ORIGINAL COMMUNICATIONS.

The ANATOMY *of the* EARTHWORM.

By E. RAY LANKESTER.

PART III.

IN the present number of the Journal the hæmal and nervous systems of the earthworm remain to be described. No special respiratory organs can be indicated. The processes, therefore, of the oxygenation of the blood and tissues will be considered in connection with the hæmal system.

HÆMAL SYSTEM.—In the earthworm, as in other Annelidæ, there are two fluids, each of which has claims to rank as "blood." One of these fluids is red and free from corpuscles, and contained in a very extensive series of vessels; the other is colourless and transparent, abounding in nucleated cells and corpuscles, and occupies the general or perivisceral cavity —the space intervening between the digestive tube and the muscular parietes of the body or integument. It is obvious that the latter corresponds to the fluid contained in and circulated by the heart of the Insecta and Crustacea, as has been shown by the researches of De Quatrefages. It is no less evident, as Professor Huxley has suggested, that the red vascular fluid is homologous with the water-vascular system of the Turbellaria, Trematode worms, and other Scolecida, which again appears in the Echinodermata as the ambulacral system, communicating with the exterior in the Echinidea and Asteridea, but definitely closed in the Ophiuridea, Crinoidea, and Holothuridea. The two fluids of the Annelid are represented still lower down in the scale of creation by one, as that contained in the somatic cavity and canals of the Clenophorous Actinozoa, which gives evidence of its homologies with the ambulacral system of Echinoderms by its relation to the tentacular processes, and with a nutrient system, such as that of the Asteropods by its intimate connection with the contents of the stomach. Thus, then, we gain a very definite view of the probable homologies of the two fluids in the earthworm, but it is not yet apparent which of the two should be called "blood," and recognised as the homologue of that fluid in the vertebrata—whether that which represents the sauguineous system of Insects, or the red fluid, homologous with the water-vascular system of Scolecida.

The following view, which tends to explain the matter and place it in a clear light, is put forward by my friend Professor Busk. In vertebrata the blood can be separated into two parts—the red corpuscles and the clear white plasma with the white corpuscles. The function of the red corpuscles, it is generally admitted, is to carry oxygen—in fact, is respiratory. The function of the plasma, on the other hand, with its white corpuscles, is simply nutrient. Assuming that this is a correct view of the case, since it is supported by many and conclusive facts, and, indeed, is very generally conceded, let us turn to the Annelida. We find a red fluid, undoubtedly devoted to respiratory purposes in many genera, and a colourless plasma with white corpuscles, bathing all the organs of the body. The conclusion is, obviously enough, that the red vascular fluid represents simply the corpuscles, whilst the colourless corpusculated fluid is homologous with the white plasma of vertebrate animals. It would be unsafe to draw any conclusions as to the respective functions of the fluids from this comparison. The functions of the two fluids in the Annelida have yet to be much studied, all that zoologists at present appear to be agreed upon being that the red vascular fluid is the chief medium through which respiration is effected; how far this function is shared by the corpusculated fluid, or how far nutrition is also a part function of the red fluid, are questions to which no decisive reply has yet been offered, though the considerations above adduced would tend (perhaps erroneously) to the conclusion that respiration belongs to the one and nutrition to the other exclusively.* In speaking, then, of these two fluids, I prefer

* M. Milne Edwards, in the remarkably exhaustive and valuable work, which he is now completing, commenced in 1857, and entitled 'Leçons sur la Physiologie,' adopts, to a great extent, the view advanced first by De Quatrefages, and used aftewards, more or less, by Dr. Williams, that in the Annelida, as a rule, the perivisceral fluid becomes oxygenated and transfers its oxygen to the vascular fluid, which, however, in other cases may become directly oxygenated by the direct contact of its containing vessels with external fluids. He also considers the vascular fluid as having a nutrient function (vol. ii, p. 95; vol. iii, p. 239).

Professor Huxley, on the other hand, is inclined to regard the system of vessels in which this usually red fluid is contained as an extreme modification of the water-vascular system of Trematoda and Cestoidea, which is by M. Milne Edwards considered as an excretory apparatus, by others as adopting such names as "red" and "colourless," or "vascular" and "perivisceral," fluids, to using the terms "pseudo-hæmal" or "chylaqueous system."

Colourless or Perigastric Fluid.—On opening an earthworm by a longitudinal incision the various chambers of the body formed by the interseptal muscles will be found to contain a certain amount of a free fluid, having a more or less milky appearance, but generally very nearly clear. This is the "colourless" or "perigastric fluid;" it varies very considerably in amount in different specimens, but is always most abundant towards the posterior end of the body. Though the interseptal muscles or diaphragms divide the perivisceral cavity of the earthworm into various chambers, it must not be supposed that each of these is hermetically sealed. In addition to the general osmosis by which the fluids of two contingent chambers can be exchanged, there are openings in the diaphragms, imperfect attachments to the intestinal wall and ganglionic cord, by means of which a communication is established freely from one end of the body to the other. Thus it is that in the last segments of the body we find by far the largest amount of perigastric fluid, containing also a variety of conspicuous foreign bodies, in the form of small white cysts, detached setæ, &c; the fluid itself also has a decidedly milky appearance. It was this congregation of foreign bodies at the posterior portion of the worm which led Sir Everard Home to regard the earthworm as self-impregnating and viviparous; it is, no doubt, owing to the continual pressure in an antero-posterior direction, to which the movements of the worm subject its body, that this accumulation takes place; but it of course depends also on the fact that there is a free communication between the various cavities, and that the fluid has no definite course of circulation to follow. In most cases, when a worm is opened, the anterior segments of the body will be simply moist, whilst the fluid increases in quantity as the posterior annuli are approached.

Communications with the exterior.—The perigastric fluid has two direct and apparently special series of communications with the exterior, by means of which it can escape from the worm's body; and another equally special series of communications, by which it appears that fluids can pass *from* the exterior, and become part of its substance. The most important of the two series of exits is that furnished by the "segmental organs," described in my last paper, which, by

respiratory, and by others as nutrient; the truth being, probably, that its function combines, more or less, the offices of all three, or of the first two at least.

means of their ciliated inductors and interiors, establish a continuous current, setting from their internal to their external apertures, which, of course, carries off daily a certain amount of the perivisceral fluid, since the trumpet-like inductors of the ciliated canals float freely in this liquid. Placed along the dorsal aspect of the worm's body, my friend Professor Busk has pointed out to me a series of openings or pores of considerable size, which form a second means of exit for the perivisceral fluid. They are situated nearly in the median line, and number three or four in each segment. All do not seem directly to perforate the integument and subcutaneous muscular layers; but they vary in this respect, as also in their relative position, which is not subject to any regularity. One of these orifices, situated in the median dorsal line of the segment, appears always to be larger than the others, and penetrates directly to the perivisceral cavity (fig. 9). That these openings form a very ready and frequent means of escape to the "colourless fluid" may be ascertained by handling a large earthworm, when some considerable quantity of colourless fluid is nearly invariably found to escape from its dorsal surface.*

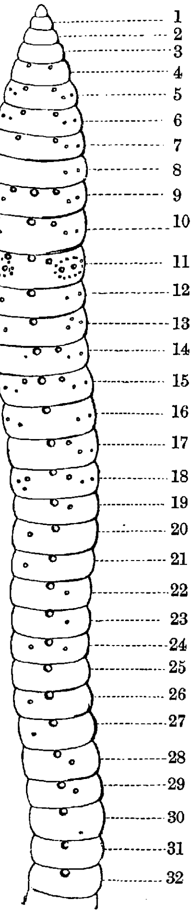

FIG. 1.

* The following are Prof. Busk's notes on the subject, which, with Fig. 1, he has kindly given me to make use of.

LUMBRICUS TERRESTRIS.

Large specimen, with clitellus, &c., apparently well developed. Killed with chloroform, and the cuticle stripped off.

Surface presented pores as shown in figure No. 1.

The range of median dorsal pores commenced in the interspace between the 8th

The means whereby the aqueous constituent of the perivisceral fluid appears to me to be chiefly replenished is to be found in the remarkable minute tegumentary canals, described and figured in my last paper, and resembling somewhat in their appearance "dentinal tubules." These minute canals

and 9th rings, and was thence continued, apparently without interruption, to the caudal extremity.

The fluid expressed from these pores was of a dirty grayish colour, thin and opaque. Examined under the microscope it contained numerous spherical particles and pyriform granular bodies, besides irregular organic particles. The only other openings observable on the dorsal aspect, as far as to the 32nd ring, where the clitellus commenced, were minute rounded pores of smaller size than the median dorsal, and situated, not in the intervals between the rings, but on the sides of the rings themselves, at a greater or less distance from the dorsal median line; they occurred in the following rings, viz. (see Fig. 1, p. 102).

There being none on the 1st, 2nd, 3rd, 8th, 12th, 16th, 25th, 30th.

From these puncta could be expressed a clear fluid, containing only minute nucleolar particles, and it was probably derived from the subcutaneous *glandular* tissue, constituting the lubricating fluid of the surface.

In a second specimen, prepared in the same way, and at the same time, and apparently in the same condition as to development, the arrangement of the pores and puncta was as follows.

No. 2.—Median dorsal pores commenced between 8th and 9th rings, and they afforded a fluid precisely like that of the former case. The puncta were situated in the following rings:

There being none perceptible on the 1st, 2nd, 3rd, 4th, 16th, and they were not looked for beyond the 22nd. The fluid expressed from them was the same as in the former case.

In other cases, again, the median dorsal pore did not exist anterior to the 11th segment, and the lateral puncta appeared very variable.

Besides these pores and puncta, in a worm which had been immersed in water, a general sweating or oozing from very minute pores, was observable all over the surface, especially on the dorsal aspect.

No other kinds of permanent openings exist in any part of the body except the mouth and anus. The sexual openings in the 16th segment appear to be formed only at the time they are wanted, and of these, as well as of the smaller lobes on either side, no vestige whatever is perceptible, even in very large worms, when not sexually mature. The same may be said of the clitellus, of which no indication whatever is often perceptible; one, also, of the two adherent discs (?) in the 27th segment, which appear to be formed solely for the purpose of sexual congress. They are developed on the situation, and, in fact, by a thickening of the integument immediately around the inner pair of setæ in that segment. This swelling is very porous, and a mucous fluid can be freely expressed from the pores. Another change in the external aspect of the worm, connected with the period of sexual activity, consists in the thickening and opacity of the subcutaneous tissue, in the ventral halves of the segments, extending from 8th or 9th to 14th or 15th (?), and which is more observable in the inside. And in the 11th segment, at this time, an elevation and porosity of the skin is set up around the inner pair of setæ, which, in some cases, are themselves altered in shape from the rest, and when pulled out they draw out with them a long stringy appendage, not apparently of cætera descent.

undoubtedly have the power of absorbing liquid by capillary attraction from the external surface, as may be demonstrated by immersing the caudal extremity of a worm in a solution of carmine and ammonia, when the capillary tubes will be found containing carmine if viewed under the miscroscope. *Composition.*—The composition of the perivisceral fluid which is thus situated in the worm's body now remains to be considered. Chemically, it appears to resemble dilute serum, and to have much the same constitution as the blood of higher animals, being, however, poorer, or containing a larger amount of water. Portions of it coagulate, and it becomes turbid when submitted to the action of strong spirits of wine; it has, moreover, a slightly saline taste, and an alkaline reaction with turmeric paper. When examined with the microscope it is seen to consist of a plasma and corpuscles, the latter varying in number, size and form. The general form of the corpuscles is a flattened transparent cell, containing granules and a nucleus, and about the $\frac{1}{1000}$th of an inch in diameter; sometimes they exhibit amœboid movements, but generally are inert. A great variety of particles of other forms are to be found in this perivisceral fluid, particularly at the posterior portion of the body. Among these are young forms of the *Monocystis Lumbrici,* one of the Gregarinidæ,* encysted individuals of this species, its pseudo-navicula, parasitic nematodes, and their eggs (fig 6). The colourless fluid presents, therefore, a marked contrast to the vascular fluid with regard to its intimate structure; its function may be briefly considered when the disposition and nature of the vascular fluid has been described.

Vascular, Non-corpusculated, or Coloured Fluid.—The vascular fluid of the earthworm is contained in a very extensive series of vessels, which have three principal trunks and various ramifications. The vascular system in Annelida is divided, by M. Milne Edwards,† into two parts—the cutaneous and the visceral. In the ideal representative, Annelida, the *cutaneous system* is considered as being composed of two longitudinal lateral trunks, which communicate with one another by their cutaneous and terminal capillaries, and also (as in the higher forms of Annelida) by direct transverse vessels, called by M. Milne Edwards the "inferior commissural vessels." This forms the cutaneous system; the two lateral trunks may be united into one and form a single *ventral* vessel, when, of course, there are no inferior commis-

* See the author's paper in this Journal, April, 1863.

† Loc. cit., vol. iii, p. 252.

sural vessels. In order to understand well the *visceral system* it is necessary to consider it as being composed again of two dorsal and two sub-intestinal trunks, each pair having a tendency, in the various modifications met with in the class, to coalesce and form a single vessel. The two dorsal vessels, when they are developed, are connected by transverse vessels, called "superior commissural vessels;" the two sub-intestinal vessels, or the one which they form, also communicate with the dorsal vessel by lateral branches, called "deep commissural vessels;" and, again, the capillaries of the cutaneous system communicate with the dorsal vessel, or it with them, by the "latero-dorsal" vessels, thus establishing a general communication.

Having thus seen what is the general arrangement in the Annelida, let us turn to the earthworm. If killed with chloroform, the worm presents on the dorsal surface of its alimentary canal, when opened, a rhythmically moving dark-coloured vessel, generally containing a considerable amount of the red fluid. This is the dorsal vessel of the visceral system, and extends from the eighth segment throughout the body (Part I, Pl. VII, fig. 5, and Pl. II, figs. 1, 2, 3, *a*). Beneath the intestine, but not closely attached to it as is the dorsal trunk, is the single sub-intestinal vessel (Pl. VI, figs. 1, 2, 3, *b*), also with highly contractile walls, but generally not to be observed in movement, inasmuch as the dissection required before it is reached destroys the lingering vitality of the worm. The sub-intestinal vessel extends throughout the whole length of the body excepting the first four or five anterior segments, where it is broken up into capillaries. The dorsal and sub-intestinal vessels are connected by the lateral "deep commissural vessels" (Pl. VI, figs. 1, 2, 3, *l*), thus completing the visceral system of M. Milne Edwards. Of the deep commissural vessels there are two in each segment posterior to the sixteenth, embracing the alimentary canal; those from the sixteenth to the nineteenth, in connection with the stomach and gizzard, dividing into a wonderfully fine capillary plexus, the vessels of which in the fibrous gizzard have a horizontal parallel disposition. From the nineteenth ring backwards the deep commissural vessels consist merely of a pair in each segment, closely attached to the wall of the intestine, and imbedded in or covered up by the yellow granular substance which is spread over its surface and is supposed to have a biliary function. Anteriorly to the sixteenth ring the deep commissural vessels are single; in fact, the two are fused into one, and, until the seventh segment is reached (when they cease to exist or become as the dorsal vessel itself, broken up into a capillary network investing the pharynx), they assume a more or less doubly conical form, and have been called by authors on the subject "hearts" (see Part I,Pl. VII, fig. 1).*

When the nervous cord extending along the ventral interior surface is dissected away from its attaching branches, and its inferior surface is examined, a delicate vessel, capable, however, of much expansion, is seen closely attached to it, sending out branches with the nerve-branches, and, in fact, following the ganglionic cord and its branches throughout the worm (figs. 1, 2, 3, *b*). It forms a capillary plexus at the cephalic and at the caudal extremities, thereby communicating with the dorsal and sub-intestinal trunks; this is, then, the main trunk of the *cutaneous system,* the single ventral vessel representing the two longitudinal lateral vessels met with in some other Annelida. The rest of the cutaneous system (figs. 1, 2, 3, *e*) of vessels is seen in the innumerable ramifications and delicate networks visible on the inner surface of the perivisceral cavity, which form one of the main objects of beauty attracting the eye when an earthworm is opened for dissection. There is no special superficial cutaneous circulation, that is to say, disposed near the external surface; a few vessels penetrate the muscular layers of the integument and give off numerous delicate branches, which are occasionally seen in the pigmentary layer; but there is no great cutaneous plexus, as, in fact, may be partly seen by the completely colourless aspect of the posterior three fourths of any worm's body; in fact, the integument of the earthworm has a *remarkably small* true cutaneous circulation, being, such as it is, merely adapted to perform the general offices of a vascular fluid. It is upon the interior superficies of the integuments that a plexus exists, belonging to the *cutaneous system* of M. Milne Edwards, which, perhaps, it were better to call *peripheral.* This plexus is supplied in each segment by a branch on either side from the ventral or sub-ganglionic vessel; it is also connected in each segment (the seven cephalic segments are exceptional) with the sub-intestinal vessel by a special branch on either side, and with the dorsal vessel by large vessels, given off on either side, closely connected with the diaphragmatic muscle, and sending branches elsewhere also. These latter vessels, or their representatives in other Annelids, are what M. Milne Edwards calls the *latero-dorsal* vessels. Thus, then, we see a general connection

* A somewhat serious error has been unaccountably made in the figure referred to. There should, of course, be but *one* pair of "hearts" in each segment.

established between the three longitudinal trunks—between the great dorsal and the sub-intestinal by the deep commissural vessels, between the ventral and the dorsal and sub-intestinal by the internal superficial tegumentary plexus, and, again, between all three by the capillaries into which they break up at either extremity of the worm.

There is, however, another distribution of the branches of the great trunks by which they become connected, and it is in the diaphragmatic muscles and the segment-organs. A branch is given off on either side in each segment from the sub-intestinal vessel near the anterior septum, from the ventral vessel near the posterior, and these on either side entering the diaphragmatic muscle are distributed to the segmental organs in the manner described in my last paper, forming small lacunæ and networks most intricately and intimately ramified; and thus we have in connection with each segment-organ a special *afferent* and *efferent* branch. The latero-dorsal vessels send ramifications through the diaphragmatic muscles with which they are closely connected, as also do the branches from the ventral vessel, which, though not so constant and regular in their disposition as the pair of vessels in each segment given off from the dorsal trunk, may nevertheless be conveniently spoken of as the *latero-ventral* branches. Neither the latero-dorsal nor the latero-ventral vessels send any branches whatever to the segmental organs, which are supplied solely by the special branches from the sub-intestinal and ventral vessels; these branches may therefore be called the afferent and efferent excretorial vessels.

A modification of the visceral circulation takes place in the seven segments posterior to the seventh. It is in these segments that the organs of generation are situated, as also the three pairs of œsophageal glands, organs which are all most profusely supplied with the vascular fluid, and for the purpose of feeding which it would be supposed that the arrangements of an ordinary segment would be found inadequate. Accordingly, parallel to the sub-intestinal vessel are found two others, one on either side, with which the enlarged, deep, commissural vessels, or hearts, communicate (fig. 2, *p*). Branches are given off from all three of these longitudinal vessels to the various organs; the central sub-intestinal vessel supplying, especially, the testes and ciliated inductors of the vasa deferentia, whilst the parallel additional vessels seem more closely connected with the œsophageal glands.

We have, then, in the various segments of the worm's body four principal modifications of the circulation, the simplest of which is that extending from the 19th segment to the penultimate one, and represented diagrammatically in figs. 1 and 3. The seven cephalic segments, and the one caudal, in which the circulation is merely capillary, all the great trunks being broken up, form a second modification, whilst the third is that described above in the generative segments, and represented diagrammatically in fig. 2; whilst a fourth modification occurs in the 15th, 16th, 17th, 18th and 19th segments, where the deep commissural vessels are large and *single*, but there are no additional parallel vessels.

Structure of the Vessels.—The vessels, thus disposed for the purpose of circulating the red fluid, may be considered as possessing an internal structureless amorphous tunic, without epithelium, and an external tunic of more or less modified connective tissue; between these two are longitudinal and transverse muscular fibres in some of the smaller as well as in the large vessels.* In most of the vessels the transverse fibres are radiated from a point and placed in bundles at intervals (fig. 7). The result is that when the transverse fibres contract they produce an uneven moniliform appearance in the blood-vessels, but are the more effective in propelling the fluid. The alternating points of contraction and expansion in the dorsal vessel and so-called hearts are well seen when a worm is freshly opened.

Structure of the Vascular Fluid.—The vascular fluid is completely devoid of corpuscles, and is entirely structureless. It is more easily coagulated than the perivisceral fluid, but otherwise appears to have the same composition. The nature of its colouring matter is not known.

Functions and homologies of the Vascular and Perivisceral Fluids.—It has been already pointed out that De Quatrefages has established the existence of undeniable homological relations between the perivisceral fluid of the Annelida and the fluid occupying sinuses and lacunæ among the Crustacea, Arachnida, and Insects,† and circulated by a heart with valves, and considered as true blood. The researches of Professor Huxley‡ tend to establish the conclusion that in the vascular system we have a closed representative of the water-vascular system of Scolecida. The function of the two fluids does not in any way necessarily affect the question of their homologies, and in considering the part which they play in the animal economy we must not be hampered by the

* See Leydig's 'Lehrbuch der Histologie.'

† 'Annales des Sciences Nat.,' 1843—1854.

‡ 'Brit. Ass. Reports,' 1854.

hypothesis sometimes hazarded as to the function of the water-vascular system of Scolecida or the blood-sinuses of Arthropods. There can be no doubt that the vascular system of the earthworm, as in other Annelids, is adapted for exposing its fluid to the action of oxygen. How does it do this, and has it any other functions? In no Annelid can it be satisfactorily shown that the vascular fluid has a definite circulation; the fluid is made to move, to oscillate, and pass more or less from one series of vessels to another by the contractions of the vessels, but, as M. Milne Edwards observes, there is no definite circle of movement. In certain Annelids M. De Quatrefages has shown that the perivisceral fluid absorbs oxygen; this he has demonstrated chemically, and it appears that, as a rule, the perivisceral fluid absorbs oxygen, to which the vessels of the vascular system afterwards become submitted. In the earthworm, then, it is probable that the perivisceral fluid absorbs oxygen or water containing oxygen through the capillary canals forming a characteristic structure of the integuments. To the action of this the fluid contained by the vascular plexuses and the great vessels is everywhere more or less exposed by osmotic action. It would appear also that this process takes place to a very large extent in the vessels distributed to the numerous diaphragmatic muscles, which are necessarily very largely subject to the action of the perivisceral fluid.

Another vastly important function of the vascular fluid, and one for which it seems specially adapted, is *excretion*. This takes place through the segment-organs, and is also shared in a minor degree by the perivisceral fluid which is continually passing through them.

Absortion of alimentary matters may equally be the function of both fluids; certain matters passing by osmose through the very delicate walls of the intestine into the perivisceral cavity, and others possibly, though not very probably, being absorbed by the delicate networks formed by the visceral branches of the vascular system. It has been hinted by Claparède* that the greenish-yellow mass of granules enveloping the intestine and the dorsal vessel and its branches, even at its anterior extension, may have some connection with the formation of the corpuscles of the perivisceral fluid, and assist materially in other respects in the functions of that liquid. It appears very certain that in the earthworm the perivisceral fluid absorbs aliment through the intestinal walls, and nourishes all the organs which it bathes, and also it brings oxygen to the vascular

* 'Recherches sur les Oligochetes.'

fluid, whilst this latter removes waste matters from and oxidizes the tissues, and performs all the offices of excretion and secretion.

NERVOUS SYSTEM.—The nervous system of the earthworm consists of a sub-intestinal and supra-intestinal chain of ganglia, with their branches. I have little or nothing here to add to the very elaborate, accurate, and detailed description given by Mr. Lockhart Clarke, in his paper published in the 'Proceedings of the Royal Society' for 1857, but will give a brief description of the subject of his researches, in which I shall make extensive use of his essay.

In the centre of the third ring of the worm, overlying the pharynx, are two closely united pyriform ganglia, or a single bilobed ganglion, of which the lobes are united by their broad ends in the mesial line. This is the *supra-œsophageal ganglion.* The small end of each of its lobes divides into two nerve-trunks, of which one forms the root of its cephalic nerves (fig. 6), and the other the *pharyngeal crus,* which curves round the sides of the pharynx, to join the first subventral ganglion.

From each crus, or from either side of the collar thus formed (see fig. 6), there spring eight or nine nervous branches. The first four or five arise from the under part of its anterior half, and immediately enter the upper surface of a minute and delicate cord-like chain of ganglia, the chain which was above designated the *supra-intestinal portion* of the nervous system. This very interesting structure was, to all intents and purposes, discovered by Mr. Clarke, since Brandt and others had only spoken of it as a simple dorsal twig, given off from the bilobed cephalic ganglion. The chain lies on the side of the pharynx, concealed by the crus. The breadth of its first ganglionic enlargement is the $\frac{1}{200}$th of an inch in a good-sized worm. Each border of the chain gives off several trunks of considerable size, which unite to form a continuous plexus, supplying with its inner part the muscular and mucous coats of the pharynx, with its outer the muscular bands and salivary tubules. From the pharynx the plexus descends along the side of the œsophagus, lying on the abdominal vessels, and communicates with minute filaments from the nerves of the subventral ganglia.

The four or five nerves which are given off on either side from the posterior part of the crus communicate with each other by loops before they leave it. The first and largest sends some filaments to the muscular bands of the mouth, upon which they communicate by evident but slight dilatations with the plexus of the pharyngeal chain, and, after supplying the muscles of the anterior segments, are lost in the integument of the lower lip. The rest take nearly the same course. But what is extremely interesting is that the roots of the nerves of this the posterior set are continuous across the crus with those of the anterior set belonging to the supra-intestinal chain.

The *subventral chain* of ganglia forms with its nerves the sub-intestinal portion of the nervous system. It is a double cord, gangliated at short intervals by the addition of vesicular substance and extending from the third ring throughout the body. Anteriorly the cords are divergent and form the two pharyngeal crura, posteriorly they become closely cemented along the middle line. The ganglionic enlargements vary in shape, size, and approximation, at different parts. Each gives off from its sides two pairs of nerves, which, after sending some filaments to the diaphragmatic muscles and bands, supply the longitudinal circular and oblique muscles of the rings midway between the ganglia; the intervening cords give off a single pair, which are distributed to the deep muscles on each side (see fig. 6).

The *cephalic nerves*, which take their origin in one of the trunks on either side, into which the bilobed supra-pharyngeal ganglion divides, are distributed to the lower surface of the first segment, forming a very delicate organ of touch; another portion of the nerves forms a curious plexus in the pigmentary layer, and is connected with the large clear cells there met with. Mr. Clarke suggests the possibility of these forming a mechanism adapted to the perception of diffused light, though not of distinct vision. That the first segment of the worm, with its nervous plexuses, does form a very important organ of perception, there can be no doubt.

Structure of the Nerves and Ganglia.—In fig. 8 nerve-cells and a portion of a nerve-fibre from the sub-ventral chain are drawn. In fig. 7 a portion of the cord, less highly magnified, is represented. The structure of the various parts of the nervous system of the earthworm, as studied by Mr. Clarke, has yielded most interesting and important results. Each lobe of the cephalic or supra-pharyngeal ganglion is a pyriform sac, which is very thick and convex posteriorly, where it is partially separated from its fellow by a deep notch. This convex portion is opaque white, and filled with a mass of semifluid granular substance, and oval, round, and pyriform cells of various sizes, but often very large. The anterior half, by which the lobes are joined, is merely lined by a lamina of cells, and only at its upper part, its under side having a cell here and there. The interior of this portion is entirely fibrous, and consists of a broad, transverse, commissural band, derived from the pharyngeal collar, and of fibres from the roots of the cephalic nerves. Each crus of the collar enters its lobe on the under side. Some of its fibres curve backwards to the convex vesicular mass; others ascend to, perhaps partly terminate in, the cells near the roots of the cephalic nerves, and the rest cross transversely, as the broad band, to be continuous in front of the notch with that of the opposite ganglion.

The supra-intestinal chain of ganglia, when placed under a $\frac{1}{8}$th objective, displays a remarkable structure. The under surface of the entire chain—cords as well as ganglia—is covered with a lamina of round, oval, and pyriform cells, and on its upper surface a row of cells of the same kind is found along each border. At every point of communication between the branches which form the plexus a minute ganglionic enlargement is seen, from which new branches proceed to form other enlargements of the same kind. As the plexus extends from the chain the ganglionic points diminish in size, while the smaller branches given off from the trunks increase in number, and communicate like a capillary network. The ganglia of the subventral chain have their vesicular substance on the under surface, and consist of about two strata of cells continuous in a lamina across both cords. Along their borders, however, the cells form a thicker layer or column, which extends for some distance along the intervening cords. In form and general appearance the cells are similar to those of the pharyngeal chain, but many of them are larger. Within the ganglia the roots of the nerves diverge in three different ways—1, longitudinally; 2, transversely; and 3, to the gray or vesicular substance. The first, or longitudinal, form a large portion of the nerves, and run in equal numbers in both directions, backwards and forwards, along the whole length of the corresponding cord. In their course some of them near the border separate in succession from the rest and enter the lateral column of cells; others proceed as far as the next nerve, with the roots of which they form loops, and pass out, while the rest continue onwards and, perhaps, in succession form similar loops with distant nerves. Mr. Lockhart Clarke has shown that the same kind of arrangement exists in man and the mammalia as well as here. The second order of fibres are less numerous and, in general, less distinct than the rest. They proceed from the middle of each opposite root, and cross the cords directly. The third order of fibres are those distributed to the vesicular substance. Mr. Clarke was not able, after repeated examinations with the microscope, to trace an undoubted continuity between the cells and nerve-fibres in more than one or two instances, although there is good reason to believe that such a connection exists. Dr. Rorie, in a paper published in this Journal two years since, which cannot certainly bear comparison with Mr. Clarke's,* figures multipolar nerve-cells from the ganglia of the earthworm. His observations are, in all probability, erroneous, as my own entirely confirm those of Mr. Clarke, whose accuracy, care, and acuteness, are, moreover, too well known to be doubted.

Functions and Homologies.—The supra-intestinal portion of the nervous system evidently presides over the operations of the viscera, whilst the sub-intestinal portion is more closely connected with the locomotive function. The supra-intestinal chain is, however, as we have seen, connected by its branches with the sub-intestinal ramifications, and its roots also are closely associated with those of the other nerves arising from the pharyngeal crura. Mr. Clarke considers that it combines the office of a sympathetic with certain other functions which in many invertebrata are entrusted to separate and special centres; such as the labial, pharyngeal, and visceral ganglia in cephalophorous mollusca. By experiments I have satisfactorily demonstrated to myself that the pharyngeal chain is independent of the other nervous centres, although, at the same time, subject to their influence, and can control the suctorial movements of the mouth and pharynx, and is a centre of reflex action. Mr. Clarke has also established this fact by experiment.

Two parts of the human brain are compared by Mr. Clarke to the transverse cephalic band of *Lumbricus*. One is the arched and commissural band of fibres prolonged through the corpora quadrigemina, from the upper and inner part of the fillet on each side. The other part, which is analogous or homologous with the cephalic band, is the corpus callosum. Dr. Rorie, in the paper quoted above, advances the opinion—stating, at the same time, that he reserves his reasons—that the supra-œsophageal ganglia are analogous to the cerebrum of man and the higher mammalia, and to the spinal cord, whilst the ventral chain he regards as belonging to the sympathetic system, and the pharyngeal crura he considers to be the homologue of the vagus. I need hardly say that, as Dr. Rorie brings forward no facts to support this view, and as Mr. Clarke very ably and carefully gives details of structure and anatomy to support his, the opinion of most intelligent persons will coincide with that of the latter observer.

RECAPITULATION.—*The hæmal system* of the earthworm

* 'Quart. Journ. Micro. Science,' April, 1864.

consists of a corpusculated colourless fluid, contained in the somatic cavity, and provided with exits and a series of capillary canals for the entrance of liquid, and of a red-coloured, non-corpusculated fluid contained in three longitudinal trunks and their ramifications. Both are albuminous; the former is homologous with the blood of Insects and Crustacea, and probably performs a nutritive function; the latter is homologous with the water-vascular system of Scolecida, and has an excretory or urinary function through the segmental organs, and a respiratory function, in connection with the oxygen absorbed by the perivisceral fluid.

The nervous system consists of a supra- and a sub-intestinal portion, both of which present the usual components of fibres and cells. The principal centre is the cephalic bilobed ganglion, homologous with the corpus callosum and the commissure prolonged through the corpora quadrigemina. From this in one direction pass the cephalic nerves, in the other the phargyngeal crura, uniting beneath the pharynx to form the subventral cord and ganglia. From the pharyngeal crus four branches on either side unite to form the supra-intestinal chain or plexus discovered by Lockhart Clarke, and homologous with the sympathetic and visceral ganglia of mollusca. Four other twigs on either side are distributed to the pharynx. The muscles of the segments are presided over by the subventral cord. There are no special organs of sense, unless the labial segment should be so considered.

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RECORD *of the occurrence, new to* IRELAND, *with* NOTE, *of a Peculiar Condition of the* VOLVOCINACEOUS ALGA, STEPHANOSPHÆRA PLUVIALIS (Cohn), *and Observations thereon.* By WILLIAM ARCHER.*

THE discovery in Ireland of the very interesting and very beautiful and apparently very rare organism, *Stephanosphæra pluvialis* (Cohn), would in itself alone be worthy of a record in the 'Proceedings' of this society. But inasmuch as, whilst I had a supply of this "Volvocine" in my possession, a remarkable phase or condition in its history—so far as I am aware, not before observed in this form, though not without parallels elsewhere—presented itself to my notice, the value of that record becomes thereby in so far enhanced.

Spending an evening in the month of June last at Bray, I took a walk upon the "Head," promising myself, indeed, not much of interest (save the beautiful view), from its dry and rocky summit. The weather had lately been showery, and during the day a considerable quantity of rain had fallen. This had left behind small deposits of rain-water in a few little hollows amongst the rocks. In one of these tiny pools I perceived the water tinged with a beautiful light-green colour. A few moments' inspection, even without a lens, was sufficient to indicate that this green hue was due to the presence of myriads of some "volvocinaceous" plant; and with a lens I soon perceived, by the annular and band-like green portions of the organisms, as they appeared under so low an amplification, alternately brought to view, that I had had the good fortune to encounter that seemingly rare organism, *Stephanosphæra pluvialis* (Cohn), which Professor Cohn journed from Breslau to Hirschberg to see, and for the occur-

* Read before the Natural History Society of Dublin, May 6, 1863.