THE DEVELOPMENT OF ADMETUS PUMILIO KOCH

A CONTRIBUTION TO THE EMBRYOLOGY OF THE PEDIPALPI.

INAUGURAL-DISSERTATION

PRESENTED

TO THE HIGH PHILOSOPHICAL FACULTY

OF THE

UNIVERSITY OF BASLE

TO OBTAIN THE DEGREE OF DOCTOR

BY

LEWIS HENRY GOUGH

OF OXFORD.

STRASBURG

Alsatian Printing Office, formerly G. Fischbach

1901

The Development of Admetus pumilio Koch; a Contribution to the Embryology of the Pedipalps.

BY

L. H. GOUGH.

Introduction.

I BEGAN my investigations of the development of Admetus pumilio in November 1899. During the previous year I had been studying the development of spiders under Prof. A. Goette, in Strassburg.

Through the kindness of Prof. R. Burckhardt I received materials to examine, which he had obtained from Dr. Goeldi in Para. These materials consisted of two females of Admetus pumilio each of which carried a batch of eggs, which will be described under Stages II and V.

In January, 1900, I received two further batches of eggs, this time through the kindness of Dr. G. Hagmann, also in Para; unfortunately only one of these batches was of use; from it I procured Stages I, II, and IV; the other had been deserted by the mother animal, as Dr. Hagmann stated. Cuts through embryos coming from this batch only show an inner mass of yolk surrounded by a thick and dense layer of bacilli. I was not able to procure any further material.

At this place I must also express my thanks to Prof. F. Zschokke, Director of the Zoological Institute of the University of Basle, in whose laboratory this paper was prepared, and to Prof. R. Burckhardt, to whom I am much indebted for the help he rendered me during my studies, and more especially whilst working at this paper.

I must also express thanks publicly to Dr. Goeldi and Dr. Hagmann for having procured me the materials, and to my friend and fellow-student Oskar Huber, for some of the drawings given in this paper.

Technical remarks.

It was at first very difficult to obtain good cuts through the eggs, because of the presence of the great amount of yolk which they contained. When embedded in paraffin the yolk always crumbled away before the knife of the microtome.

The following is the method I usually used: — The embryos were brought through successive degrees of alcohol into absolute alcohol. Next they were left in celloidin for some days. They were then taken from the celloidin and put directly into chloroform. This has the double effect of making the celloidin firm, and of rendering the embryos ready to be transferred into paraffin. After having been treated thus, the embryos were cut as ordinary paraffin objects. The cuts were attached to the object-glass with water; when all the cuts were arranged on the glass, the water was quickly removed with a piece of blotting-paper, whereupon very fluid celloidin was poured over the cuts; they were then allowed to dry, but being still enclosed in paraffin the cuts could not shrink in any way. When quite dry the coating of celloidin became very thin indeed.

To remove the paraffin I again always used chloroform. Afterwards the cuts were treated in the usual manner. In this way I managed to obtain several perfect series, the yolk remaining in its place without being liable to crumble.

The staining was always done with eosin and hæmatoxylin, and invariably after cutting, the outer cuticle of the embryos being impermeable to the reagents used.

Literature.

The object of this paper is to supply, as far as the materials at my disposal permit, a gap in the literature of the embryology of the Arachnids. Only three papers have as yet appeared treating the development of the Pedipalps. Of these one is on the development of the Thelyphonidæ, the other two treating the development of the Phrynidæ. Their titles are: —(1) Dr. Strubell (42), 'Zur Entwicklungsgeschichte der Pedipalpen' (Vorläufige Mitteilhung); (2) Sophie Pereyaslawzewa (37 and 38), (*a*) 'Les premiers stades du développement des Pedipalpes; (*b*) Les derniers stades du développement des Pedipalpes; (3) M. Laurie (31), 'On the Morphology of the Pedipalpi. Of these three authors only fhe two last mentioned treated of the Phrynidæ.

When we compare the ages of the embryos I intend to treat about, we find that my first two are younger than Pereyaslawzewa's youngest, my third one is of the same age as her second, and my fourth corresponds to her third. My fifth stage is younger than both Pereyaslawzewa's last stage and Laurie's embryos.

Preliminary remarks.

I intend to divide the description of the embryos into five parts, giving each stage in my possession a section to itself. In each stage I will first consider the general superficial appearance, and then the details found in the sections.

Stage I.

The earliest stage at my disposal was obtained out of a batch of well-developed eggs, the rest of which had already undergone reversion. The egg in question had for some reason or other, probably pressure, stopped growing very soon after fertilisation.

It was perfectly spherical before being cut into sections, and was enclosed in a loose outer membrane. Superficially no differentiation whatever could be discovered.

After having cut it I found it to contain about eight nuclei; these were all situated near each other, not far from the surface. The rest of the egg consists of yolk, the whole being surrounded by a delicate inner membrane.

The position of the nuclei in a group near each other, under the surface, makes it seem probable that the fertilisation of the egg took place in the middle of the egg, and that the first cleavages took place there too; the cells resulting from these cleavages then wandering towards the surface, just as they do in spiders. The pressure of the two membranes also points to a resemblance with most of the other orders of Arachnids, whose eggs are also regularly enclosed in two membranes.

The yolk itself consists of at least two different kinds of yolk elements. The first of these tinges very freely with eosin, and is not influenced by hæmatoxylin. It consists of larger and smaller spherules measuring between ·09 mm. and ·02 mm.; they form the greater bulk of the yolk. The other yolk element is much more irregular in shape, and helps to fill the spaces between the spherules of the element first described, to which it adheres, thus becoming crescent-shaped in cuts, and in reality forming convex-concave lenses. It also differs in tinction from the first described kind of yolk, staining both with hæmatoxylin and eosin to a light purple.

The size of these yolk-bodies varies between ·036 mm. and ·05 mm. The distribution of the yolk elements does not seem to follow any definite rule, unless, perhaps, that the yolk elements last described are more numerous in the interior of the egg. I shall not again refer to the yolk or to the membranes, excepting where I have to point out a change in them.

Stage II.

The next stage at my disposal is only a little further developed than the one just described. It is derived from a batch of eggs which are all at about the same stage of development.

Surface views of these eggs show that the blastoderm is already formed. It appears as a long white ribbon covering about one third of the surface of the egg in length and one sixth in breadth. At one end the white patch seems much thicker, being more opaque in reflected light. The blastoderm is not of the same breadth throughout its length, but is somewhat narrower in the middle, and rounds out at both ends. The margins are not distinct or abrupt, but gradually fade away until at last they become invisible.

It is not possible to distinguish any further details superficially, the material having, unfortunately, been kept too long in alcohol.

Sections through the egg at this stage show that the blastoderm already consists of the three germinal layers.

The ectoderm consists of a continuous epithelium or layer of cells covering the surface of the egg. The walls of these cells are distinctly visible. The cells themselves are rounded, their nuclei fairly large and somewhat oval; they measure ·01 mm. in length by ·007 mm. in breadth. The chromatin is not evenly distributed, but forming a number of small particles, gives the nuclei a spotted appearance. This layer is sometimes as much as three cells deep.

The mesoderm lies directly under the ectoderm. The cells forming it are disconnected; whether they form a continuous layer in life or not I am not able to decide, as the cells may have shrunk in alcohol. Between the cells of the mesoderm yolk-particles are often to be seen, which makes it probable that the mesoderm never consisted of a continuous layer. The nuclei of the mesoderm cells are larger than those of the ectoderm, and also rounder; they measure .014 mm. in diameter.

The cells of the mesoderm seem to be engaged in rapid reproduction, karyokinetic phenomena being very frequent, and the centrisomata very often visible.

The entoderm consists of single cells, lying deeply embedded in the yolk. Generally only the nuclei of these cells are to be seen. The nuclei are of about the same size as those forming the ectoderm, measuring ·01 mm. by .012 mm. Their shape is sometimes convex-concave. Their chromatin is very evenly distributed, but still presents a slightly granular appearance.

These three germ layers correspond in appearance and position very closely to the same three of spiders, as described in the handbook of Korschelt and Heider (**26**).

The yolk only differs from the description given in the first stage in the parts nearest to the blastoderm. Where the yolk penetrates the mesoderm, and in all parts adjacent to the same, the yolk spherules have become very small indeed; which would lead one to think that the mesoderm is causing the yolk to break up.

The outer membrane shows no difference from that described in Stage I. The inner has, however, changed since the first stage, having risen above the surface of the egg in the region of the blastoderm, leaving a free space between itself and the ectoderm.

Stage III.

The third stage at my disposal is considerably more advanced than the last. The reversion of the embryo has already taken place, and the extremities have begun to grow. I have only found one egg at this stage; it comes from the same batch as the eggs described unter Stage I and Stage IV. Its growth had evidently been stopped by the pressure of the surrounding eggs, which also caused the embryo to develop in two disconnected halves, only held together by the yolk. The embryo also showed several other signs of not having developed normally.

My sections through this egg are, unfortunately, not all that I could wish, but still they are good enough to make out several details. For this reason I shall only attempt to describe a few of the organs.

The brain is already divided into its three parts, the commissures and the two kinds of nuclear tissue, the difference of which will be explained in full in Stage IV. These two tissues are chiefly characterised by the size, tinction, and density of the nuclei they contain, the smaller being closely packed, and stained darker. They measure ·005 mm., the larger, lighter stained, and less dense nuclei, on the other hand, measuring as much as ·009 mm. to ·01 mm.

The ventral ganglion-cord has not yet begun to appear. Those parts of the abdomen and cephalothorax which are bent upon each other at the time of the reversion of the embryo are devoid of any cellular integument, although lined by a thick cuticle. It is in this part that the ventral ganglion-cord takes its origin in the next stage.

It is interesting to observe that, as in spiders, the legs are full of yolk, only the tips being free. The yolk seems to get pushed backwards during the growth of the legs pari passu with the growth of the muscles and nerves. Neither the median nor the lateral eyes have yet begun to appear, nor are the lungs, heart, coxal gland, lateral organs, or alimentary canal in any degree traceable.

It is in the yolk that the chief peculiarity is to be seen. The neighbouring eggs have, through pressure, caused a deep semi-circular impression on one side of the embryo, and at the same time caused it to develop in two halves. The pressure has also influenced the yolk, causing several of the yolk-spherules to amalgamate and to form a mass without any regular shape. The appearance of this fusion necessitates the conclusion that the living yolk particles were of a fatty nature, and that they were suspended in a watery lymph, forming a kind of emulsion.

Stage IV.

The next stage which I possess is only a little more mature than the one just described. The reversion of the embryo has taken place long ago, the cephalothorax being separated from the abdomen. The extremities are much further advanced than those of the third stage and, except at their bases, are devoid of yolk. In surface views one sees the Anlage of the brain as two white spots at the front end of the cephalothorax. On the sides may be seen, at the base of the fourth pair of extremities, a horseshoe-shape excrescence; this is the lateral organ, first described by Laurie as occurring in Phrynus it is always covered by a shred of some dark substance.

The joints of the legs can already be distinguished, the embryo at this stage greatly resembling the one given in the drawing (figs, 1 and 1*a*) less the eyes, and with a much smaller amount of brain.

There are six pairs of extremities to be observed. The first pair, the cheliceræ, now lie before and on both sides of the mouth, and under the fold which carries the median eyes; their bases lie fairly wide apart. They are double-jointed, the second joints pointing towards each other, not as in adults, parallel and pointing downwards; this becomes still more conspicuous in the fifth stage.

The pedipalpi, too, begin near the same fold, to which, indeed, their bases are attached. At their bases they give off a branch, the endopodite, which forms a kind of mandible. As yet no thorns are to be found on the ectopodite; they first begin to appear in the fifth stage. The ectopodite is much larger than the endopodite.

The third pair of extremities corresponds to the first pair of walking legs in spiders; here they are developed into long whip-like legs, with probably only a sensory function. They lie doubled upon themselves, surrounding the pedipalpi, and with their tips reaching as far as between the cheliceræ. At the bases of this and the next posterior extremity I have been able to find the coxal gland. The next three pairs of extremities are the walking legs; they are all of about the same length, and shorter than the whiplegs. They are likewise doubled upon themselves, and their free ends are tucked under the preceding legs, only the sixth pair making an exception, the tibia and tarsus of which run along the under side of the other legs.

The whole embryo is enclosed in a loose outer skin, which follows the contour of the whole body, extremities included, without ever actually touching it, except, perhaps, in the region of the lateral organ, and in parts of the dorsal side of the abdomen. This cuticle is covered in parts with numerous wart-like processes, as mentioned by Pereyaslawzewa (**37**) and Laurie (**31**). On surface views nothing further is to be seen; we will therefore proceed to the description of the organs as seen in cuts.

(1) The Skins. — The outer cuticle just mentioned is seen in cuts to consist of several exceedingly thin stratæ; it is otherwise perfectly structureless. The embryo itself is covered by a thin epidermis, which in

most places consists of a single layer of cells. It does not as yet extend over the entire surface of the embryo, patches on the sides of the abdomen being still void of this covering.

(2) The Cœlom. — I have not been able to follow out the development of the cœlom. In my younger embryos it was, of course, not to be found. At this stage it has already reached a high development. I consider two layers of cells found under the epidermis, which send folds into the interior of the yolk, to be the cœlom, from their resemblance to the cœlom of Spiders and Scorpions. The cœlom also enters the bases of the legs. With the folds the Anlagen of the future dorso-ventral muscles of the cephalothorax and abdomen also enter the yolk. Between cœlom aud epidermis are also found the first Anlage of the segmental muscles, which arise from the somatic cœlom layer.

(3) The Lateral Organ. — The lateral organ of the Pedipalps has already been described by Laurie (**31**) and Strubell (**42**); it has also been described by Bruce (**9**) and Pereyaslawzewa (**37**).

In the stage which we are now considering the lateral organ seems to be at the height of its development. It appears as a horseshoe-shaped excrescence on the base of the coxa of the fourth extremity, which it covers on both sides. It is always covered by shreds of some dark substance, which is probably secreted by it. Cuts show that the lateral organ is a more complicated structure than it seems to me to have been considered as yet.

I am not able to state anything as to the origin of this structure, as I possess only embryos without the lateral organ, or with it in later stages of development.

Cuts show that the lateral organ consists of an outer layer of cells, forming the external wall of the sac; the interior of the sac contains two cavities filled with yolk, which are separated from each other by a second internal wall of cells, running nearly parallel to the external wall. The cells forming the outer wall of the lateral organ (fig. 5) are deeply stained with eosin; they protrude into the processes of the cuticle, at whose bases a dark substance is being deposited. The nuclei of these cells are oblong, and take a deep stain from hæmatoxylin.

The internal wall of cells resembles the external in its histological elements, with the difference that its cell walls are not visible, and that the cells have no distinct outline, so that it is almost impossible to determine their boundaries. On the side of this wall nearest to the body of the embryo protoplasmic processes of these cells are seen enveloping yolk particles.

The yolk in the one cavity does not resemble that in the other. In the outer cavity, enclosed by the external and internal wall, this yolk consists of very minute particles, which appear to have had to pass the internal wall before having reached the external cavity. The yolk in the internal cavity still in every respect resembles that filling the abdomen, and is in direct communication with it.

At the base of the lateral organ, where it is attached to the base of the fourth extremity, the epidermis has begun to grow inwards, forming a partition between the lateral organ and the leg. This partition has still an opening in the middle, through which the inner cavity of the lateral organ communicates with the yolk of the embryo. Later on this opening closes, after which the lateral organ becomes functionless and drops off.

The lateral organ of the Thelyphonidæ has been described by Strubell (**41**), and there is no doubt that it is identical with that of Admetus. In other orders of Arachnids we only find the lateral organ in Solpugids and Pseudoscorpions.

Croneberg (**10**) described the lateral organ of Galeodes. This also seems to be very similar to that of Admetus. I have also been able to find a similar organ in a young adult Chelifer; it seems to me to have already become functionless, and much resembles that described for Admetus in the fifth stage. The possession of a lateral organ seems to me to point out a nearer relationship between these three groups.

(4) The Coxal-gland. —There is in Admetus, as in all Arachnids, a so-called coxal-gland. I have found it, like the authors already cited, Miss Pereyaslawzewa excepted, at the base of the third extremity; I am also able to prove its existence, if only as a rudiment, at the base of the fourth extremity. This last atrophies very soon. At this stage the coxal-gland consists of a perfectly straight tube, running from the under surface of the coxa inwards, and lying immediately on the surface of the brain itself. It is easily distinguishable from the brain by the lighter tinction of its nuclei. It is everywhere surrounded by connective tissue. Whether it is still in open communication with the cœlom or no I am not able to decide. The occurrence of the coxal-gland at this stage in the fourth extremity as well as in the third makes it appear probable that it was originally segmental, as in scorpions, and it is likely that it would be discoverable in every segment in earlier stages of growth.

(5) The Nervous System and Sense-organs.— The nervous system at this stage consists of the cerebral ganglia and of the ventral ganglion-cord; this last extends far into the abdomen.

Of sense-organs only the median eyes and the coxal sense-organs have as yet made their appearance.

The præ-oral part of the brain consists, as in Stage III, of two distinct tracts, distinguishable by size, colour, and number of nuclei. The more anterior part consists of closely packed, small and darkly-stained nuclei, averaging ·0034 mm. in size. Nowhere in the rest of the brain are the nuclei so small, so densely packed, or so darkly stainable. We shall call this part of the brain the accessory brain. In all other parts of the brain the nuclei are less densely packed; they average ·01 mm. in diameter. The brains of adult Admetus also show the same division.

These two parts of the brain, following Laurie (**31**), who has briefly referred to the difference, are also said to be distinguishable in Scorpions.

I am in a position to give more notes about the development of the ventral ganglion-cord. This last extends on the one hand from the cerebral-ganglia, into which it merges imperceptibly, and runs along the ventral side of the cephalo-thorax and ends in the abdomen. In the latter it merges into the ectoderm so continuously that it is impossible to say where the ventral ganglion-cord begins and the ectoderm of the abdomen ends.

As all the different stages of the embryonic development of the brain are to be found in the ventral ganglion-cord of one embryo, it will be as well to give an account of it, beginning, for the sake of simplicity, with the distal and least-differentiated part of the cord (see fig. 8 .

If we examine the epidermis covering the median ventral line of the abdomen at the part where it is thinnest, we find that it consists of two layers of cells, surrounded by much protoplasm. The cell walls are not visible. The nuclei are oblong and tinge deeply with hæmatoxylin; the chromatin not being equally distributed, but collected in small masses, gives the nuclei a spotted appearance. The micro-nucleus is conspicuous in several of the nuclei.

The nuclei of the two layers lie with their axes pointing in different directions, the rounder nuclei of the outer layer, which measure ·01 mm. in length and ·008 mm. in breadth, being mostly inclined at an angle of about 75° to the surface; the more oblong nuclei of the inner layer measuring ·01 mm. in length and ·004 mm. in breadth, lie parallel to the outer surface of the embryo. This inner layer is continued forwards, and forms a skin covering the inner surface of the brain; it is of mesodermatic origin.

The first step towards the differentiation of the brain out of the epidermis just described consists of a rapid thickening of the outer or germ layer, through the multiplication of its cells. It soon becomes six to seven cells thick, and the nuclei have no longer any common direction. Through the thickening of the outer layer the surface of the embryo has here become a little arched. After this the outer or germ layer again becomes thinner, and only consists of one layer of cells. The inner layer also thickens till it becomes two or three cells deep; but as it does not take part in the construction of the brain I shall refer to it again as little as possible.

After proceeding forwards a short distance, probably corresponding to one abdominal segment, the cell-mass of the germ layer becomes again reduced to a single layer of cells; then it thickens again as before.

When the germ layer has reached its former thickness we observe several important changes. In the first place a new element has begun to develop. The cells of the germ-layer nearest to the surface have changed the direction of the axes of their nuclei. The nuclei themselves have become much elongated, measuring now ·015 mm. in length by ·004 mm. in breadth; they have also become poorer in chromatin. In this manner a new outer integument, the definite epidermis, has been formed.

The cells forming the germ-layer were till now equally distributed throughout the whole of the layer; this now ceases to be the case. A little space void of nuclei is formed on the surface of the germ-layer. This is filled with plasm; just above it there is a gap in the epidermis. For convenience sake I shall call such superficial masses of un-nucleated protoplasm „surface pits"; this name I give only with reference to their appearance and not, to their structure, and I desire that this may be distinctly borne in mind. The nuclei of the cells of the germ-layer adjacent to this "surface pit" are beginning to arrange themselves radially around the centre of the hollow. Further on, again proceeding forwards, the germ-layer again presents its former appearance. Still proceeding towards the cephalothorax, we meet with another new change. Just before the next thickening containing a "surface pit" is reached, the mesodermatic inner skin begins to lift itself from off the nuclei of the germ-layer. The space between both is now filled with nerve-fibres, the longitudinal fibres being the first to appear, as in Scorpions (Brauer, [7]). This "surface pit" only distinguishes itself from the last by the presence of a slight depression on its surface.

After the next "surface pit" has been reached, the germ-layer loses its continuity and breaks up into a number of groups of cells, each lying in front of its corresponding "surface pit". The space around these groups is filled with nerve-fibres, forming the commissures; they seem to run in every direction. A change has also taken place in the epidermis; its nuclei are no longer so elongated, having become more rounded; they now measure ·01 mm. by ·005 mm.

The first of the groups of brain-germ cells met with measures ·08 mm. in length by ·02 mm. in breadth, and lies ·02 mm. from the surface of the embryo. It is composed of nuclei lying about three deep and twelve broad, measuring between ·009 mm. and ·01 mm. They all lie with their long axes pointing towards the surface. The nuclei of these groups are all connected with the centre of the "surface pit" by radial fibres, which all converge towards it. The fibres probably belong to the neuroglia, and serve as a supporting tissue.

The epidermis is discontinued just at this "surface pit", as it was in the last. The "surface pit" also resembles the last described in having a slight depression on its surface. The cells of the epidermis also take an active part in the building up of the groups, by forming a funnel-like sheath around the radial fibres. The nuclei of the cells forming this sheath measure about ·018 mm. in length by .005 mm. in breadth. Karyokinetic figures are sometimes to be found in them.

The next such collection of germ-cells is, perhaps, even more typical. It lies just at that point where the abdomen forms an angle to the cephalotorax (fig. 8). Although more advanced than the last its dimensions are not larger.

The length and breadth are the same as those of the last group, the length of the radial fibres being ·02 mm., as in the last case; the group, however, now lies ·037 mm. from the surface.

The cause of the group lying deeper than the last described is an ingrowth of the epidermis in the shape of a narrow tube. Its bore is ·007 mm., and its length ·01 mm. The walls of this tube are formed by a single layer of cells, whose nuclei are but lightly stained, and which contain very large micro-nuclei. One nucleus 1 measured was ·01 mm. long by ·004 mm., its micro-nucleus, however, actually measuring ·004 by ·003 mm.

The nuclei of the cells forming this tube are all arranged with their long axes lying at right angles to the axis of the tube. The tube ends in an expansion, forming a nearly spherical sac, whose diameter is about ·01 mm. The walls of this sac are formed by the ends of the radial supporting fibres. The sac just described lies within the funnel-shaped sheath, which encloses the radial supporting fibres. The next group of cells so much resembles the last described that it is not necessary to go into any details about it.

Still proceeding forwards, we now meet with a group, which half retains its original form and independence, and is half connected with and converted to the ventral ganglion-cord in its definite form. The original germ-group lies ·1 mm. from the surface; its inner surface abuts on the commissures. On the side of the group which is turned towards the abdomen, the sheath covering the radial supporting-fibres and the germ-cells forming the group are as before, but the cells forming the tube have multiplied rapidly, and now reach as far as the cells forming the group. On the anterior side all parts of the group have multiplied their cells to such an extent that they build a solid mass of nuclei, reaching from the surface to the commissure. In this mass only the nuclei of the sheath can be distinguished from the others. The interior of the epidermis-tube is now filled with supporting fibres.

From the interior surface of the nucleiferous mass are seen in parts nuclei wandering through the commissural part of the brain, the „Punktsubstanz“; these afterwards form a cellular layer on the dorsal side of the commissures, which had been hitherto only covered by the mesodermatic inner skin mentioned at the beginning of this description. That the whole of the post-oral ventral ganglion-cord is formed in the manner just described is proved by the presence of numerous remains of tubes, filled with tangled masses of supporting fibre, in the brain-mass. Each such tube denotes the place where there was such a group of cells during the earlier development of the cord. Later on the tubes become entirely obliterated. These groups of cells, with their radial supporting fibres, their sheaths and tubes, possibly represent what Patten (**34**) compares to ommatidia in his description of the development of the brain of Arthropods. The comparison with sense-organs is certainly very good. I find, however, more resemblance with the „Hügelorgane der Seitenlinie", as described by Leydig for fishes, and by the Sarasins (**40**) for the larvæ of Amphibians. Judging by Patten's figures, however, I must conclude that he saw a phenomenon in part different to that which I have just described. In his drawing one sees that each segment of the brain is composed of several sense-organs, with larger ones in the middle line. I have only been able to find one in each neuromere. This probably corresponds to the larger sense-organs in Patten's figures. It is to be regretted that Patten did not publish any drawing of a transverse section of such a sense-organ, or a description of their development. Kishinouye (**22**) also states that the nervous system of Limulus consists at one period of peculiar cell-groups resembling ommatidia. According to the drawings he gives, he must have cut them at right angles to the direction in which I have cut them in the embryo described.

According to the description just given, we find that the brain is derived in all its parts from the ectoderm, as follows:

(1) Directly, as regards the germ groups.

(2) Indirectly, through the epidermis, as regards the sheaths surrounding the radial supporting-fibres and the tubes.

In more mature portions of the brain the cell-elements have reached a higher development. We find in the ventral ganglion-cord the two usual kinds of nerve-cells, lying the one amidst the other.

(1) Cells with smaller, generally oblong nuclei, measuring ·01 mm. by ·007 mm., without visible protoplasm; these form the chief part of the brain behind the accessory brain. It is impossible to distinguish these nuclei from those of the germ-layer or from the neuroglia.

(2) Cells with larger, generally round nuclei, measuring ·015 mm. in diameter; these nuclei do not generally stain so deeply with hæmatoxylin. They are usually surrounded by protoplasm, and often have very distinct micro-nuclei. They are usually to be found near the commissural substance. They much resemble the ganglion-cells of other animals.

The real meaning of the just-described process of development becomes clearer when we compare the development of the central nervous system of the Arachnids with that of other classes of animals. Since the Arachnid brain has reached such a high degree of perfection, we must look for analogies chiefly in classes of similar development of brain. First we may look to the Vertebrates.

In the central nervous system of Vertebrates and Arachnids the grey and the white matter seems to have totally different relative positions; the white substance surrounding the grey in Vertebrates, and being almost surrounded by it in Arachnids. This seeming dissimilarity is soon explained. Since the central nerve-tube of Vertebrates becomes folded inwards during its development, it is clear that its innermost walls, which abut on the canalis centralis, are that part of the wall which was originally outermost. Thus we would in both cases have the grey substance outermost, the white substance lying under it.

His (**16**) describes the spinal cord of Vertebrates as arising out of „Zwei Kernfrei Zonen, eine äusserste und eine innerste, und eine die Kerne enthaltende Mittelzone". He terms the outer of the two zones without nuclei the „Randschleier", the inner the „Säulenschicht". These three layers or „Zonen" are all to be met with in Arachnids, though somewhat modified, having in part become discontinuous. The columnal layer, „Säulenschicht", could be compared to the „surface-pits"; but it, of course, no longer forms a continuous layer in Arachnids as it does in Vertebrates. The „Mittelzone" can be compared, as regards position and structure, to the nuclei-groups in the developing ventral ganglion-cord of Admetus, and the „Randschleier", which gives rise to the white matter in Vertebrates, is evidently equivalent to the commissural subtance, or „Punktsubstanz" of the brain of Admetus, also as regards position and structure.

The ganglion cells of Admetus are almost always to be found in the depth of the grey matter, just below the Punktsubstanz or white matter, as is also the rule with Vertebrates. In the latter all nerves proceed out of the white subtance. Even this has an analogy in Arachnids, as all the nerves I met with in my cuts left the ventral ganglion-cord just above the grey matter, at places where the nucleiferous covering of the „Punksubstanz" was very thin. These were the chief points of resemblance. The chief points of difference are: — In Vertebrates the origin of the neuromeres is evidently secondary; nerves issue from the spinal cord only in those places where the vertebral sheath leaves them spaces to pass through; in Arachnids the neuromeres appear, in Admetus at least, to be primary in origin, and at the same time to be segmental. This does not point to any fundamental difference in the whole process; on the contrary, it is only to be expected that the segmentation which occurs in Arthropods should be more constant and more early in appearance than that of Vertebrates. In these the segmentation is disappearing everywhere, and in all systems of organs.

According to a theory of von Kupffer and others, the sense-organs of the Vertebrates are derived from a hypothetic primitive form of sense-organs, the so-called placods. The placods remain in their least changed form as the "Hügelorgane der Seitenlinie" of Leydig, and as papillæ of the organ of taste. These sense-organs much resemble those just described as building part of the Anlage of the ventral ganglion-cord of Admetus. A similar feature is that the epidermis of the branchial region of Vertebrates gives rise to the epibranchial ganglia, that is to say, in Vertebrates, as in Arachnids, primitive sense-organs take part in the building up of the ganglia.

The Sarasins (**41**) have also pointed out the resemblance of small sense-organs of Helix Waltoni to the "Hügelorgane" of Ichthophis. Here the sense-organs also seem to take part in the building up of the ganglia. A peculiar coincidence is to be found when we compare the brains of Helix Waltoni with that of Admetus. The Sarasins mention that the most anterior portion of the brain of Helix Waltoni consists of very small, darkly stained, and closely packed nuclei, containing no Punktsubstanz, and no ganglion-cells; this portion of the brain of Helix Waltoni they call the accessory brain. The process of the development of the accessory brain of Helix Waltoni resembles the same process in Admetus very closely and conspicuously. According to the Sarasins the accessory brain of Helix Waltoni takes its origin out of the so called cerebral tubes; by analogy with Scorpions, it is perhaps possible to prove the same for Admetus, though I can only find it by comparing the papers of Brauer (**7**) and Laurie (**29**). Laurie says that the median eyes of Scorpions arise out of an invagination, which takes place just iu front of the Anlage of the brain; he describes the cells forming it as resembling brain-cells, but having smaller, darker-stained and more densely packed nuclei; in another paper (**31**) he states that the brain of Phrynus resembles that of Scorpions in as much as in both cases we find a division of the brain in a part containing smaller, darker, and more densely packed nuclei, and a part with lighter, larger, and less dense nuclei. According to Brauer the median eyes arise on a small projection, which lies beyond the invagination mentioned by Laurie, this invagination becoming deep, and giving rise to an accessory part of the brain. Brauer however, omits to mention whether he found the nuclei composing this part to differ from those forming other parts of the brain.

According to Kleinenberg (**25**) part of the nervous system of Lopadorhynchus is also formed out of primitive sense-organs, which afterwards become converted entirely into ganglion-masses.

We are thus led to suppose that the central nervous system of Arthropods to some extent corresponds in origin and structure to that of Vertebrates; namely, as regards the origin of the three layers ("Saulenschicht," "Mittelzone," and "Randschleier" "surface pit", germ-group, and commissural substance), and as regards the conversion of sense-organs into ganglia. To some extent it corresponds to that of Molluscs, namely, as regards the origin of ganglia out of sense-organs, and perhaps in possession of an accessory brain. Lastly to that of Worms, namely, as regards the origin of ganglia out of sense-organs.

The Median Eyes.—As yet only the median eyes have begun to make their appearance. Being unpigmented they are not visible on surface views. The lateral eyes are first met with in more mature stages. Just above the cheliceræ, on the front of the cephalothorax, we meet on each side with a lappet-like excrescence, the bases of which have already begun to unite with each other where they meet in the median plane; thus they form a kind of mask in front of the embryo, covering its mouth. The space beneath this mask remains hollow till much later.

These folds are the Anlagen of the median eyes, they consist of two simple thickenings of the ectoderm, which have probably been inverted in the way described by Brauer for Scorpions.

The front wall of the eyes still only consists of a single row of cells; in the posterior wall the cells have begun to multiply. The space between the anterior and posterior walls of the eyes contains no nuclei, being only filled with cell-walls and plasm.

The eyes measure in length ·1 mm., they are ·04 mm. thick.

Besides the eyes there is only one other set of sense-organs to be found. These are the segmental sense-organs first described by Patten (**34**) as occurring at the base of the legs of Spiders; they were also described by Brauer (7), who found them in Scorpions. The description and drawings given by Brauer accord with those which I could give for Admetus.

(6) The Alimentary Canal. — The alimentary canal is at this stage still very incomplete, only the most anterior part existing as yet. It consists of a simple tube which just pierces the brain. Its outer anterior end does not project beyond the brain, the posterior end doing so for about one-third of its length. From the point where it leaves the brain it is slightly bent in a ventral direction. The cells forming the walls of the alimentary canal form a thick layer at both ends of the tube. No muscles are as yet observed in connection with the alimentary canal. In transverse sections it otherwise presents a similar appearance to that of more advanced stages.

The cavity of the alimentary canal is **Y**-shaped; the cells composing its walls are high and cylindrical. The nuclei chiefly lie at the end of the cell nearest to the cavity. A thin cuticle has been secreted by these cells.

The whole is surrounded by a thin layer of mesoderm cells, which form a skin round the tube. The nuclei of these cells have begun to elongate, and will probably form the ring-shaped muscle found later on in this part.

7. The Heart. — The circulatory organs are at present represented by the heart alone. The origin of the heart seems to me to be the same as in Scorpions Brauer (7) and other Arachnids. It is evidently formed by the cœlom on both sides of the embryo meeting, leaving a space between the walls on either side, which, although surrounded by cœlomatic walls, does not belong to the cœlom itself. The heart causes a slight ridge on the surface of the embryo.

8. The Lungs. — At this stage the lung-books are just beginning to make their appearance. They belong to the first and second abdominal extremities. Laurie (31), however, has located them on the first and third. They differ neither in development nor in appearance from the lungs of other Arachnids.

9. The Muscles. — Typical muscles are as yet nowhere to be found. In the extremities, and also in the abdomen, we find the cells which give rise to the future muscles. These are distinguishable by their long, granular nuclei. Though already spindle-shaped, they do not as yet stain with eosine, as the muscles in more advanced embryos always do.

10. The Genital Organs. — The genital organs have not as yet begun to make their appearance.

Stage V.

The two illustrations (figs. 1 and 1*a*) of the embryo at this stage will give a very good idea of the general superficial appearance of these embryos. They appear in almost every respect similar to the embryos of the fourth stage, and the description of those embryos only requires a few additions to be perfect for the embryo of the fifth stage.

In the first place we must remark the median eyes. They are now very deeply pigmented, except in a narrow line which separated the two eyes.

The lateral eyes are now also visible; they resemble **Y**-shaped marks on both sides of the median eyes. This is caused by the pigment being deposited between the single ocelli, which are three in number. The margin of the fold carrying the median eyes is also more distinctly visible than in the fourth stage.

1. The Skins. — No important change can be observed in the skins since Stage IV.

2. The Cœlom. — The cœlom has undergone many changes since Stage IV. It has, for instance, given rise to the muscles, of which at least two sets are to be distinguished. A dorso-ventral muscular system has followed the foldings of the cœlum, and now consists of a paired muscle in each segment, running from the carapace to the ventral side, except perhaps in the first two segments of the cephalo-thorax. The other set consists of the inter-segmental muscles. These run parallel to the surface, from segment to segment. The walls of

the cœlom also take part in building up the mid-gut. On the ventral side of the abdomen we also find the genital cells lying inside the cœlom, as will be described further on.

3. The Lateral Organ. — The lateral organ is still to be found, but it seems to me to have ceased to have any function. Superficially it seems to be in the same state as it was in the fourth stage; it is only on cuts that the difference is remarked.

Sections show that the lumen of the lateral organ is no longer directly connected with that of the rest of the body, and with the base of the fourth extremity in particular.

The cells which at a less mature stage formed the walls of the lateral organ have died off, and it is only here and there that traces of them are found. With the drying up of the wall cells their plasma has been withdrawn from the interior of the wart-like processes of the cuticle.

In the fourth stage the outer cavity of the lateral organ was filled with very small yolk particles; these have now conglomerated and form a solid mass, staining deep red with eosine. The partition that had begun to form between the base of the lateral organ and the base of the fourth extremity is now complete.

A remarkable fact is that a substance resembling the filling of the lateral organ is to be found in the adjacent parts of the base of the fourth extremity.

The shreds of dark substance covering the lateral organ in the fourth stage have become much thicker (they have been removed in the drawing (fig. 1*a*), so as not to hide the lateral organ). This makes it appear more probable that they have been secreted by the lateral organ.

4. The Coxal Gland. — At this stage the coxal gland is at the height of its development. Only the gland belonging to the third extremity is still to be found. It occupies all the space between the cerebral ganglia and the ventral ganglion-cord that is not occupied by the muscle-stomach. Bulging over the sides of the ventral

ganglion-cord, it now lies in at least four segments, namely, the third, fourth, fifth and sixth, its opening lying at the base of the third extremity.

There are two different parts of the gland which can be distinguished, namely, the mouth end and the gland proper. The mouth end is composed of cells in every way resembling those that form the epidermis. Its nuclei are oblong, and stain deeply with hæmatoxylin. In this part I observed no trace of cell-walls. The second part builds up the chief bulk of the gland itself. It consists of an unbranched tube, much convolved at its inner end. The tube runs nearly straight from the surface up to near the brain; next it bends backwards and runs in almost a straight line till it reaches the sixth segment; then it begins to twist and turn so much that it is impossible to follow it further. As I have nowhere been able to observe a branching of the tubes, I suppose that it must be simple in its whole length, as in other Arachnids.

The cavity of the gland is about ·01 mm. wide. The cells composing the tube have very distinct cell-walls, the cellplasm being very clear and staining very slightly. The nuclei are perfectly round, and do not stain very deeply; their diameter is ·007 mm. They lie almost always on the side of the cells nearest to the lumen of the gland, leaving, however, a space between themselves and the cell-walls. In this space the plasm seems at its thickest. The length of the cells, measured from outside the gland to the cavity of the gland, is ·02 mm.

The tube forming the gland itself is enclosed in a sheath of flat cells, of mesodermatic origin, as in other Arachnids. The space between the windings of the tube is filled out by connective tissue. The whole gland is likewise covered by an outer skin, the elements of which somewhat resemble those forming the sheath of the tubule.

5. The Central Nervous System. — The nervous system now consists of the cerebral ganglion, the ventral ganglion-cord and the nerves.

When compared with the fourth stage, the ventral ganglion-cord appears much contracted. In the fourth stage it was continued far into the abdomen, now we only meet with it in the cephalothorax.

A great advance on the fourth stage is also to be observed in the development of the ganglia. In Stage IV it was impossible to distinguish them from each other; now they are very distinct. The whole brain has become very similar to that of the adult.

The outer form is to be seen in the illustration (fig. 2), made after a model constructed by me from a section-series. I will begin by a description of the superficial appearance of the brain.

A glance at the illustration will show that the brain consists of two parts, a smaller dorsal and a larger ventral. It is pierced by the alimentary canal in the region where the two parts are joined to each other.

Five pairs of nerves issue from the ventral or post-oral part of the brain; these belong to the pedipalpi and the legs. The nerves and ganglia belonging to the cheliceræ are præoral.

No other nerves at yet leave the dorsal portion of the brain, though two swellings on each side of it, just behind the ganglion of the cheliceræ, denote the optic ganglia. They are not yet connected with the eyes by nerves, these being very late to appear. The dorsal portion of the central nervous system contains the accessory brain, the four cerebral ganglia, and part of the ventral ganglion-cord, containing the ganglia of the cheliceræ.

The ventral ganglion-cord consists of eighteen ganglia, six belonging to the extremities. The other twelve are very small; although lying in the cephalothorax they really belong to the abdomen.

The elements forming the brain and ventral ganglion-cord are histologically mostly the same as those described in the fourth stage. We now remark, however, small masses of darker stained fibres in the commissural parts of the central nervous system, the origin and structure of which it is difficult to understand. They are not to be found in the adult brain.

6. The Eyes. — The median eyes have become much further developed since the fourth stage. This can best be described in connection with the drawing (fig. 6). The median eyes are still situated on a fold in front of the mouth. The mouth opens into the cavity (*c.*) formed between the fold carrying the eyes and the cephalothorax. We can distinguish between three distinct layers of the fold—the corneal, the retinal, and the sub-retinal layer. This last is separated from the retinal by a fissure.

The stratum corneum (*co.*) consists of a layer of nuclei, two or three deep. In front it has begun to deposit chitin, the future lens (*l.*)

Under the cornea lies the retina (*r.*) It is deeply pigmented in its anterior half. One can distinguish thicker and thinner lines of pigment (*p.*) in front. The retinæ of the two eyes are very distinctly separated from each other by a light unpigmented line (*s.*).

The post-retinal layer (*pr.*) resembles the epidermis elsewhere.

I am not in a position to say how the eye has developed out of the Anlage described in the fourth stage.

There are three lateral eyes on each side of the cephalothorax. They lie in groups in a line with the median eyes. The lateral eyes originate out of simple ectoderm thickenings, as Laurie stated, as will be seen in the drawing (fig. 7). Pigment is as yet only deposited in the spaces between the single eyes. The lateral eyes of the adult also consist of three facets.

7. The Alimentary Canal. — Since the fourth stage the alimentary canal has made very rapid progress. It now forms a nearly complete tube, only the foremost part of the midgut remaining absent. The alimentary canal now consists of the following parts: — mouth, pharynx, œsophagus, muscle-stomach, midgut, and rectum. The mouth is situated on a small protuberance, which projects into the subocular cavity, and lies between the bases of the pedipalpi. Just behind the mouth we find the pharynx; that has a I-shaped cavity, the walls of which are lined

with a thin chitinous membrane. The cavity measures ·1 mm. by ·01 mm.

The cells forming the walls of the pharynx have very distinct cell-walls; the nuclei are small, oblong, and stain very deeply with hæmatoxylin; they measure ·007 mm. by ·004 mm. Besides the lateral and dorsal muscles attached to this part of the alimentary canal, described by Laurie, I must draw attention to another set of muscles connected with the pharynx. This set is a ring-muscle, which runs round the pharynx; it evidently acts as the antagonist of the lateral and dorsal muscles, and serves to close the cavity when it has been distracted by the other muscles.

The pharynx goes over into the œsophagus, when it enters the brain-mass. Its hollow is now **Y**-shaped. The cells forming its walls are similar to those of the pharynx. A distinct cuticle is still to be seen. It is no longer enclosed in a ring-muscle, but is only covered with connective tissue. After having passed through the brain, the alimentary canal again changes its character and becomes muscular once more. Its cavity is much wider here and is **X**-shaped in transversal sections. The cells forming this part much resemble those of the parts already described.

The musculature of the muscle-stomach can be divided into two systems, similar to those of the pharynx. The first of these consists of radial muscles, the longest of which runs dorsally towards the carapace; the two others are much shorter, and insert laterally in a cartilage, which also serves to support the coxal gland.

The other system again consists of a ring-muscle, which is much stronger than that in the region of the mouth.

As yet the muscles are all smooth, in the adult they are striated. The dorsal and lateral muscles pierce the ring-muscle and insert in the walls of the stomach it self.

The alimentary canal has a break in its continuity, just behind the muscle-stomach; we next meet with it in the abdomen.

Through in-foldings of the cœlom the yolk is divided into several distinct masses. The walls of the midgut are in part formed by the cœlom. At its anterior end it is wide, open, and funnel-shaped, and it tapers towards its posterior end. It is everywhere filled with yolk. On the interior side of the funnel formed by the cœlom the entoderm cells have built up an epithelium. This epithelium seems to be separated by a membrane from the walls composing the cœlom.

The cells forming the lining of the midgut have distinct cell-walls; their nuclei stain lightly with hæmatoxylin; they are perfectly round, and measure ·01 mm. in diameter. A micro-nucleus is often to be found in them.

The end of the midgut is not in open communication with the rectum, being closed by a plug of entoderm cells.

The rectum is formed by an invagination of the ectoderm. At its exterior end its cells quite resemble those forming the epidermis, at its interior (proximal) end the cells are vacuolarised. The rectum, as also the most anterior parts of the alimentary canal, is supplied with powerful muscles; one set, the dilators, runs from its walls to the skin of the abdomen; the contractors being ring-shaped, as in the pharynx and muscle-stomach.

As in Scorpions the Malphigian tubes are without doubt of entodermatic origin, as they enter the alimentary canal near the posterior end of the midgut. In this stage they are already well developed; they are very long and run parallel and juxta-apposed to the alimentary canal.

8. The Heart. — The heart of the Pedipalpi has been best described by Pereyaslawzewa as yet.

The heart at this stage consists of a long tube, lying dorsally, immediately beneath the skin, in the median plane of the abdomen. Its walls are thick, but do not contain many muscle elements.

At each segment the heart widens, and seems to me to give off a pair of small arteries. A large artery leaves the heart at its anterior end, this runs into the cephalothorax; following the outer surface of the embryo and reaching the cerebral ganglion it suddenly bends downwards; soon afterwards it divides into two branches, which run forwards on both sides of the muscle-stomach till they reach the central nervous system when, they terminate abruptly.

My embryos not being so advanced as Pereyaslawzewa's (**37**), I am not in a position to state anything about the other arteries and veins which she has seen; at the same time I consider her statement that the heart terminates "par une artère post-abdominale" as at all events not perfectly correct, since, as is hardly necessary to state, the Phryniscidæ have no post-abdomen, either as embryos or as aduts.

Inside the heart the blood-cells are to be seen. These are large cells, staining red with eosine. They are usually nearly spherical, measuring up to ·036 mm. in diameter, and seem to be surrounded by a thin membrane. The nuclei of the blood-cells always lie on the surface of the cell, and are oblong. Each cell contains many nuclei, of which one is always remarkable as being several times larger than the others; this one measures ·007 mm. and is often in a state of mitosis. These cells are possibly the same as the fat-cells seen by Kishenonye (**23**) in spiders, but are here confined to the interior of the heart. Besides these larger blood-cells, smaller ones are also to be seen in the cavity of the heart. These have only one nucleus, and are poor in plasma; they resemble those found in the heart in the fourth stage. There the larger, spherical blood-cells are missing.

9. The Lungs. — It is not necessary to follow the development of the lungs, as it follows the same type as most other Arachnids.

10. The Genital Organs. — I am not in a position to state anything new about the genital ducts, Pereyaslawzewa (**38**) having given a fuller account of them than can be made out of my embryos. I have only been able to find the genital germ-cells. These are the largest cells in the whole embryo. They are situated in the remains of

the cœlom, on the ventral side of the abdomen, in the region of the second, third, fourth, fifth, sixth, and seventh abdominal segments.

The shape of the genital-cells in always more or less oval (fig. **4**), the nucleus resembling the cell in shape. The genital cells are surrounded by a thin cell-wall; the plasma stains red with eosin, and is granular in appearance. It often contains as many as three vacuoles; one at all events seems never to be wanting.

The nucleus stains only a little darker than the plasma, and is little influenced by hæmatoxylin. The chromatophores are distinctly visible in the shape of bands of darker-stained substance. The nucleus also seems to be separated from the cell-plasm by a thin membrane.

The micro-nucleus is very conspicuous; it is always perfectly round, and stains very deeply with hæmotoxylin. It is almost always surrounded by a clear space containing little stainable matter. It is always found inside the nucleus.

The average measurements of the genital cells are: — Length of cell ·07 mm., breadth of cell ·03 mm., length of nucleus ·03 mm., breadth of nucleus ·02 mm., diameter of micro-nucleus ·004 mm.

11. The Muscles. — The two chief systems of muscles have already been referred to under the heading Cœlom. They are at this stage very well developed, and are composed of smooth fibres only.

Pereyaslawzewa (**38**) declares that the muscles of the cephalothorax are all striated, those of the abdomen being all smooth. It is hard to understand why this should be the case, and I think that the statement requires further confirmation, especially as all the muscles are derived from the same segmental sources, both in cephalothorax and abdomen.

12. The Yolk. — It is now only necessary to state that pari passu with the development of the central nervous system and with the contraction and withdrawal of the ventral ganglion-cord into the cephalothorax, the chief bulk of the yolk has been forced back in the abdomen, as is the case with all Arachnids.

Conclusions.

On the whole the development of the Pedipalps follows the types prevalent among other Arachnids, sometimes leaning more towards the one, sometimes more towards the other class. It resembles

(1) That of Spiders : —

a. In the first cleavages (probably).

b. In the egg-envelopes.

c. In the general build of the blastoderm.

d. In the development outside the mother animal.

e. In the development of the lungs, heart, alimentary canal, and coxal-gland.

(2) That of Solpugids and Pseudo-scorpions.

a. In the development of the lateral organ.

(3) That of Scorpions.

a. In the development of the central nervous system.

b. In the presence of an accessory brain.

c. In the development of the median and lateral eyes.

d. In the development of the lungs, heart, coxal-gland, and parts of the alimentary canal and Malphigian tubes.

The mode of development of several of the organs is the same in Spiders as in Scorpions, for example, heart, lungs, etc.

Bibliography.

1. **Adensamer.** — "Die Coxaldrüse von Thelyphonus caudatus," 'Zoolog. Anzeiger,' XVIII.
2. **Bernard.** — Terminal Organ of the Pedipalpi of Galeodes, and the Discovery of a Homologous Organ on the Pedipalp of Phrynus," 'Ann. Nat. Hist.,' XII.
3. **Bernard.** — "On the Spinning-glands of Phrynus, with an account of the so-called Penis, and of the Morphology of the Operculum," 'J. Linn. Soc.,' XXV.
4. **Bernard.** — "The Comparative Morphology of the Galeodidæ," J. Linn. Soc.,' XXV.
5. **Bertkau, Zu Lebidinsky.** — 'Die Entwicklung der Coxaldrüse von Phalangium," 'Zool. Anz.,' 1892.

6. **Brauer.** — "Beiträge zur Kenntniss der Entwicklungsgeschichte des Scorpions I," ,Zeitschr. f. wiss. Zool.,' 1894.

7. **Brauer.** — "Beiträge zur Kenntniss der Entwicklungsgeschichte des Scorpions II," 'Zeitschr. f. wiss. Zool.,' 1896.

8. **Bruce.** — "Observations on the Embryology of Spiders," 'Am. Nat.,' XX.

9. **Bruce.** — "Nervous System of Insects and Spiders, with Remarks on Phrynus," 'Johns Hopkins Univ. C.'

10. **Croneberg.** — "Uber ein Entwicklungsstadium des Galeodes." 'Zool. Anz.,' X.

11. **Faussek.** — "Zur Embryologie von Phalangium," 'Zool. Anz.,' 1891.

12. **Froriep.** — "Uber ein Ganglion des Hypoglossus und Wirbelanlagen in der Occipitalregion," 'Arch. f. Nat. and Entwicklungsgesch.' 1882.

13. **Griffiths.** — "On the Blood of Invertebrates, Arachnids," 'Proc. R. Soc. Edin.,' XIV.

14. **Hentschell.** — "Zur geographischen Verbreitung der Thelyphonen," 'Zool. Anz.,' XXII.

15. **Hentschell.** — "Beiträge zur Kenntniss der Spinnenaugen," 'Zool. Jahrb. f. Anat.,' XII.

16. **His.** — "Die Neuroblasten und deren Entstehung im embryonalen Mark," 'Arch. f. Anat. and Entwicklg.,' 1899.

17. **Jaworowsky.** — "Uber die Extremitäten, deren Drüsen und Kopfsegmentierung bei Trochosa singoriensis," 'Zool. Anz.,' 1892.

18. **Jaworowsky.** — "Über die Extremitäten bei den Embryonen von Arachniden und Insecten," 'Zool. Anz.,' 1891.

19. **Jaworowsky.** — "Die Entwicklung der sogenannten Lungen bei den Arachniden und speziell bei Trocha singoriensis, nebst Anhang über Crustæceen Kiemen," Ztschr. f. wiss. Zool.,' LXVIII.

20. **Kingsley.** — "The Embryology of Limulus," 'J. Morph.,' VII.

21. **Kishinouye.** — "On the Lateral Eyes of Spiders," 'Journ. Coll. Sci.,' 1892.

22. **Kishinouye.** — "On the Development of Limulus longispina," 'J. Coll. Sci.,' 1892.

23. **Kishinouye.** — "On the Development of Araneina," 'J. Coll. Sci.,' 1891.

24. **Kishinouye.** — "Note on the Cœlomic Cavity of the Spider," 'J. Coll. Sci.,' VI.

25. **Kleinenberg.** — "Die Entwicklung von Lopadorhynchus," 'Ztschr. f. wiss. Z.,' 1886.

26. **Korschelt** und **Heider.** — "Entwicklungsgeschichte der wirbellosen Thiere."

27. **Lankester, E. Ray.** — "On Skeletotropic Tissues and Coxal-gland of Limulus, Scorpio and Mygale," 'Q. Journ. Micr. Sci.,' 1891.

28. **Lankester, E. Ray.** — "Limulus an Arachnid," 'Q. Journ. Micr. Sci.,' 1881.

29. **Laurie.** — "The Embryology of a Scorpion," 'Q. Journ. Micr. Sci," 1891.

30. **Laurie.** — "On the Development of the Lung-books in Scorpio fulvipes." 'Zool. Anz.,' 1892.

31. **Laurie.** — "On the Morphology of the Pedipalpi," 'J. Linn. Soc.,' XXV.

32. **Lebidinsky.** — "Die Entwicklung der Coxaldrüse bei Phalangium," 'Zool. Anz.,' 1892.

33. **Locy.** — "Observations on the Development af Agalæna nævia," 'Ann. Nat.,' XX.

34. **Patten.** — "Segmental Sense-organs of Arthropods," 'J. Morph.,' 1889.

35. **Patten.** — "On the Origin of Vertebrates from Arachnids," 'Q. J. Micr. Sci.,' 1891.

36. **Patten.** — "On the Morphology and Physiology of the Brain and Sense-organs of Limulus," 'Q. Journ. Micr. Sci.,' 1894.

37. **Pereyaslawzewa.** — "Les premiers stades du développement des Pedipalpes," 'C. R. Ac. Sci.,' CXXV.

38. **Pereyaslawzewa.** — "Les derniers stades du développement des Pedipalpes," 'C. R. Ac. Sci.,' CXXV.

39. **Purcell.** — Über den Bau der Phalangiden Augen," 'Ztschr. f. wiss. Z.,' LVIII.

40. **Sarasin.** — "Zur Entwicklungsgeschichte und Anatomie der ceylonesischen Blindwühle Ichthyophis glutinosa," 'Erg. wiss. Forsch. in Ceylon.'

41. **Sarasin.** — "Die Entwicklung von Helix Waltoni," 'Erg. wiss. Forsch. in Ceylon.'

42. **Strubell.** — "Zur Entwicklungsgeschichte der Pedipalpen," Zool. Anz.,' 1892.

43. **Tarnani.** — "Die Genitalorgane der Thelyphonus." 'Biolog. Centralbl.,' 1889.

44. **Tarnani.** — "Zur Morphologie der Thelyphonus," 'Zool. Anz.,' XIX.

45. **Thiele.** — "Über Sinnesorgane der Seitenlinie und das Nervensystem der Mollusken," 'Ztschr. f. wiss. Zool.,' XLIX.

46. **Wagner.** — "Zur Entwicklungsgeschichte des Ixodes," 'Zool. Anz.,' 1892.

47. **Watase.** — "On the Morphology of the Compound Eyes of Arthropods,' 'Q. J. Micr. Sci.,' 1890.

48. **Watase.** — "Neuroblasts in the Arthropod Embryo," 'J. Morph.,' IV.

Explanation of figures.

Illustrating Mr. L. H. Gough's paper on "The Development of Admetus pumilis: a Contribution to the Embryology of the Pedipalps.

[N. B. — It must be borne in mind that the descriptions in the text are made from whole series of sections, but that the drawings were each made from one cut only.]

Fig. 1 and **1a.** — Embryo of Stage V; explanations in the text. Magnified 6 times.

Fig. 2. — Reconstruction of brain of embryo of Stage V. The parallel lines are to demonstrate the position of the cavity caused by the alimentary canal, otherwise as in text. Magnified 9 times.

Fig. 3. — Sagittal section of lateral organ of embryo of Stage IV. Magnified 80 times. *c.* Cuticle. *d.* Deposit. *e. w.* External wall. *i. w.* Internal wall. *p.* Pertition. *o. c.* Outer cavity. *i. c.* Inner cavity. *y.* Yolk.

Fig. 4. — Sagittal section of part of the abdomen of embryo of Stage V, with genital cells. Magnified 110 times. *v.* Vacuole of germ-cell. *mn.* Micro-nucleus of germ-cell. *n.* Nucleus of germ-cell. *c p.* Cell-plasm of germ-cell. *a. e.* Fifth abdominal extremity. *c.* Remains of cœlom.

Fig. 5. — Sagittal section of a portion of the heart of embryo of Stage V. Magnified 165 times. *w.* Walls of heart. *b. c.* Blood-cells. *y.* Yolk *e.* Epidermis.

Fig. 6. — Sagittal section through cephalothorax of embryo of Stage V. Magnified 30 times. *c. g.* Coxal-gland. *o. c. g.* Opening of coxal-gland. *d. v. m.* Dorso-ventral muscles. *a. b.* Accessory brain. *b.* Brain.

Fig. 7. — Horizontal section of rectum and midgut of embryo of Stage V. Magnified 110 times. *e.* Epidermis. *re.* Rectum. *en.* Entoderm cells forming mid-gut. *m.* Muscles forming sphincter and dilators. *y.* Yolk.

Fig. 8. — Sagittal section through embryo of Stage IV, showing Anlage of part of ventral ganglion cord, and development of ganglia out of small sense-organ-like structures. Magnified 140 times. *S.* Surface pit. cav. cavity. *S. f.* supporting fibre. *tu.* tube. 1—9 Sense organ-like structures at different periods of growth.

Figs. 9 and **9a.** — Sagittal sections through lateral eyes of embryo of Stage V. Magnified 210 times. 1, 2, 3. First, second, and third eye.

Fig. 10. — Horizontal section of median eye of embryo of Stage V. Magnified 240 times. *l.* Lens. *co.* Stratum corneum. *p.* Pigment. *R.* Retina. *F.* Fissure. *P. R.* Post-retinal layer. *c. c.* Subocular cavity.

Elsäss. Druck. vorm. G. Fischbach, Strassburg. — 6097

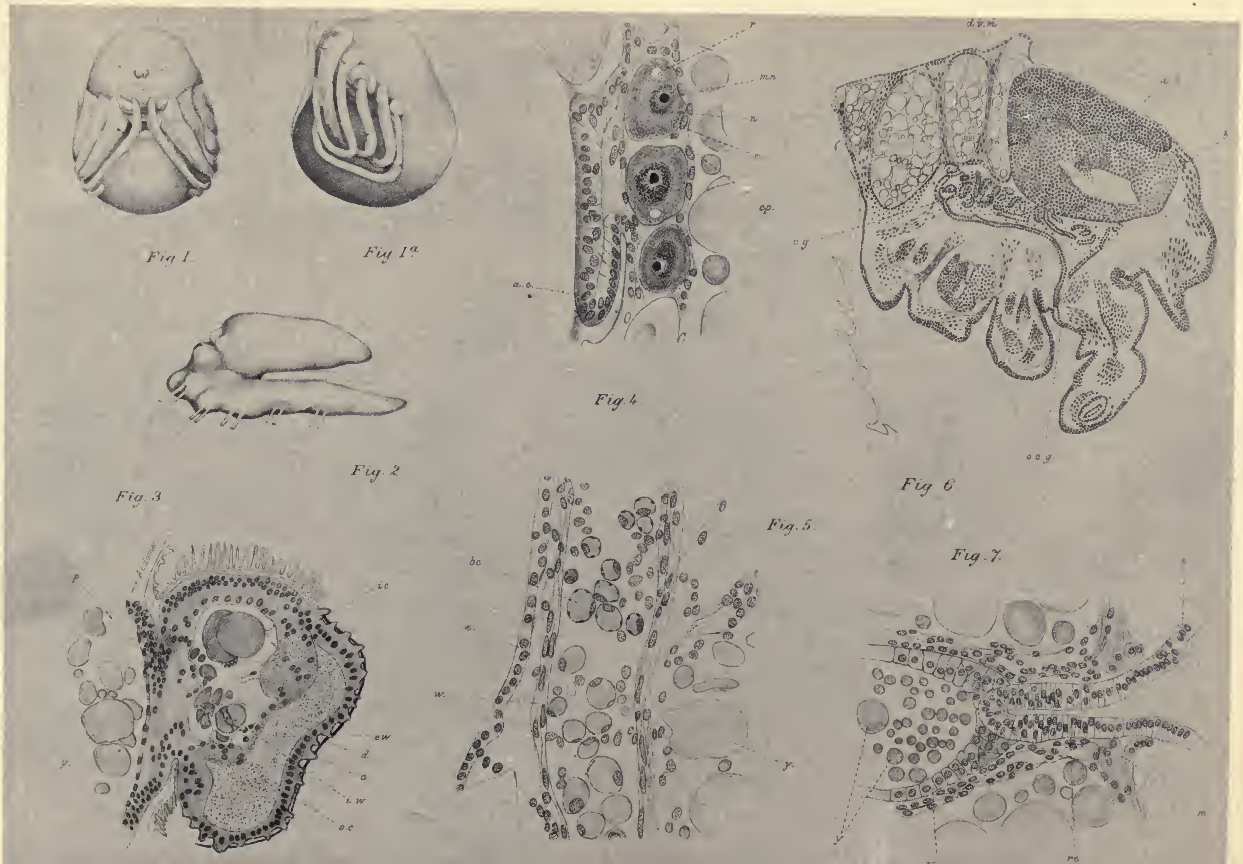
Fig 1.
Fig 1a.
Fig. 2
Fig. 3
Fig. 4.
Fig. 5.
Fig 6
Fig. 7.
d.v.m
a
mn
n
op.
a.o.
c g
o c g.
p
ic
ew
d
c
i w
o.c
y.
bc
e.
w.
m
re

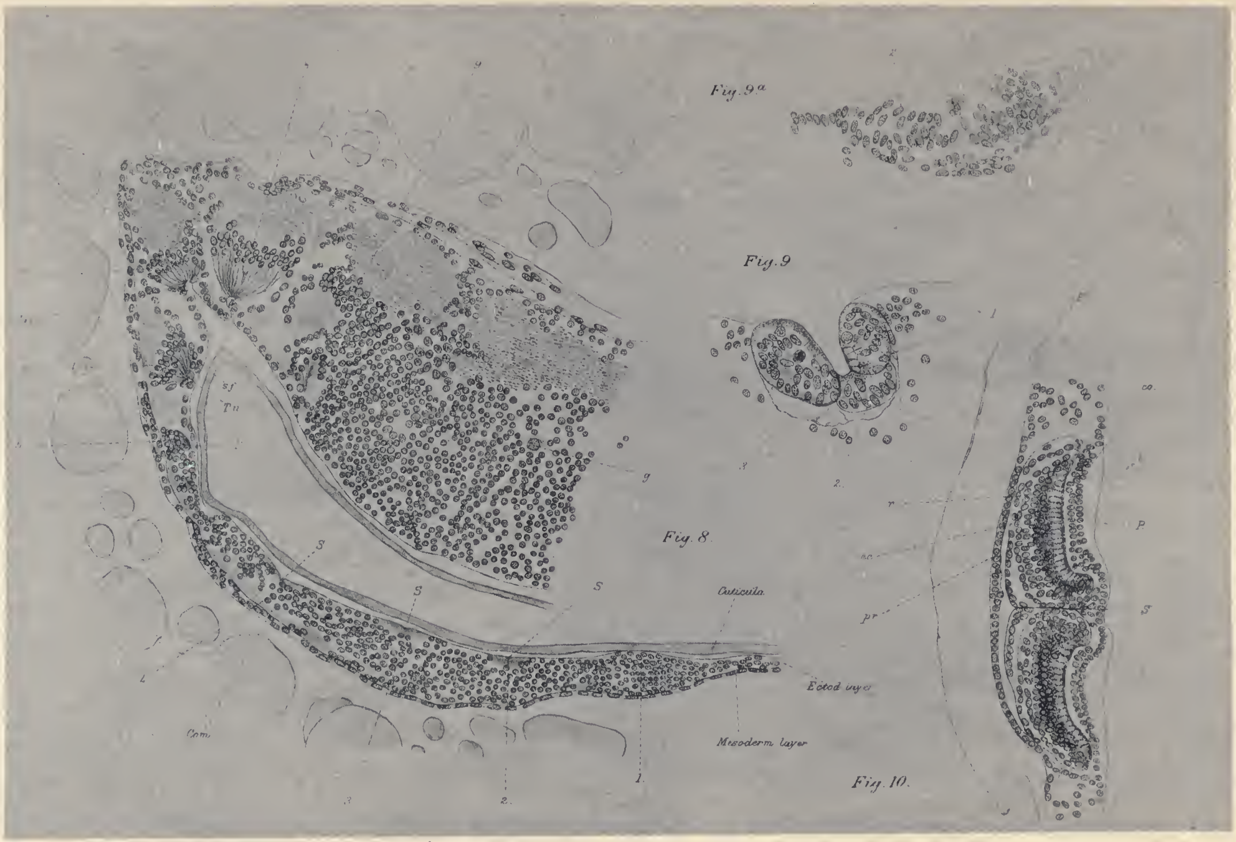

Fig. 9a
Fig. 9
Fig. 8
Fig. 10
Cuticula
Ectod. layer
Mesoderm layer
Com