however, a true hepatic organ in all the other genera examined (namely *Ascidia*, *Styela*, *Pelonaia*, *Clavelina*, and *Perophora*), quite distinct from that gland-like substance coating the alimentary tube in the first of these forms, and which has occasionally been considered to subserve the hepatic function.

This substance is of a very peculiar character, and it is difficult to say what its office really is. In all the *Ascidiæ* it forms a pretty thick coating over the stomach and intestine, and is composed of comparatively large globular vesicles, with thin reticulated walls, each having a large, opaque, simple or compound nucleus on one side. These vesicles have no communication with each other, though they lie in contact and are cemented together; nor are they connected with any duct, or in any way open into the alimentary tube. Blood-channels are hollowed out, as it were, amidst the vesicles; and the reproductive organs ramify throughout the agglomerated mass which overlies, for the most part, the true hepatic organ. These vesicles will therefore act as a sort of packing to the parts of these organs, and will give support and protection to them, whatever higher function they may have to perform. They may likewise assist the heart in the performance of its work by their resiliency when the mass is gorged with blood; for it is evident that, when the interstices or blood-channels are filled, the vesicles will be more or less collapsed in proportion to the pressure of the blood-current; and when the latter changes its direction the reaction will be assisted by their expansion. In our present state of knowledge, however, nothing positive can be said of the uses of this very curious structure.

The true hepatic organ, as already intimated, lies beneath this vesicular mass, and forms a thin coating on the surface of the intestine. In all the examples observed it is composed of delicate tubes, which divide dichotomously, but frequently without much regularity. At the points where the branches are given off, the tubes are usually enlarged, and the twigs terminate in rounded extremities more or less inflated. The ultimate divisions of the organ are so minute that they can only be observed by the aid of the microscope after a portion of the intestinal tube has been removed, laid open, and deprived of the mucous membrane, so as to render the tissue as transparent as possible.

In *Ascidia mentula* the dichotomous division of the tube is very obvious, and the enlargements or ampullæ at the junction of the branches are greater than usual, and they assume a triangular form; also oval enlargements frequently occur along the branches, which latter uniting go to form two long slender ducts that pass backwards within the loop of the intestine, buried amidst the vesicular substance already described, and at length open through the left wall of the stomach, about midway between the cardia and pylorus, towards the anterior margin. These two ducts come from the middle portion of the intestine; another duct, passing from the lower part of the intestinal tube, unites with one of those first mentioned, just before it sinks into the wall of the stomach. All the three ducts are exceedingly slender; and for their detection it is necessary to dissect carefully the vesicular matter within which they lie buried: when thus exposed their white walls can easily be traced, with the aid of a good lens, running amidst the comparatively dark surrounding tissue.

In *Ascidia sordida* and *A. scabra* the arrangement of the parts of the hepatic organ is similar to that in the above species; but in *A. parallelogramma* the minute structure is considerably modified. In this species there is a minute network of anastomosing tubes spread over the intestine, the tubes being divided into systems by the interruption of the anastomoses along certain lines where the twigs end in blind sacs, which are occasionally a little enlarged and rounded. The main branches leading from the network exhibit a tendency to divide dichotomously, and unite to form two slender ducts, which pass at once from the intestine to the left side and close to the posterior margin of the stomach, into which they pour the biliary secretion a little in advance of the pylorus.

In *Pelonaia* there is only one hepatic duct, which is very slender, and passes in a fold of the lining membrane or "inner tunic" of Huxley, that extends from the intestine to the right side of the stomach, a little way in advance of the pylorus. Before terminating, it receives a twig or two from the surface of the stomach; so that in this genus the liver is apparently not confined to the intestine, but is also spread over a portion of the stomach. The ultimate twigs divide dichotomously with considerable regularity, and terminate in round or ovate vesicles, which are very numerous and form a distinct, opaque, yellowish layer.

The liver in *Stycla* is not more conspicuous than it is in *Ascidia*. It is well developed nevertheless, and is provided with its secreting vesicles and ducts. In *S. tuberosa*, and, indeed, in all the members of this genus that have come under my observation, there is a fold of the lining membrane within the loop of the alimentary tube, which passes between the stomach and intestine. This fold is united to the pyloric end of the stomach, where there is a cæcal prolongation of that organ. The hepatic ducts lie within this fold; and before they reach the stomach, in this species, they unite to form a simple, slender duct, which opens into the left side of the cæcum. The branches of the ducts ramify dichotomously over the lower portion of the intestine, and communicate with comparatively large rounded vesicles, arranged like those in *Pelonaia*.

In *Clavelina* there is only one hepatic duct, which passes from the middle portion of the intestine, and opens into the alimentary tube immediately below the rounded stomach. The branches of the duct ramify over the intestine, dividing dichotomously, and ending in comparatively large, oval vesicles. Exactly the same form of organ is observed in *Perophora*; but in this genus the duct opens through the right wall of the stomach, near the pylorus. The hepatic organ in this interesting form was undoubtedly noticed by Dr. Lister; for he figures and describes, in his well-known memoir in the 'Philosophical Transactions'*, "transparent vessels" ramifying over the intestine; but he does not appear to have observed the terminal vesicles, and the termination of the duct in the stomach, or he scarcely could have supposed, as he did, that the vessels he described were lacteals.

With this exception, this peculiar form of the hepatic organ seems entirely to have escaped notice until A. Krohn gave a very good description of a similar structure in a paper "On the Development of the Ascidians," published in Müller's Archiv, 1852–53†. The species examined by this naturalist was *Ascidia mamillata*; and although he appears to have traced with great accuracy the development of the organ, he seems to have failed in detecting the duct in the adult animal. From the general characters, however, obtained by his examination of the young and adult combined, he is disposed to conclude that the "secretion prepared in the cæca must be accessory to digestion; but whether or not the watery secretion is bile, and the gland therefore a liver," he concludes, "must for the present be left undecided." Nevertheless, after the above description of the numerous modifications of the organ, and particularly when the position of the duct in relation to the alimentary tube is taken into account, few physiologists will be inclined to doubt that this organ is a true liver, though low and rudimentary in structure.

The reproductive organs are well developed in the Tunicates; and in all of them the two sexes are combined in the same individual, though the male and female elements are always secreted by distinct organs, which, however, frequently compose one or more compound masses that have the parts so intimately united that careful examination is required to detect them; hence in several of the *Cynthiadæ* the testis has been entirely overlooked: the oviduct and *vas deferens* are likewise constantly distinct.

In *Ascidia sordida*, the ovary is composed of numerous tubular branches, which ramify in a radiating manner over the left side of the looped portion of the intestine. The oviduct passes

* "Some Observations on the Structure and Functions of Tubular and Cellular Polypi and of Ascidiæ," Phil. Trans. 1834, p. 380.

† See 'Scientific Memoirs,' edited by Henfrey and Huxley, p. 328. Before I was aware of the discovery by Krohn, I had worked out the details of the hepatic organ in the genera mentioned in the text; it was therefore highly satisfactory to find his description of this organ in *A. mamillata* agree so closely with my observations, particularly in *A. mentula*.

through the loop, and, following the curvature of the intestine, opens by the side of the anus into the cloaca. The *vas deferens* terminates near to the same point, and is adherent to the oviduct throughout its course. In the vicinity of the ovary it receives several much attenuated branches from either side of the intestine; these divide dichotomously, the ultimate twigs terminating in elongated and irregularly lobulated vesicles, which are spread over the intestinal tube, and which also exhibit a tendency to dichotomous division: these vesicles secrete the male element.

In *A. scabra*, *A. affinis*, *A. mentula*, and *A. venosa* the same arrangement of the reproductive organs is apparent; but the ovary in *A. mentula* is a lobulated organ, and, lying within the loop of the intestine, is seen at both sides of the alimentary tube, and consequently has the appearance of being double; and in *A. venosa*, the male vesicles are exceedingly minute and are very numerous. In *A. parallelogramma* the genitalia have much the same disposition; the ovary, however, which is branched and lobulated, is spread out on both sides of the alimentary tube—as is likewise the male organ, the secerning vesicles of which are clustered into dendritic systems.

These organs, however, are modified to a much greater extent in the *Cynthiadæ*—in many of which it is not easy to determine the parts, on account of their intimate union; and very careful examination is requisite in these cases. In *Styela tuberosa* the so-called ovaries are very numerous, and are studded over the inner surface of the mantle, on both the right and left side of the body, causing the lining membrane to bulge out. When fully developed they form protuberant, ovate, orange-coloured masses, each having at the attenuated extremity a projecting nipple-like papilla. This is the oviduct, leading out of the ovarian mass or ovigerous sac; for each mass is really a sac, in the walls of which the ova are developed. And firmly attached around the base of these sacs is a series of pale oval vesicles, which are sunk in the substance of the mantle, and which form for each sac a sort of cup within which it rests. These vesicles are the male secreting organs, and their ducts, extremely delicate tubes, pass upwards over the surface of the sac, and go to join, on the median line, a slender *vas deferens*, which, passing forward, terminates at the extremity of the short nipple-like oviduct above described. Thus it is seen that the so-called ovarian mass is a compound organ, combining both the male and female parts, each with its proper secreting organ and duct. There are therefore as many oviducts and outlets for the male secretion as there are compound reproductive masses ; and the eggs must be shed everywhere into the space between the branchial sac and the wall of the respiratory chamber, and afterwards carried by the atrial currents to the cloaca, and so pass out, as usual, by the excurrent tube.

These reproductive masses should not be confounded with other very similarly formed bodies that everywhere stud the mantle, and fill up, to a considerable extent, the spaces between the former. These latter bodies are most frequently pedunculate, and are sometimes as large as the reproductive masses, from which they chiefly differ in colour, being pale, somewhat pellucid, and almost homogeneous in structure. They do not seem to have any high functional import, their office apparently being to form, along with the generative bodies, a sort of pad or level surface for the support of the branchial sac, which otherwise might suffer from the inequality produced by the genitalia. These peculiar organs are found in all the *Cynthiadæ* that have been examined, including *Pelonaia*, in all of which the reproductive organs project boldly from the surface of the mantle.

This arrangement of the reproductive organs also occurs in *Styela mamillaris*, and in two undescribed species of the genus, recently obtained by the Rev. A. M. Norman at Guernsey. In *Thylacium aggregatum* the same disposition of these parts is also found to exist.

In *Cynthia ovata*, an undescribed species allied to *C. squamulosa*, we have a very remarkable modification of these organs. Here there are only two generative masses—one placed immediately above the alimentary tube, the other within the intestinal loop. They are elongated and fusiform, each being composed of a double parallel series of squarish nodules, in which both ovary and testis are combined. Each mass has its own proper oviduct, and *vas deferens*, which pass forward, united, between the series of nodules, and, extending a little way in advance of the organ, open into the cloaca near to the anal orifice.

But perhaps the most interesting variety of this apparatus occurs in *Pelonaia*, in which there are two elongated tubular ovaries, each being bent so as to form a wide loop ; they are attached throughout to the mantle, and bulge out the lining membrane ; one is on the right, the other on the left of the branchial sac in front of the greater portion of the alimentary tube. The oviducts advance a short way beyond the ovaries, and open into the cloaca, one on each side of the intestine, but considerably in advance of the anal orifice. The testis is composed of numerous elongated, simple or lobed vesicles, which are placed with one end in contact with the sides of the ovaries, and are arranged in parallel order at right angles to them, fringing both sides of these organs from end to end. From the proximate extremities of the vesicles extremely delicate ducts pass across the surface of the ovary, to which they are attached, and go to join the *vas deferens* that extends along the middle line from end to end of each ovigerous organ, and, advancing along the oviduct, terminates at the extremity of that tube.

I have not met with this peculiar arrangement of the genitalia in any other species, though, after all, it is but, as it were, an amplification of that which we have seen to exist in the compound genital masses in *Stycla tuberosa* and its immediate allies. If one of these masses were greatly elongated, so as to become tubular, and if the male vesicles were increased in number, their lower extremities pulled from beneath the ovigerous sac, and stretched out on the mantle, we should have something very similar to that which subsists in *Pelonaia*.

Another modification of these organs occurs in *Stycla variabilis*, an undescribed species related to *Cynthia Canopus*, Savigny. In this the ovaries assume the form of distinct, wide, slightly undulated tubes, of which there are two on the right and two on the left side of the mantle, each having its own short nipple-like oviduct, which opens into the cloaca, there being two on each side of the anus. The testis is composed of numerous irregularly lobulated vesicles scattered over the lower portion of the mantle, in the vicinity of the posterior extremities of the ovaries, but with which they have no connexion, each separate vesicle having its own short nipple-like duct or *vas deferens*.

The reproductive organs do not exhibit any great diversity in the genus *Molgula*, the ovary and its testis being always combined, and forming one or two elongated masses, in which, however, the two component elements can always be detected by the aid of their colour and structure. The testis is composed of a vast number of branched vesicles or cæcal tubules, crowded together and sometimes assuming a dendritic appearance, while the ovary seems to be a lobulated sac, usually well filled with eggs.

In *M. conchilega* there are two such masses, placed transversely, which are generally irregular in form, but sometimes are broadly fusiform, and a little arched. That on the right side of the mantle lies upon the upper border of the intestine; the other occupies the centre of the left side of this tunic. The oviducts are two short tubes; they pass out of the ventral or anterior extremity of the mass, and open into the cloaca on each side of the intestine. There are four or five long nipple-like sperm-outlets, situated at a little distance from each other along the body of the organ. These open directly into the atrial space on either side of the branchial sac.

A similar arrangement of the genitalia, with numerous short deferent canals, has been described by Van Beneden, in his *Ascidia ampulloides* *, which is, there can be little doubt, a *Molgula*. There are two similar genital masses in *M. simplex*; but they are comparatively slender, and are pretty regularly fusiform; they are situated exactly in the same way as those in the former species; but that on the right side is overlapped by the looped portion of the intestine.

In an undescribed species obtained by the Rev. A. M. Norman in Guernsey, the genital masses are ovate, and are placed as usual, but differ from those of all other species in having the oviducts passing from their dorsal extremities, and consequently turned towards the endostyle instead of being directed to the cloaca. The products of these organs are consequently thrown into the dorsal portion of the atrium, far from the cloaca.

There is only one reproductive mass in *M. arenosa*; it is larger than usual, is of irregular form, and belongs to the right side of the mantle, but overlies to a considerable extent the alimentary tube. The oviduct, as usual, opens into the cloaca; but the *vas deferens* has not yet been observed, though the male secreting organ is distinctly visible, forming a considerable part of the mass.

In *Clavelina lepadiformis*, one of the Social Ascidians, the genitalia are placed in the loop of the intestine, near to the lower extremity of the abdomen, the ovary lying on the right of the alimentary tube, the testis being spread over both sides of it. The former resembles a bunch of grapes in which the berries are of various sizes; and the oviduct, like the stem of the fruit, is seen in the midst of the ova; and I believe I have traced it passing up the abdomen in the direction of the cloaca, but did not succeed in determining its outlet. M. Milne-Edwards, in his well-known work on the "Ascidies composées"†, states that he could

* "Recherches sur l'Embryogénie, l'Anatomie, et la Physiologie des Ascidies Simples," Mémoires de l'Académie Royale de Belgique, t. xx., 1847.

† 'Observations sur les Ascidies composées des côtes de la Manche,' p. 22.

not discover how the eggs passed from the ovary to the neighbourhood of the branchial sac, and suggests the possibility of the *vas deferens* acting also in the capacity of an oviduct. This, however, is exceedingly improbable; and, from what I have seen, there can be little doubt of the presence of a true oviduct, although I do not consider my observation a sufficient demonstration of the fact. But there can be no mistake as to the existence of a *vas deferens*; this tube is sufficiently conspicuous; passing up by the side of the alimentary canal, it penetrates the lower wall of the cloaca, and terminates by the side of the anal outlet. The testis is a much-branched organ; the branches are extremely fine, and, dividing dichotomously, terminate in numerous elongated fusiform vesicles, which are united in pairs; or, in other words, the ultimate twigs may be said to bifurcate, each branch being immediately enlarged, so as to form an elongated cæcal vesicle.

The blood-system in the Tunicata is perhaps the most difficult branch in the anatomy to investigate; for these animals are generally too minute and delicate to be successfully injected, and it is not easy to obtain living specimens sufficiently transparent to permit of the blood-current being traced through the tissues. Nevertheless much good service has been done in this way by M. Milne-Edwards and others; but perhaps no one has done more by this method than Dr. Lister, who had the good fortune to meet with a species in every respect suited to the purpose. So far as I have been able to ascertain, the blood-system has been as fully, if not more fully, determined in *Perophora* than in any other Tunicate. It is therefore satisfactory to find that my results perfectly agree with those obtained by Dr. Lister, so far as they go*. This is particularly gratifying, as the mode of investigation adopted by me is very different from that followed by this distinguished anatomist; and, moreover, *Perophora* is one of the Social, while the species used by me are all Simple Ascidians.

I have relied almost entirely on dissection, aided by the accumulation of blood-corpuscles in the various parts of the system. In this way the minutest ramifications can be traced with the greatest precision. A vast number of specimens, however, are required; for many individuals may be cut up before one is met with in a proper state. Large specimens, too, are necessary; and they must have the tissues sufficiently transparent, and the blood-globules opake or coloured; in such only can the blood-channels be distinctly traced. And when the specimens are even in the

* Philosophical Transactions, 1834, p. 375.

best condition, many may be opened before the blood-globules are found lodged in the part of the system requiring elucidation. This method is consequently very laborious; but the results are satisfactory; for in such natural injections there is very little danger of being deceived by the blood having extravasated from its natural channels.

Ascidia mentula and *A. venosa* are good species for this purpose; but the one that appears the best-adapted to this mode of investigation is an undescribed species closely allied to the former. In this the blood-globules are of a brownish colour and very numerous; so that it sometimes happens that in this animal large portions of the blood-system can be traced in a single individual. Most of the information, on this portion of the anatomy, has been obtained from these three species; but nevertheless several important points have been verified in the living animal.

The blood-system in the simple Tunicates may be looked upon as closed, how limited soever the true vascular portion of it may be. The blood-channels throughout the organism are well defined; but whether or not they are provided with proper walls, and, if so, to what extent, is not easy to determine. The trunk channels leading to and from the heart have certainly all the appearance of being true vessels; and the branchial network has likewise the character of being truly vascular. The blood-channels in the test have also distinct walls; but in this case they are apparently composed of a prolongation of the mantle or inner tunic. Traces, however, of an inner vessel may be observed in the main trunks; but this apparent vessel may be nothing more than a continuation of the lining membrane or "inner tunic" of Huxley. In fact, the so-called vascular ramifications of the test, however minute and divided, ought perhaps to be regarded as prolongations of the pallial cavity, although it is quite possible that they carry true vessels; and, indeed, from the way they are connected with the heart, this would seem almost probable.

The heart is tubular, and is of considerable length. In *Ascidia* it is attached to the lower border of the stomach, one end extending some way up the dorsal region towards the intestinal tube; this may be called the dorsal extremity; the other, the ventral end, points in the direction of the œsophagus. It lies between the mantle and the lining membrane, within a distinct chamber or pericardium, along one side of which it is attached from end to end. The chamber seems as if formed by a fold of the lining membrane; and the heart is probably coated with it in the manner of a peritoneum, and is so attached to the wall of the chamber.

A large trunk vessel passes from the dorsal extremity of the heart, and immediately divides into three branches, one of which advances between the mantle and the lining membrane along the dorsal region at the back of the endostyle; another passes in the opposite direction down the dorsal margin to the bottom of the branchial sac. These two form the great dorsal branchial channel, and are equivalent to the ventral or thoracic sinus of Milne-Edwards; and they both communicate with the dorsal extremities of the transverse channels of the branchial sac. The third branch turns off at right angles to this great dorsal channel, close to the point where it is united to the heart, and, in company with another vessel, to be shortly described, penetrates the mantle and goes to ramify in the test.

From the other or ventral extremity of the heart there are two large trunk vessels given off, one to each side of the stomach. These ramify over the digestive organs, and supply a minute network spread over both sides of the visceral mass; this network may be termed the visceral plexus. It is in direct communication with a similar plexus of blood-channels or sinuses that lies between the mantle and the lining membrane of the right side; and this latter is continuous with another plexus similarly situated in the left side of the mantle; these together form what we shall call the pallial plexus. The trunk branch that supplies the left side of the stomach and the portion of the visceral plexus there situated divides into two large stems, one of which inclines towards the intestine, the other towards the œsophagus; the former passes for some little distance along the intestinal tube, and then, leaving it, penetrates the mantle in the dorsal region, and goes associated with the third branch from the dorsal extremity of the heart, already described, to ramify in the test. Thus originates the double vessel that carries the nourishing fluid to and from that envelope or tunic. The stem that goes towards the œsophagus passes along by the side of the lower extremity of the intestine, and, just before reaching the anus, turns aside to join a large vessel that extends along the ventral margin from one end to the other of the branchial sac. This, which is the great ventral branchial channel, is the dorsal sinus of Milne-Edwards. It communicates with the ventral extremities of the transverse branchial channels; and its lower extremity bifurcates, a branch passing on each side of the mantle.

The two great branchial channels, the dorsal and ventral, communicate with each other, as we have already seen, by the numerous transverse channels of the branchial sac; they likewise intercommunicate above through a sufficiently obvious channel that encircles the entrance of the sac, immediately above the vascular network, and just below the anterior cord, afterwards described; the lower extremities also appear to communicate with each other by a much-constricted channel. Thus the circle of the blood-apparatus would seem at first sight to be complete; and as the opposite ends of the heart operate upon the two great branchial channels respectively, and as the blood oscillates first in one direction and then in the other, we might look upon the mechanism as sufficiently perfect for all the purposes of the circulation.

But something is still wanting, as is evident when we refer to the fact that the influence of the heart is chiefly confined to the branchial organ, the visceral plexus, and the vascular system of the test. The pallial plexus of the right side is certainly in connexion, as we have seen, with the visceral plexus of that side; but, so far as our examination extends, the plexus of the left side of the mantle is connected with the general system through the minute network of the pallial plexus only. It is obvious that the blood-current would be feeble in these parts, if the whole of the mechanism is now before us. And, moreover, it would be most languid in the left pallial plexus—in that very portion of the mantle, in fact, that is most amply supplied with muscular fibres, and which, being comparatively free, has undoubtedly the greatest mobility. Indeed, unless some additional means exist to aid the circulation, engorgement of the blood-channels must inevitably take place in the pallial plexus when the heart pulsates in the direction of the viscera; and when its action is reversed, exhaustion would ensue in this portion of the system.

Now, though the branchial sac is attached to the walls of the pallial chamber in front and behind and along by the dorsal margin, it is necessary that the lateral or reticulated portions of the organ should be suspended, and in such a manner as to leave a considerable space between the sac and the pallial walls. Consequently a number of suspenders are provided, which, while they retain the branchial sac in its proper position, allow the required space. These suspenders are in the form of cylindrical bands or ties, and are contractile; they pass from the transverse branchial channels and from the great ventral channel to the walls of the pallial or respiratory chamber; they are hollow or tubular, and are the means of communication between these blood-channels and the pallial plexus of both sides, and also with the visceral plexus of the left side. Thus the blood-currents in every part of of the organism are brought under the influence of the heart. One of the suspenders, larger than the rest, connected with the ventral branchial channel, opens into a considerable channel or sinus in the mantle in which the nervous ganglion is placed; and the vessel which carries the blood from the heart to the great branchial channel has also much the character of a suspender.

There can be no doubt whatever of the fact that the branchial suspenders are tubular, and that they carry the blood, as above stated, from the branchial network to the visceral and pallial plexuses. I have seen in several instances the channels in the suspenders gorged with blood-corpuscles, as well as the channels connected with them in the pallial and visceral plexuses, and the transverse channels of the gill-sac; and thus by such natural injections the fact has been demonstrated over and over again. And, moreover, I have witnessed blood-corpuscles pass through the channels in the suspenders in young living individuals of *Ascidia sordida.*

When the heart acts in the direction of the dorsal extremity, the blood will at once be thrown into the dorsal branchial channel, and will pass by the dorsal trunk of the compound vessel into the test; all the transverse channels of the branchial sac will be filled; and through the agency of the suspending tubules or vessels the pallial plexuses of both sides of the mantle, as well as the visceral plexus of the left side, will be supplied in all directions; while that portion of the blood-current that is retained in the vascular reticulation of the branchia will be hurried into the great ventral channel, and by this to the ventral extremity of the heart. But before it reaches so far it will be joined by the streams derived from the visceral plexuses of both sides of the body, and in this way with that from the pallial plexus, chiefly, of the right side. The greater portion of the blood from the left side of the mantle will reach the heart by the ventral branchial channel, having been brought hither by the suspenders. The blood thus returned will likewise have commingled with it that which is drained from the vascular system of the test by the ventral trunk of that system. It is thus apparent that the blood which arrives at the heart in this direction is only a partially aerated current.

When the action of the heart is turned in the opposite direction, just the reverse of all this takes place. The blood-current will now fill, in the first instance, the visceral plexuses of both sides, then the right pallial plexus; at the same time it will reach the great ventral channel of the branchial sac, and through it the transverse branchial channels; while simultaneously the blood will be pushed into the left pallial plexus through the suspenders placed along the ventral channel. The blood that now enters the vessels of the branchial sac will be joined by numerous streamlets issuing from the suspenders, and brought by them out of the visceral and pallial plexuses, and will ultimately arrive in the great dorsal channel, and so to the dorsal extremity of the heart, at which point it will be mingled with the current from the test brought by the dorsal branch of the compound vessel ramifying in that tunic —the trunk, in fact, that in the first instance carried the blood to the test. Here, then, as well as in the former case, the current returned to the heart is only in part aerated; but the aeration is undoubtedly more complete when the stream sets in this direction than in the other; for now the only unaerated portion is that from the test, while in the first case the blood from the visceral and pallial plexuses is likewise in a partially aerated condition.

The pulsations of the heart appear to vary considerably in number even in the same individual; and the numbers of the oscillations in the same direction seem never exactly to agree; neither is there any constancy as to whether the dorsal or the ventral oscillation has the greater number. In a young individual of *Ascidia sordida*, in which the movements of the heart were carefully observed, the pulsations were counted four times in each direction, and the following was the result. On the first occasion there were 73 beats in the ventral direction, 70 in the dorsal; on the second, 64 ventral, 68 dorsal; on the third, 74 ventral, 88 dorsal; and on the fourth, 63 ventral, and 64 dorsal. It required $2\frac{1}{4}$ minutes to accomplish the beats during a single oscillation. In another individual of the same species, considerably larger than the former, but still quite immature, there were 138 pulsations in one direction, and 120 in the other. Two or three of the concluding beats of each oscillation were not so vigorous as the rest; and when the action was about to change, a dead pause ensued of about two seconds.

In *Polyclinum aurantium* the pulsations were found to be 112 in one direction and 115 in the other; and on starting, the beats were slow. They afterwards became rather rapid, and before ceasing were again retarded; the action then stopped for a second or two before recommencing in the opposite direction. The pulsations in *Botrylloides radiata* are nearly as numerous as they are in the last species. In one individual 102 beats were counted in the one direction, and 115 in the other.

The above account of the circulation will be found to agree with Dr. Lister's description of it in *Perophora*, so far as it was determined in that form; but that excellent observer did not detect the flow of the blood through the suspenders, although "filaments" attaching the branchial sac to the mantle are described and figured by him. Their function as blood-carriers seems equally to have escaped detection by Van Beneden, though he must have been aware of their existence as bands or ties; for they were figured by Savigny*, who described them as ligaments attaching the branchia to the inner tunic, and they are well known to anatomists generally. Van Beneden, however, discovered the necessity of a passage for the blood-current from the "periintestinal cavity" to the branchia to prevent engorgement when the pulsations of the heart were continued for any length of time in one direction. He therefore believed that the required communication was effected through the agency of the "respiratory tentacles"†.

It will now, however, be of no avail to discuss the improbability of such an opinion, since ample communications have been demonstrated. But it may be remarked that these tentacles are undoubtedly hollow, and that in each there is a double channel, that the blood will assuredly pass up one of them and down the other, and that it will oscillate in unison with the movements of the heart. In fact, Van Beneden states that he has seen it do so. I have observed nothing to warrant the belief that either of the channels is in immediate communication with the vascular network of the branchial sac. On the contrary, they both seem to me to open into the pallial plexus, which of course is continued into the wall of the inhalant tube.

The blood-system does not appear to vary much in the Tunicata: though certainly I have not traced it in the other genera so completely as in *Ascidia*, yet enough has been seen to warrant the above assertion. The heart is very similar throughout all the various forms examined; but its position is not by any means constant. In *Ascidia parallelogramma* it is placed on the anterior margin of the stomach, and in connexion with the left side of the mantle or inner tunic, following the removal, in this instance, of

* Mémoires sur les Animaux sans Vertèbres, pt. ii.

† *Op. cit.* p. 113.

the visceral mass from the right to the left side. In *A. intestinalis*, in which there is developed an abdominal chamber, it is doubled upon itself, and lies in this chamber towards the dorsal margin and between the stomach and the bottom of the branchial sac. The heart in *Stycla* is very long, and narrower than usual; in this form it lies between the inner tunic and lining membrane on the left, and a little way from the posterior extremity of the mantle, following the curvature of, but at some little distance from, the alimentary tube. The posterior extremity opens into the dorsal branchial channel a considerable way up the endostyle; the ventral extremity is attached to the stomach, to either side of which it gives a branch in the usual manner. In *Pelonaia* the heart is likewise in connexion with the left side of the mantle, and in other respects resembles the arrangement in *Stycla.* And in *Molgula* it holds much the same situation—but is placed between the reproductive mass which is above it, and a hollow cylindrical body with hard walls, the nature of which is not understood.

The branchial sac is usually more complicated than is generally supposed. Hitherto its mechanism has been spoken of in this communication only so far as was necessary to the full comprehension of the blood-system; it is now time to say something respecting its more minute structure. In all the Tunicates there must of necessity be present the two great branchial or thoracic channels (the dorsal in connexion with the endostyle, and the ventral at the opposite side of the thorax), even when the branchial sac is only partially or not at all developed; and in every instance where a true gill is present, the transverse channels or primary vessels must also exist. These latter may be considered the essential or elementary parts of the respiratory organ; the minute details, consisting of secondary vessels, are variable, even in very closely allied species, and are not always present.

The simplest form of the organ that occurs in the genus *Ascidia* is found in *A. venosa.* In this species the transverse or primary vessels, or channels, are placed at regular intervals, and scarcely vary at all in size; and between and opening into them at right angles are numerous small, longitudinal, secondary vessels divided by elongated spaces or stigmata; so that the whole forms a reticulation of vessels, in which the transverse channels are large and distant, the longitudinal ones small and numerous and divided only by narrow open spaces. Or the structure may be described, for convenience, as it frequently is, as a vascular membrane with large transverse channels and minute longitudinal ones connecting the former, and divided by narrow elongated stigmata. This is the true aerating surface of the gill; and were there no additional appendages, the organ would appear to be composed of numerous transverse series of short longitudinal vessels and narrow openings, divided by large transverse channels or vessels ; it would appear to be, in fact, what it essentially is. But on first inspection, with the aid of a low magnifying-power, it seems to be formed of a comparatively coarse reticulation of longitudinal and transverse vessels of nearly equal size, crossing each other at right angles, and having four or five narrow longitudinal openings or stigmata in each square mesh, dividing as many minute vessels.

This appearance is produced by the existence of a number of stout so-called longitudinal vessels or bars that extend from one end to the other of the branchial sac, and project considerably from the inner surface of the organ, to which they are attached only at the points where they cross the transverse channels. Here they are supported upon short wide pedicles, through which they receive their supply of blood from these channels ; they are thus lifted some little distance above the general surface of the gill. At these points the longitudinal bars are a little enlarged, and have on their upper margin a stout elongated papilla with the extremity rounded. There is thus a papilla at the angles of each mesh ; and they are all inclined towards the ventral side of the respiratory sac, and have on the upper surface, and in front, an elongated disk, which is apparently ciliated.

The walls of the longitudinal bars are comparatively thick ; and hence these organs have a certain degree of rigidity. It is not very easy to determine of what use they are ; but perhaps their chief function is to protect the more delicate tissue of the true aerating vascular surface ; while the papillæ will conduce to the same end, and by the aid of their cilia probably sweep the sedimentary matters towards the oral lamina, the water being beat through the stigmata by the cilia that fringe their borders. From the stiffness of the bars themselves it may be inferred that they will also give support to, and keep stretched out, the vascular network of the sac. They seem ill calculated, on account of the thickness of their walls, to give much assistance in aerating the blood, and are certainly unnecessary as part of the circulatory mechanism.

The blood, as we have already seen, is brought to and taken from the aerating reticulation by the dorsal and ventral branchial channels, and by numerous suspenders connecting it with the visceral and pallial plexuses. We have also traced the blood through the principal channels of the organ from one side of it to the other. All, therefore, that remains to be done is to follow the flow of the stream through the minute portions of the structure.

The extremities of the heart, we have seen, do not open into the ends of the two great branchial channels, but a considerable way above their lower terminations. It is consequently evident that the blood will move upwards in these channels above the point where it enters, and downwards below it; and when we consider the action of the current so brought to the transverse channels, it is clear that the flow will be in contrary directions in the small longitudinal or secondary vessels above and below this point. Now it has been already stated that on the reversal of the action of the heart there is a pause of a second or two, so that for this period the currents cease to move and the fluid becomes perfectly stagnant. On resuming its function, the first act of the heart is to dilate; consequently, the blood is drawn towards it from the respiratory organ; and it follows, as a matter of course, that the fluid in the secondary vessels above the point just alluded to in the great branchial channels must flow downwards, and in those below this point upwards. This will be the case whether the blood is brought to the branchial sac by the dorsal or the ventral channel. Such downward and upward set of the blood-current in the secondary vessels has actually been observed in *Perophora* by Dr. Lister, who states that "the horizontal vessels were connected also by the smaller or vertical channels between the spiracles—the set of the current in the latter being upwards for the two lower rows, and downwards for the two upper rows." If the heart in the first instance threw the blood into, instead of drawing it from, the gill, the reversal of this motion would take place; namely, the flow in the secondary vessels above the point indicated would be upwards, and downwards below it.

Such are the characters of the branchial sac as seen to exist in *A. venosa*. The minute network, however, is not continuous throughout the whole organ, but is interrupted in such a manner as to show that it is composed of two lateral lobes or laminæ. It is divided along the dorsal line by two parallel folds of the lining membrane, which are separated by a deep groove; the tissue at the base of each fold is stiffened by a flattened rod of a somewhat rigid, opake, yellowish substance, which together form the endostyle, that lies, as it were, in the bottom of the groove, along which the rods appear to be united. The upper extremities of these folds diverge right and left, and become continuous with the lower member of what may be termed the anterior cord or collar—two narrow folds also of the lining membrane that encircle the base of the respiratory tube, a little above the anterior margin of the branchial sac, and having the circular blood-channel, previously mentioned, immediately below them. The ventral margin of the sac is furnished with a wide, longitudinal, delicate, membranous fold, which apparently also originates in the lining membrane, and which interrupts the continuity of the minute network in this direction. This is the ventral or oral lamina; it extends from end to end of the branchial sac, and is ribbed transversely; the margin is entire. The mouth opens close by its left side, about one-third from the lower extremity; the upper extremity for some little way downwards is divided longitudinally, showing that the lamina is really composed of two lateral membranes; and each division is united to the lower member of the anterior collar, much in the same manner as the latter is attached to the dorsal folds connected with the endostyle. The upper member of this collar is divided from the lower by a narrow groove, and is uninterrupted by either the oral lamina or the dorsal folds. The oral lamina is connected below by another narrow cord to the posterior extremity of the dorsal folds: this is the posterior cord.

In this way are traced the boundaries of the two lateral laminæ composing the branchial sac. They are attached by their upper borders to the walls of the pallial or respiratory chamber, a little below the anterior collar or cord; the dorsal margins are attached along the sides of the endostyle, and the lower margins along the line of the posterior cord. In all other parts the two lobes are free, except at the points where the suspenders bind them to the walls of the chamber, and where the extremity of the œsophagus penetrates the branchial sac; and here, of course, the latter is attached to the alimentary tube. The supposed function of the endostyle has been already indicated; the folds of the lining membrane to which it is adherent are no part of the gill; neither can the oral lamina be considered a portion of the breathing-organ: it is certainly highly vascular; that is, minutely ramifying blood-channels can be traced in it; but similar vessels (or channels) are seen in all the membranes of the organism, and also occur in the dorsal folds in connexion with the endostyle. The office of the oral lamina is to conduct the food to the mouth. And it has already been stated that the sedimentary matters are there accumulated and formed into a cord, and so carried to the oral aperture along the lamina. The anterior cord may perhaps also aid in collecting sedimentary aliment, if it be ciliated, as its homologue in *Salpa* is stated by Professor Huxley* to be.

The simple form of gill above described is not by any means constant in *Ascidia*; in fact it seems but rarely to occur in this genus. The same simplicity of structure, however, is found in *Pelonaia*, with only some unimportant changes. In *Clavelina* and *Perophora* the vascular network is not more complicated; and in the former, at least, the longitudinal bars have entirely disappeared. And in it there are numerous transverse laminæ which are adherent throughout to the walls of the transverse channels; they are united to the filaments of the oral lamina, and perhaps are mainly instrumental in carrying the food in that direction. The structure of the gill is equally simple in the compound Tunicates; and in them the longitudinal bars seem to be occasionally present.

In *Ascidia mentula* and *A. sordida* the branchial network is fundamentally the same as in *A. venosa*; but in the two former, and in some others, it is minutely folded longitudinally, so that, on making a transverse section of it, the edge presents a deeply undulated line. The surface is not altogether unlike corduroy; it is, in fact, finely plaited (or crimped, as the laundress might say); but the flutes or grooves between the ridges or plaits are interrupted wherever the transverse vessels cross them, the vessels at these points filling up the hollows. Thus there are numerous septa formed, turning the grooves into series of minute recesses or pouches.

The longitudinal bars are strong and raised considerably above the inner surface in *A. mentula*; and there are smaller intermediate papillæ, as well as larger ones at the points where the bars cross the transverse vessels. All the papillæ bear ciliated disks; and a wide membrane stretches from the back of the larger papillæ for a considerable way along the transverse vessels. In *A. sordida* the bars are likewise strong; but the papillæ are rather small, and there are no intermediate ones. Between the longitudinal bars there are two oval ciliated disks, one on either side of the middle line of the transverse vessels.

The oral lamina in *A. sordida* is a wide plain membrane; but in *A. mentula* it is strongly ribbed transversely; the ribs passing beyond the margin as fine points give to it a pectinated appearance.

* "Observations upon the Anatomy and Physiology of *Salpa* and *Pyrosoma*," Phil. Trans. 1851, pt. 2. p. 567.

In *Stycla tuberosa* and its immediate allies we have another modification of the branchial network. In them it is provided with eight simple longitudinal folds or laminæ—four on each side of the oral lamina; these stretch from one end of the sac to the other, and terminate below by the sides of the oral orifice. The network is, in other respects, as simple as it is in *A. venosa*, there being no minute plaiting such as is seen to exist in *A. mentula*. The folds, however, give to it a very interesting character, inasmuch as we observe in them a very ready and efficient mode of increasing the aerating surface, as, indeed, the same end is gained by the minute plaits in the vascular network in *A. mentula* and *A. sordida*. In *Stycla* the folds are formed in exactly the same way as those minute plaits; that is, they are each composed of a fold of the branchial sac, and the space within is divided into pouches by septa situated at nearly equidistant points. In this genus the transverse vessels vary considerably in size, there being usually one or two smaller between larger ones; and the septa are placed wherever the latter cross the structure. Thus a series of pouches of nearly equal size occupy the interior of the folds, and open at the outer surface of the branchial sac into every part of the atrium. In fact, we see here an arrangement very similar to that observed in the interbranchial water-channels in the Lamellibranchs; and in this case, as in them, the purpose is to allow the water, after permeating the walls of the fold or lamina, to escape externally.

The longitudinal bars in *Stycla* assume the form of delicate ribbon-like membranes attached by one edge to the principal transverse vessels; they are numerous, and are found on the folds as well as on every other part of the organ. The oral lamina is a wide simple membrane.

The branchial sac in *Molgula conchilega* and its allies is characterized by longitudinal folds or laminæ, formed much in the same way as those in *Stycla*. In the former there are six such folds on each side of the sac. The vascular network, however, is very different, having the secondary vessels, or those which are usually arranged at right angles to the transverse channels, disposed in imperfect spiral coils or convolutions, the vessels themselves frequently intercommunicating; consequently the stigmata or open spaces separating them are broken into various lengths. There are also a few delicate radiating vessels which pass from the centre of the coils to the circumference, but mostly in the direction of the transverse channels that convey the blood to and from the coils. The chief purpose of these radiating vessels is apparently to prevent engorgement of the coil, and to aid the reflux of the stream by conveying the blood in the most direct manner to and from the centre of the coil. When the spiral arrangement is more imperfectly developed than usual, the radiating vessels are very irregularly dispersed; but even in such cases there can be little doubt that their function is as above stated. The longitudinal bars have the ribbon-like character of those in *Stycla,* and are principally confined to the folds.

Ascidia parallelogramma has also the secondary vessels spirally arranged, as originally pointed out by Mr. Alder*; and here the coils, which form slight conical eminences, are disposed in regular transverse series between the transverse channels. The coiled vessels do not so frequently intercommunicate as they do in *Molgula*; consequently the stigmata are much longer, being less interrupted. The radiating vessels are not numerous, and they pass from the centre of the coil to the transverse channels. The longitudinal bars are more rigid and cord-like than usual; they project considerably from the surface of the gill; and the papillæ which are attached to them are not elevated, but inclining backwards are united throughout their length, and give support to wide membranes that extend from the surface of the transverse vessels. In this species the oral lamina is replaced by a series of well-developed filamentous processes.

The most perfect, however, of the spiral type of gill is found in *Molgula arenosa.* In this interesting species the interior of the branchial sac is furnished on each side with six or seven wide, longitudinal, ribbon-like bands, which are attached by one edge to the transverse vessels at the points where they cross them. These bands, how like soever in general appearance, are not to be confounded with the branchial folds in *Stycla* and *Molgula*; they are the homologues of the longitudinal bars so constantly present, and with the transverse vessels give to the surface a coarse reticulation, the square meshes of which are each occupied by a conical eminence. On account of the prominence of the longitudinal bands these eminences, which look like so many miniature bee-hives, seem to be arranged in six or seven longitudinal series. Each cone is formed of a double spiral coil of secondary vessels united at the apex; the coils are perfect, and the stigmata, which are coextensive with them, appear to be scarcely, if at all, inter-

* "Observations on the British Tunicata," Ann. & Mag. Nat. Hist. S. 3. vol. xi. p. 158.

rupted by intervascular communications. Radiating vessels, however, which are sufficiently numerous to prevent engorgement, pass from the apex of each cone to the transverse vessels, and are the principal interruptions to the continuity of the spiral stigmata. The oral lamina in this, as in all the members of the genus, is a plain simple membranous band.

All the simple Ascidians that have come under my notice, not even excepting *Pelonaia*, have a collar of tentacular filaments situated at the base of the incurrent tube, some distance above the entrance of the branchial sac; indeed the distance in some species is considerable, and no instance has occurred in which they could be said to be connected with the gill. They are usually linear or slightly conical, and are rather numerous, except in *Pelonaia*, which has not more than twelve or fourteen; but in *Molgula* and in some of the other *Cynthiadæ* they are branched or pinnate, and are not very abundant. They, however, all agree in being soft, delicate, hollow organs; and the simple ones ,at least, have the interior divided by a septum into two longitudinal channels, so that the blood will circulate freely through them. They appear to be an outgrowth of the lining membrane, and are supplied with blood from that which flows between it and the mantle or inner tunic.

That enigmatical organ the branchial tubercle (the anterior tubercle of Savigny) is situated in the space between the tentacular filaments and the anterior margin of the branchial sac, in contact with the upper membrane of the anterior cord or collar, and immediately in front of the upper extremity of the oral or ventral lamina. It is formed of two parallel folds of the lining membrane pressed close together and united at the extremities; they seem but as one fold, and are bent into a loop with the ends turned towards the inhalant orifice, and, inclining inwards, are a little convoluted. Thus the organ assumes a rounded or oval form, rising above the surface to which it is attached as a depressed compact tubercular swelling. An opaque white line marks the separation of the two folds, and follows the convolutions to the extremities.

This is the form that this curious tubercle assumes in *Ascidia scabra*, *A. affinis*, a closely allied species, *A. mentula*, and *Pelonaia corrugata*. In *A. sordida* one of the extremities turns inward, the other outward, so that both are bent in the same direction. But more striking modifications occur in some other species. In one allied to *A mentula* there are three loops, crowded upon each other, and having their extremities only slightly incurved; and in another closely related form the organ is dense, large, and somewhat quadrangular, with numerous irregular convolutions formed apparently of several loops of the lining membrane. In *Stycla tuberosa* and *S. mamillaris* it is large, oval, and disk-like, with the extremities so indistinct as to be scarcely traceable. The reverse of this is the case in *Molgula conchilega*, in which it is almost crescent-formed, with the extremities very obvious and well turned inwards. And in *Ascidia venosa* it is still more simplified, being a mere horseshoe-like loop, with the extremities pointed and very slightly incurved.

It is not easy to assign a function to this peculiar organ—though, from its position at the entrance to the branchial sac, it may be inferred that it is of the nature of a special sense, testing the quality of the inhaled water. Taste could be of little use to an animal that has not the power of selecting its food; but it would seem necessary for the creature to be warned of the approach of aught deleterious in the respiratory currents. The function of this organ is therefore probably more akin to that of smell than of taste. It is certainly of some importance in the economy of the animal; for it is constantly present, and is usually closely associated with the ganglion. In some species the tubercle rests upon the nervous centre; and when placed at a little distance from it, a nerve may generally be traced running towards (and in some instances having all the appearances of supplying) it.

The nervous system is in a very rudimentary condition in the Tunicata. There is but one ganglion; and it is invariably placed between the two respiratory tubes, in a blood-sinus situated between the inner tunic and lining membrane, which sinus, communicating directly with the great ventral channel of the branchial sac, will be well supplied with aerated blood. The ganglion is fusiform, more or less elongated in the antero-posterior direction, and usually a little constricted in the middle, as if composed of two centres. In *A. mentula*, and in several other species that have been examined, it is partially folded in a much folliculated gland-like substance, and gives off from each extremity three or four nerves, all of which go to the respiratory tubes and to the adjacent portions of the inner tunic or mantle. A branch from one of the principal nerves has been traced to the branchial tubercle in one or two species. There is no variation of any consequence in the nervous element in any of the forms examined.

The organization of *Salpa* is highly instructive; for in this form we have a Tunicate in which development has been arrested, and which, to a certain extent, has an embryonic character. In it the branchial sac is entirely absent, and the circulatory system is much in the same condition as it is in the young of *Ascidia* before the respiratory organ is developed.

In *Salpa* the outer tunic or test appears to be quite free from the inner tunic or mantle, except at the margins of the anterior and posterior orifices, where they seem to be united. The inner tunic and lining membrane, or that which forms the inner wall of the respiratory cavity, are, on the contrary, adherent throughout, spaces only being left for the passage of the blood-currents; for it is between this tunic and membrane that the "sinus-system" is situated. The respiratory cavity corresponds pretty accurately to the pallial chamber of a simple Ascidian—were the branchial sac entirely removed, leaving only the endostyle with its two lateral folds, the ventral or oral lamina, and the connecting cords.

On examining the great respiratory chamber or cavity in *Salpa spinosa*, for instance, an endostyle with the two lateral membranous folds, similar in all essentials to that organ in the other Tunicata, is seen adhering to the dorsal wall of the cavity; and the so-called "branchial band" or "gill" is conspicuous on the opposite side, passing forward from the nucleus in an inclined position, the posterior extremity being attached in the vicinity of the mouth, the anterior to the ventral wall of the cavity. The two folds in connexion with the endostyle and the "branchial band" are connected in front by a narrow band (the "ciliated band" of Huxley) that encircles the anterior extremity of the respiratory cavity: and another similar band, or pair of parallel bands, passes from the posterior end of the dorsal folds, and terminates near to the posterior extremity of the "branchial band." Thus we observe certain lines or bands which, together with the endostyle, correspond to the boundary lines of attachment of the branchial sac of a simple Ascidian; and if we suppose a vascular network extended from either side of the endostyle to the lateral margins of the "branchial band," and imagine it to be attached in front and behind along the ciliated bands, we shall see how readily a Salpa may be made to assume the most striking feature of an ordinary Ascidian.

Now the ciliated bands are the homologues of the posterior cord and the lower member of the anterior cord or collar of the branchial sac of the simple Ascidians; and the "branchial band" is the equivalent of the oral or ventral lamina of the same group. The relation of the ciliated bands, particularly the anterior, to the "branchial band," and the characters of the latter, sufficiently prove this.

The so-called branchial band has the appearance of a cylindrical tube; but it is easily seen that it is formed of two laminæ, the lower or ventral margins of which are a little separated, while the upper or dorsal are brought together, forming a ridge along this margin. A large blood-channel runs along in connexion with, and immediately below, the ventral margins; this is the homologue of the ventral branchial channel. The two laminæ rise, as it were, from the sides of this channel, and inclining towards each other, are united along the dorsal ridge as just stated; but towards the anterior extremity of the organ they separate, and become united to the ends of the ciliated cord or band in exactly the same way as the lateral divisions of the oral lamina join the anterior cord or collar. In fact, in both *Salpa* and *Ascidia* the one organ seems to be a continuation of the other, as they are, no doubt in both, productions of the lining membrane, the blood-channel itself being developed in connexion with the same membrane. The "branchial band," we thus see, corresponds to the oral lamina in being composed of two laminæ, in its relation to the anterior ciliated band or collar, and in its connexion with the great ventral blood-channel. And, moreover, like the oral lamina in several of the *Ascidiæ*, it is transversely ribbed. In *Salpa* the ribs are stout and strongly ciliated; and there can be no doubt they are also ciliated in *Ascidia*.

In *Salpa*, then, the so-called branchial band cannot be looked upon as a true gill; and homologically it does not represent the branchial sac at all, but only that appendage of it the oral lamina. And as the function of the latter seems to be chiefly, if not exclusively, to carry the food to the mouth, the same office is probably performed by the so-called gill in *Salpa*. And, indeed, without some such help it is difficult to see how such an animal would be able to take its food. There can be little doubt that the walls of the respiratory cavity, as has been suggested by Professor Huxley*, chiefly effect the decarbonization of the blood; while the so-called gill will aid in this operation in proportion to its vascularity; as must, indeed, all the tissues bathed by the respiratory currents.

The ganglion lies on the ventral side of the respiratory cavity, between the lining membrane and inner tunic, a little in advance of the ciliated band, and directly in front of the anterior extremity

* *Op. cit.* p. 570.

of what we may now term the oral lamina (the pseudo-gill). All the nerves are given to the walls of the cavity—in other words, to the inner tunic or mantle. The anterior extremity of the ganglion is produced a little, giving an appearance to the organ as if composed of two centres. On the anterior surface of the produced extremity there are three or four imperfectly formed black pigment specks, having the appearance of rudimentary eyes, which, however, Professor Huxley considers auditory capsules.

The "languet," with its ciliated "fossa," is placed just in front of the ganglion, consequently on the same middle ventral line with it and the oral lamina; it is a long, tapering, conical process, with a longitudinal groove which widens at the base where it joins the fossa, over which it seems to straddle. There can scarcely be any doubt that this is an organ of special sense; and it would appear probable that its office is to ascertain the quality of the respiratory currents, and may therefore be olfactory. Thus in function the "languet" would seem to agree with the branchial tubercle so constant in the other Tunicates; but it is, moreover, homologically speaking, the same organ, as appears demonstrated by its position in relation to the ganglion, the ciliated band, and the pseudo-gill. Like the tubercle, too, it is a production of the lining membrane; and, as indicated by the longitudinal groove, like it, also, the "languet" is probably formed of two portions or folds of this membrane. It must, therefore, not be confounded, as it frequently has been, with the tentacular filaments of the oral lamina in *Clavelina*, *Pyrosoma*, and several other simple and compound Ascidians.

The homologies, however, do not stop here; the clear anastomosing vessels or tubes ramifying over the surface of the intestine, described and figured by Prof. Huxley*, and supposed to "represent a hepatic organ," or "a sort of rudimentary lacteal system," are, there can be no doubt, the homologue of the rudimentary liver before described in *Ascidia* and in some of the Cynthiadæ; and, indeed, the structure appears to resemble very closely that of the hepatic organ in *Ascidia parallelogramma*. The "mass of clear cells," the "elæoblast" of Krohn, according to Huxley, may perhaps prove to be the same as the well-known cell-structure before described as coating the alimentary tube in the *Ascidiæ*; but this is mere conjecture.

Thus we see how close the relationship is between *Salpa* and *Ascidia*; with *Clavelina*, however, the connexion is still more intimate. This is undoubtedly a near ally; it is only necessary to

* *Op. cit.* p. 570.

look to immature specimens to be satisfied of this. When the young *Clavelina* is about one twentieth of an inch long, and when the thoracic portion would scarcely be half that length, the thorax is remarkably like the embryo of *Salpa*. In profile both have a subtriangular form, the anterior opening being placed at the angle in front, and the posterior at an angle situated considerably backward, the young of *Clavelina* having the two orifices nearly as far apart as they are in the embryo of *Salpa*. At this early period of growth the endostyle is distinctly developed in both forms, and the ganglion and the oral lamina are clearly indicated, also the ciliated band or anterior collar. So far, everything is alike; the general similarity of the respiratory cavity is obvious enough; and were the nucleus in *Salpa* produced a little more than it is backwards, the resemblance of the two would be almost complete. But in the young of *Clavelina* there are, in addition to what has already been described, the tentacular filaments of the incurrent tube, which are now of considerable size; and the branchial sac has already commenced its development.

The latter organ, however, is in an exceedingly rudimentary condition: only a single transverse channel or primary vessel on each side of the great ventral channel has made its appearance, and does not yet extend much more than halfway across the thoracic or respiratory cavity, on its way (so to speak) to the dorsal channel in connexion with the endostyle. On each side of these growing primary vessels five or six secondary vessels, at right angles to them, have commenced to sprout; and the distal extremities of all of them, as well as of the primary vessels themselves, open through the lining membrane of the thoracic cavity into the sinus-system between it and the inner tunic. Thus is defined, on either side, the nascent atrium, which is only an extension of the cloaca that had been previously formed. Shortly another primary vessel makes its appearance, extending from the ventral channel and connected laterally with the extremities of the secondary vessels already formed; and then another series of secondary vessels is developed, and afterwards another primary vessel, and so on, gradually increasing the length of the two branchial leaflets (if they may be so called), which at the same time grow in breadth, passing further and further across the thoracic cavity until at length they reach the sides of the endostyle; all the while the primary and secondary vessels along the margins of the growing organ, open into the pallial sinuses in the manner already indicated; so that the boundary of the water-space or atrium is well defined, and is always coextensive with the expanding gill. The oral processes, which in this animal occupy the place of the lamina, are produced one by one, in accordance with the appearance of the primary vessels; and the vascular suspenders likewise originate at the same time.

It is unnecessary on this occasion to trace the development of the branchial sac further, or with more minute details; it should be observed, however, that the growth of the gill undoubtedly originates in the great ventral channel, which is itself a production of the lining membrane, and that during the development of the organ it is connected with this membrane, and that this connexion is ever afterwards maintained by the vascular suspenders. It may also be remarked that in no stage of the growth is the gill ever connected, on the one hand, with the margin of the oral orifice—or, on the other, with the tentacular filaments of the incurrent tube, which are, indeed, placed at a considerable distance from the upper margin of the gill; and the lower margin is some way above the oral orifice.

The above description of the development of the gill does not exactly agree with that given by A. Krohn of the branchial sac of *Phallusia* (*Ascidia*) *mamillata**. According to this author, there are at a very early stage of development two excurrent orifices, one on each side of the middle line,—necessitated by the fact that the gill commences to separate itself from the walls of the cavity at two points simultaneously, thus forming two separate water-spaces, one on each side of this line,—the great ventral blood-channel apparently not being yet detached from the inner tunic. It is not till the "branchial sac is everywhere perforated" that these water-spaces, according to this naturalist, are united by the formation of the cloaca. I have certainly not seen the young of *Clavelina* in a sufficiently early stage of development to warrant the assertion that such does not take place in this form; but assuredly in it, at a very early period, the cloaca freely communicates with the water-space or atrium on each side. At the same time it must be allowed that it is more than probable that, at the earliest stage of existence, in *Clavelina* and in other Tunicates the great ventral channel is united throughout to the wall of the pallial chamber; and hence the statement of Krohn does not seem at all unlikely. And, moreover, we thus learn that this great blood-channel is developed in connexion with the lining membrane, with which it continues ever afterwards more or less connected. We have already seen that the transverse or primary vessels take their origin in this same vessel, and that they in their turn give

* "On the Development of the Ascidians," by A. Krohn—'Scientific Memoirs', edited by Henfrey and Huxley, 1853, p. 324.

off the secondary vessels: these are the essential parts of the branchial tissue; and when we look to its anatomical structure as well as to its mode of growth, we can scarcely doubt that the network of the gill is truly vascular. Speaking, therefore, of the branchial sac as a perforated membrane, as is frequently done, gives an erroneous idea of its apparently true nature.

The longitudinal bars which have been so frequently alluded to, and which lie in a plane a little above the inner surface of the respiratory sac, are non-essential parts of the organ, their function apparently being, as previously stated, to protect the surface of the gill, and, by the aid of their cilia, to sweep the alimentary matters towards the oral lamina. They are not always developed: they do not exist in *Clavelina*; neither are they apparently present in *Perophora*; and they seem to be absent in several of the compound Ascidians; in *Doliolum* they have likewise disappeared.

It is stated above, that *Clavelina* is nearly related to *Salpa*; but *Pyrosoma* and *Doliolum* come much nearer to it in their general structure, as well as in the details of their organization. Unfortunately I have never seen either of these two interesting forms; but, judging from the able descriptions of them by Prof. Huxley in the 'Philosophical Transactions,' they both present examples of imperfectly developed gills. In *Pyrosoma* the secondary vessels are entirely absent, and the primary vessels of the two lateral laminæ of the branchial sac do not reach the endostyle, their development having been arrested before they extended so far across the respiratory cavity; their distal extremities, however, will undoubtedly open into the system of pallial sinuses; in no other way can the flow of the blood through the gill be explained: the circulation is therefore to this extent embryonic. "The longitudinal bars" of Huxley are the homologues of what have been so designated throughout this communication, and are therefore not to be confounded with the true vascular portion of the gill. To turn *Pyrosoma* into a *Salpa*, little more seems necessary than to arrest entirely the growth of the primary branchial vessels, and to give to each individual a separate test.

An arrest of development of these vessels is carried to a much greater extent in *Doliolum*. In this form the secondary vessels have not only disappeared, but the longitudinal bars are also absent, and the primary vessels themselves only very imperfectly developed. The two bands named by Huxley respectively the "epipharyngeal" and "hypopharyngeal" in this curious form, undoubtedly indicate the line of the great ventral channel and oral lamina, bent up in accordance with the peculiar development of the creature. In the *Ascidiæ* that have the branchial sac prolonged behind the mouth, the ventral channel extends likewise behind the mouth, as well as in front of it; and if we suppose the endostyle to be shortened in these species, and the posterior portion of the sac to be consequently drawn backward and upward, the corresponding extremity of the ventral channel would pass up the dorsal side of the pallial or branchial chamber; and thus this axis of the gill would at once take up the position it occupies in *Doliolum*: that is, part would be above or in front, and part below or behind the mouth; part would form a "hypopharyngeal" band, and part an "epipharyngeal" band.

Now the primary vessels or "tubular bars" originate in the sides of these bands, and are, as already stated, very imperfectly developed, extending, as they do, only for a short distance, and then terminating by opening through the lining membrane of the respiratory cavity into the pallial sinuses, just we have supposed the similar vessels do in *Pyrosoma*. The vessels or "bars," however, of the middle portion of the gill, according to Prof. Huxley, do not so terminate, but end in free loops. The branchial sac is, indeed, in such a rudimentary condition that one step more in its degradation and it would entirely disappear, and *Doliolum* would be scarcely distinguishable from *Salpa*.

In *Appendicularia* the gill is wholly absent; but the oral lamina is represented by the "ciliated band," which adheres to the ventral surface of the respiratory cavity; and it is interesting to find that the anterior extremity of this band divides into two branches, which, passing towards the dorsal region, encircle the cavity a little below the ganglion, just as the anterior ciliated band does in *Salpa*, as the anterior band or collar does in *Ascidia*.

In this interesting form, in which the embryonic characters have become permanent, we see the oral lamina still adhering to the wall of the respiratory cavity, as well as the endostyle and anterior collar or ciliated band. All these parts, then, appear to be equally developments of the lining membrane; and the gill, which in the higher forms has been described to originate in the oral band, or rather in the great ventral channel, which always accompanies it, must likewise be considered a production of this same membrane, and which, too, we have seen it is connected throughout its development.

It is not my intention, on the present occasion, to enter at any length on the relation that subsists between the Tunicata and the Polyzoa on the one hand, and the Tunicata and the Lamellibranchiata on the other. Nevertheless it seems desirable to say a few words on this important branch of the subject before concluding, with the view merely of indicating what appears to be the result, in this respect, of my recent investigations.

That the Polyzoa are very closely allied to the Tunicata is now generally admitted ; opinion, however, is divided respecting the homology of the tentacular crown—some naturalists maintaining that it is represented by the branchial sac, while others believe that it is homologous with the tentacles of the respiratory tube, and that the branchial sac is really the dilated pharynx of the polyzoon. These two views have been ably advocated respectively by Prof. Allman and Prof. Huxley.

In my paper on the "Freshwater Bryozoa," before cited, the opinion that the branchial sac is homologous with the tentacular crown was maintained ; but my belief in this view has been of late much shaken, and even Prof. Allman's ingenious explanation of his theory seems to me no longer satisfactory. The peculiar idea entertained by this able physiologist is, that the lophophore of a Hippocrepian Polyzoon is the homologue of the ventral branchial channel of the Ascidian, and that the tentacles of the former correspond to the transverse or primary vessels of the branchial sac. But the lophophore is an appendage of the mouth, and is developed from the margin of the oral orifice, and therefore can scarcely be considered to be the true representative of the branchial channel, which does not seem to be so related, but appears rather to be developed in connexion with the lining membrane coating the pallial cavity, and has all the appearance of a true vessel in direct communication with the heart. And there are other difficulties in the details of this view, to which it is unnecessary, at this moment, to make further allusion.

The view so forcibly advocated by Prof. Huxley seems to rest more upon a wide and philosophical generalization of Molluscan organization than on anatomical and embryological data, and is therefore difficult to discuss from a standpoint of the details of such matters. It must, however, be stated that the anatomical facts, so far as I have been able to examine them, do not seem to contradict this hypothetical view ; indeed, in many respects, they appear rather to support it. The anatomical data, nevertheless, will, I think, bear another interpretation, which, perhaps, it will be well to consider, merely premising that I have no wish to support it further than as a suggestion which has a few corroborative facts in its favour: more information is still required before this matter can be determined satisfactorily. The interpretation alluded to is, that the branchial sac is a new and distinct development, as the endostyle is, and as are the oral lamina, the branchial tubercle, and the tentacular filaments of the inhalant tube,—and that all these organs have equally their origin in the lining membrane or inner tunic of Huxley, and have no homological representatives in the Polyzoa.

And, further, this interpretation of the facts leads to a belief that the branchial sac is the rudiment of the Lamellibranchiate gill, the structure of the two organs being essentially the same. The principal blood-channels in the gill of the Lamellibranch are simple transverse vessels; and the most persistent and essential parts in the structure of the branchial sac of the Tunicates are the transverse or primary vessels. Thus, fundamentally, these organs are similar. And when the branchial sac is furnished with longitudinal folds, as generally is the case in the Cynthiadæ, the primary vessels assume relatively the same position as their supposed homologues do in the gill-plate. The folds, too, as the nature of the structure implies, are formed of two laminæ united at their distal margins, and have the space between them divided by septa into transverse pouches, which only want to be elongated by the further development of the fold to make them correspond in every respect to the interbranchial water-tubes of the gill-plate of the Lamellibranch. And already the pouches subserve the function of water-tubes.

Now we have seen that the branchial sac is composed of two lateral laminæ, originating in the great ventral channel, and extending to the endostyle; and in *Pyrosoma* and *Doliolum* we observe that these laminæ are curtailed in their development before they reach so far; in the latter, in fact, they are exceedingly limited. There is, therefore, no difficulty in supposing that the branchial sac might be reduced to merely four such folds as above alluded to, two being on each side of the mouth and oral lamina. Were such the fact, there would be four rows of orifices, corresponding to the pouches in the folds on the outside of the gill, opening into the cloaca, exactly like the four rows of openings of the interbranchial water-tubes communicating with the anal chamber in the Lamellibranchs. Thus, in all external characters, we should have here a very complete representation of the four gill-plates of that group. Each pair of the gill-plates, however, in the Lamellibranchiata has its own proper efferent blood-vessel leading directly to the heart; while our supposed transformed organ has only one such trunk vessel. It would therefore seem probable that the branchial sac can represent but a single gill of the Lamellibranch, and that one fold on each side of the ventral lamina (or great ventral channel) may be assumed to be the homologue of the left gill of the higher mollusk.

The branchial sac itself is not a perfectly symmetrical organ; at least the oral lamina does not exactly divide it into two equal lateral halves; for it invariably passes to the right of the oral aperture in all dextral species, and it never, so far as my observations extend, abuts directly upon it. On the other hand, the heart in the simple Ascidians usually occupies a central position, being placed in the middle line of the digestive organs; and the great vascular trunks as they leave its anterior or ventral extretremity, exhibit a symmetrical bilateral development, a trunk going to each side of the visceral mass, and there ramifying over these organs. That, however, on the left side sends a large branch along by the side of the intestine to the great ventral channel of the gill; while the corresponding branch of the right side dies out before reaching the opposite margin of the visceral mass. Here, then, ceases the bilateral symmetry of the vascular organs; were it carried a little further, there would exist two ventral branchial channels; and thus a right pair of gill-plates might be developed, one fold being on each side of the channel; and in this way the respiratory organ would be exactly similar in all essential characters to that of a Lamellibranch. And if the roots of the two lateral trunks that proceed from the heart were dilated into auricles, the rudiments of the Lamellibranchiate heart would also be established. This idea of an arrest of a bilateral growth is somewhat strengthened by Krohn's description, already quoted, of the development of *Ascidia mamillata*, in which the young at first has two distinct lateral atrial spaces and two lateral excurrent orifices; the spaces ultimately coalesce, as do also the orifices, the tendency to bilateral development terminating at a very early period.

If this view of the homologies of these organs be correct, then the cloacal, or that which has been uniformly designated throughout this communication the ventral surface, will correspond to the dorsal region of the Lamellibranch; and consequently the opposite margin will be the ventral aspect, and the so-called right and left sides will have to interchange appellations. Thus the excurrent tube will become dorsal, and the incurrent ventral, as they are in the Lamellibranchiata, and, without any great disturbance of the parts, all the viscera will assume their proper positions.

Before the probability of this determination of the homological relations can be admitted, it is necessary to ascertain the true nature of the ganglion, which, as we have seen, is placed between the respiratory tubes. In the Polyzoa the ganglion is placed on the rectal aspect of the œsophagus, immediately below the mouth, and gives its nerves to the tentacles and to the œsophagus in the direction of the mouth, but none to the "endocyst" (mantle) or to any other organ. Therefore it can scarcely be homologous with the ganglion in the Tunicata, which distributes all its nerves to the walls of the respiratory tubes (which are mere prolongations of the mantle) and to the mantle itself. In the Lamellibranchs, however, there is a ganglion (or a pair of ganglions), namely the branchial, the most constant in these animals, situated upon the posterior adductor muscle, which, besides supplying the gills, gives nerves to the dorsal portions of the mantle and to the respiratory tubes, parts which are the undoubted homologues of those which receive the nerves from the ganglion in the Tunicata. It therefore seems impossible to avoid the conclusion that the ganglion in the latter is the true representative of the branchial ganglion in the Lamellibranchiata: ganglia supplying homologous parts must likewise be homologous.

This determination of the nature of the ganglion agrees well with its position, which in relation to the respiratory tubes is almost precisely similar to that of the branchial ganglion. And we thus find in the nervous element a corroboration of the above suggestion as to the homological relation of the branchial sac.

Notes on some Insect- and other Migrations observed in Equatorial America. By Richard Spruce, Esq. Communicated by the President.

[Read June 6, 1867.]

In endeavouring to trace the distribution of plants in the Amazon valley, and to connect it with that of animals, I have been struck with the fact that there are certain grand features of the vegetation, which prevail throughout Cisandine America, within the tropics, and even beyond the southern tropic,—features independent of the actual distribution of the running waters, partly also of the