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XVI.—*Investigations on the Development of the Spiders.*

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[Plate IX.]

MY researches upon the development of the Spiders have been directed to various species—*Tegenaria domestica*, several undetermined species of *Lycosa*, and especially *Epeïra diadema*, already studied by Herold. The object that I particularly proposed to myself was to trace by means of sections the arrangement of the lamellæ and the phenomena of internal development, which have never been investigated in this group of animals. My studies have led me to modify some of the opinions hitherto accepted upon the external development; and I shall give these results together with the others. My process of research has been the observation either of fresh or slightly heated ova, or of ova coloured by bichromate of potash and osmic acid, hardened by alcohol, and cleared by essential oil of cloves; by means of the last we succeed much better in seeing the different parts. In making the sections, I employed especially Leyser's microtome, now used almost everywhere in Germany, and which I owe to the kindness of Professor Leuckart, to whom I am glad to have the opportunity of offering my thanks.

* Translated by W. S. Dallas, F.L.S., from a separate copy, furnished by the author, of the memoir published in the 'Journal de l'Anatomie et de la Physiologie,' tome xiv. pp. 529-547.

Before approaching the special subject of my memoir I will say a few words as to the formation of the blastoderm.

Since Balbiani's memoir, Ludwig has published a very complete treatise upon this subject: I adopt most of the results of this author; but there are some observations which I must offer. Ludwig has asserted that the granular layer placed by Balbiani at the surface of the vitellus (*couche plastique* of Balbiani) really belonged to the vitelline membrane; I must declare myself against this assertion. I have, in fact, found over the vitelline membrane a special layer not described by Balbiani, to which, as Ludwig says, is due the network that we observe at the surface of the ovum: it is not formed by a continuous layer of juxtaposed globules, but only of globules arranged in lines which intercross to form a kind of net, in the meshes of which the vitelline membrane is uncovered; the whole appears most distinctly in the ova of *Epeïra diadema* treated with nitrate of silver. Independently of this reticulated layer, I further distinguish, like Balbiani, the formative globules of the cells of the blastoderm. These sometimes acquire large dimensions, and present great regularity; one cannot mistake their identity with the elements described by Balbiani when one observes the ova of *Tege-naria domestica*.

I therefore regard the description given by Balbiani of the granules of the plastic layer as perfectly correct, and am of opinion that this observer has done good service by drawing attention to the strongly granular character of the protoplasm in the Spiders; but I adhere rather to Ludwig as regards the distribution of these protoplasmic elements. I have never seen them form a continuous layer at the surface of the ovum, nor divide up into germinative areas; but I see them constantly appear in the form of trains or series between the vitelline globules of the surface. Ludwig's deutoplasm-columns (*Deutoplasmasäulen*) are generally to be recognized without difficulty; but I have not been able to see them in all the species—which, without invalidating the description given by Ludwig, leads me to doubt the absolute necessity of a regular arrangement of the masses of deutoplasm. There may be a greater condensation of the embryogeny in certain species, so as to arrive at such a distribution of the protoplasm, but without such a complete fusion of the masses of deutoplasm into deutoplasm-columns—which would carry back the essential characters of the formation of the blastoderm to the strongly granulated character of the protoplasm, and to its first appearance between the vitelline globules of the surface.

This being stated, we may pass to the formation of the embryo.

The first observer who occupied himself seriously with this subject did not go so far as to the formation of the ventral embryonic band; he only described the thickening of the blastoderm, and then passed without any transition to the stage of the young spider rolled up in the egg, leaving an enormous hiatus.

This gap was in part filled up by Claparède, who greatly added to our knowledge on this subject by describing the development of the embryonic band, its subsequent division into ventral pads, and its segmentation into zonites of three kinds—thoracic, abdominal, and postabdominal. Nevertheless even he saw only half the phenomena; his description omits, between the last stage of the embryonic bands and the young spider, a second series of important phenomena which have hitherto remained unknown.

In what follows I shall divide the subject into three parts:—
 1. The stage of the embryonic bands, described by Claparède, as to which I have only a few supplementary notes to add;
 2. The Limuloid stage, hitherto unknown, and which I shall have to describe completely;
 3. The stage of the young spider rolled up in the egg, already well investigated by Herold, but which we shall have to reconsider from the point of view of the lamellæ.

I. *Embryonic Band.*

If we make a section of the egg at this stage, we see that Claparède's ventral pads are really composed of two lamellæ:—1, the external simple one, which extends over the whole surface of the egg; and 2, the intermediate one, arranged in two cords, formed of several rows of embryonic cells: these cords exactly correspond to the ventral pads; and I reserve to them the name of *germinative bands*. These germinative bands exist throughout the whole length of the egg. They are derived from the scission of an originally continuous mesodermic band, but do not present the same arrangement throughout: in the abdominal region they are thin and of but small extent; in the future thoracic region, on the contrary, they are much larger, and begin to show a division into a central part (the nervous bands) still adherent to the external lamella, and a peripheral part, which is purely mesodermic. In front the two germinative bands pass to two projections of a circular form, direct prolongations of their nervous portion, which will form the cerebral lobes; these are the representatives of the procephalic lobes of Claparède and Huxley

(*Scheitelplatten* of German authors). These lobes are bounded within and above by a groove bordered on all sides by a projecting crest due to a thickening of the cells of the blastoderm. This crest forms between the lobes a projecting tongue, no doubt the representative of the labrum (*Vorderkopf* of the Germans), and is afterwards produced on each side into two semi-circular thickenings which surround the cephalic lobes on the outside. The base of the tongue, which represents the labrum, presents a deepening of its median furrow, which indicates the commencement of the invagination of the œsophagus and constitutes the mouth. We see that the structure of the cephalic region is much more complex than Claparède supposed, and that we can recognize in it all the constituent parts of the head of the Arthropoda; its aspect presents striking analogies with what Metschnikoff has described in the Scorpions: the labium does not appear to be formed until a little later, and independently of the cephalic portion, at the expense of a median thickening of the mesoderm, placed between the first union of the two nervous bands below the œsophagus (see Pl. IX. figs. 2, 3, 4).

As regards the number of zonites of the embryonic band, I have found it, at least in *Epeïra diadema*, greater than that given by Claparède. The number of segments following the six thoracic ones appears to me in general to amount to ten (including the anal hood); the first four are more developed and constantly bear rudiments of limbs; all the others have always seemed to me destitute of appendages.

Besides the rudiment of a limb, or the vacant space which takes its place and forms the median part directly superimposed upon the germinative band of each of the segments, all the zonites of the abdomen always present, towards the last periods of the stage of the embryonic band, two lateral portions, a sternal and a tergal plate, formed by thickened cells of the blastoderm, beneath which the mesoderm of the germinative bands has begun to spread out in a thin layer. The tergals are always perfectly visible, and are wider in the four anterior abdominal segments; the sternals in the posterior segments appear under the form of perfectly distinct, thin, elongated plates, which may easily be mistaken for rudiments of limbs (as no doubt has been done by Claparède) if one does not pay particular attention to their position. In reality the six posterior segments have always seemed to me to be destitute of appendages; their median portion, superimposed upon the germinative band, being only occupied by a paler line.

This appearance of the sternal and tergal arcs shows us that

at this stage the ventral pads do not tend to become effaced, as Claparède says, but that, on the contrary, they are in a progressive course; we see, moreover, that the formation of appendages is not irregular and variable according to the species, but that it is constantly limited to the first four zonites.

II. *Limuloid Stage.*

According to Claparède, the whole passage from the state of embryonic band to that of the young spider rolled up in the egg is reduced to a translation of the ventral pads towards the dorsal region; this displacement in its turn causes an approximation towards the ventral region of the two extremities of the embryo, and thus produces its rolling up in proportion as the ventral pads separate from each other. The nutritive vitellus protrudes through the fissure which these pads have left between them (*fente sternale*, Clap.), and finally passes entirely through this fissure, so as to become completely ventral: the position of the embryo is thus entirely changed; and it becomes rolled in the opposite direction to its former one.

This process is completed at the period when the ventral pads have come to occupy the lateral epimeral region, of which, according to Claparède, they are the representatives (we have seen that this interpretation is erroneous, and that they represent in addition the sternal and tergal arcs, the part occupied by the limb alone really forming the lateral region). Their presence at this point keeps the two faces of the embryo distinct for a moment; but they soon finally disappear, so that we no longer distinguish one face from the other, and the posterior part of the body assumes the globular form so characteristic of the abdomen in the adult.

The passage of the vitellus through the sternal fissure is a unique fact in the group Arthropoda; and the interpretation of it given by Claparède makes something quite peculiar out of the embryogeny of the Spiders. Ingenious as this conception may be, however, it is far from sufficing to explain the passage from the embryonic band to the state of the young spider rolled up in the egg, and one feels the necessity of a less theoretical description.

In order to trace this passage in all its details, we shall take up again the last stage of the germinative band and examine its changes step by step; the phenomena differ according as we examine the anterior, middle, or posterior portion of the body.

1. *Anterior portion.*—The buccal depression becomes invaginated, and gives origin to a tube; the latter, which grows

rapidly inwards, is destined to form the œsophagus, the sucking-stomach, and the portion of the intestine which immediately follows—in one word, all the median tubular portion of the digestive canal contained in the thorax: it is quite completed at the commencement of the third period, in the young spider rolled up in the egg.

As this invagination penetrates inwards it gives rise to concomitant modifications, which are of great importance in understanding the structure of the thorax. If we make a transverse section in the middle of the thorax of a spider, we see that the musculature is constituted as follows (see fig. 6):—1, a central part formed by three muscular bundles (*m*) attached to the œsophagus; the first, which is unpaired, is vertical, and is attached to the vertex of the body; the other two, paired, form a horizontal plane, and, covering the ventral ganglionic masses, pass to attach themselves to the bases of the legs; 2, of a peripheral part (*m'*) composed of fibres which skirt the wall, and which constantly go from the bases of the feet to the vertex of the body. This second part of the musculature is of comparatively late formation; it does not make its appearance until rather late, and only acquires its full growth during the postembryonic development: the first, on the contrary, appears early and proceeds *pari passu* with the invagination of the anterior part of the digestive tube. It would seem, in fact, that this invagination carries with it in its movement towards the posterior part (see figs. 4, 5) the peripheral portions of the germinative bands, in such a way as to form three cellular laminae—a median one detached from the cephalic portion, the other two lateral ones from the two germinative bands. These three laminae represent the three muscular planes marked *m* in fig. 6: the first, which directly surrounds the œsophagus (fig. 4, *m*), represents a longitudinal partition which will divide the cavity of the thorax into two parts; the two others, two transverse partitions which will soon unite into a single plane directly covering the ventral ganglia. Soon after the last stages of the embryonic band the cephalic portion is rounded behind, and, as Claparède has already stated, separated from the vitellus by a deep emargination; but after the period when the three cellular plates (*m*, fig. 4) begin to form, we see it produced into an elongated point, which is already figured by Claparède, and represents the vertical partition (*m*, fig. 6) which gradually elongates simultaneously with the œsophagus.

Figs. 4 and 5 show the three planes at the moment when they begin to detach themselves from the germinative bands. In proportion as the invagination of the œsophagus progresses

it carries them with it towards the posterior part: the vertical partition is thus carried to the end of the thorax, which it completely divides into two symmetrical halves (fig. 6, *cæ*), at first filled with nutritive vitellus; the transverse partitions are simply spread out and brought nearer to each other, so as to form a continuous muscular plane, situated at first in the fore part of the thorax. In thus approaching each other these two planes carry with them the two nervous bands, which they always immediately cover; and thus is effected the approximation of these latter to form a central mass, which directly afterwards divides into ganglia. This union of the nervous bands is therefore itself only a consequence of the growth of the invagination of the œsophagus; and all the phenomena which give origin to the thorax may be referred to this single cause.

When once these processes are completely terminated, the thorax is formed in all its more essential features. One of the chief effects of its formation is to restrict the cavity of the whole anterior part of the embryo; the vitellus is driven back towards the posterior part; and there only remains in the thorax the portion which will give origin to the cæca of the stomach.

2. *Median portion.*—In this portion we see each of the tergal and sternal pieces increase to unite with that of the opposite side, so as to form a complete arch. The tergal arcs grow rapidly; and we are soon able to distinguish perfectly distinct hemizonites formed by their union in the dorsal region. Of these we always distinguish four much wider than the others, formed by the first four abdominal segments; with the other narrower ones which follow them they constitute a dorsal plate, to which we shall refer again. The sternal arcs likewise increase, but more slowly; and, moreover, their union is prevented by the projection of the nutritive vitellus, which, pushed backward by the contraction of the thoracic region and by the formation of the complete tergal arches, protrudes through the sternal fissure, passing between the two hemisternals. At the same time that the thickening of the cells of the external lamella, which constitutes the sternal and tergal plates, advances more and more towards the median lines of the back and belly, the thin mesodermic layer subjacent to it likewise increases. At the period when the tergals have united to form complete arches, we also find a complete mesodermic layer, which extends beneath the whole of the tergal plate, and which from the first begins to thicken upon the median line, to give origin to the dorsal vessel; at the edges, between the sternals and the lateral region, there is always a

thickening, the still persistent remains of the germinative bands.

3. *Posterior extremity*.—At the period of the last stage of the embryonic band this latter runs completely round the egg, and its posterior extremity comes nearly into contact with the cephalic region; lastly the germinative bands, in running to unite in the anal hood (placed high up on the dorsal surface), form between them a very acute angle. In the subsequent stages we see the anal segment gradually increase its distance from the cephalic region, and pass more and more towards the ventral region; this displacement of the anal segment in its turn causes a modification in the separation of the germinative bands, the angle formed by their union tending to become more and more obtuse. The same processes continue regularly until the anal segment has come to occupy the extremity opposite to the cephalic region, at which period the two germinative bands have come into the same plane, the progressive separation of the two sides of the obtuse angle finally producing a straight line. If we imagine a continuation of the same phenomena, we shall see the anal segment come to occupy a position upon the ventral surface, and the germinative bands approach each other again, but in the inverse sense, so as to form an angle opposed to that which they formed at the commencement; this state concludes the process by which the posterior extremity of the embryonic bands, at first directed towards the dorsal side, becomes recurved towards the ventral region.

If we attempt to trace the same phenomena in Arthropods with a projecting caudal part (*e. g.* the Phryganidæ), in which the recurvation of the caudal part is regarded as the cause and origin of the whole inversion of the embryo in the egg, we shall find exactly the same phenomena (1, retraction of the caudal region and separation of the germinative bands; 2, arrival of the anal segment at the posterior pole of the egg, and arrival of the embryonic bands in the same plane; 3, arrival of the anal segment upon the ventral surface, and approximation of the embryonic bands in the inverse direction). The only difference consists in that the same phenomena will take place in the depth instead of at the surface of the egg: and this difference is not at all essential; for we may still recognize in the Spiders a remnant of a tendency of the caudal portion to detach itself from the rest of the vitellus; the anal segment almost always forms at first a strong projection, which indicates the commencement of this process. We shall therefore arrive at the conclusion that in the Spiders, as in the other Arthropoda, the cause and origin of the pheno-

menon of inversion resides essentially in the caudal region ; the protrusion of the nutritive vitellus through the sternal fissure is a *purely passive* feature of development, and determined by the pushing back of the vitellus towards the posterior region—a movement resulting from the three processes just indicated, all three of which produce, in different degrees, the effect of restricting the capacity of the embryo.

Limuloid Stage.—The three series of modifications that we have just indicated are not all produced with the same rapidity ; the last two are more rapid, and are seen completely finished at a period when the union of the two nervous bands has only commenced under the cephalic region. At this period, in consequence of these changes, the embryo presents a very remarkable aspect (see fig. 1). It is divided into two distinct parts, answering to the thoracic and abdominal segments, and which seem to me to correspond in a very striking manner to the two divisions of the body in the Xiphosura : the posterior portion, or tergal plate, is formed by the amalgamation of all the tergal arcs ; we can recognize in it each of the segments which formed the abdomen in the embryonic band ; but here this abdomen is divided into two parts—a preabdomen composed of six segments, and a narrow postabdomen formed of four segments. The preabdomen is itself subdivided into four broad zonites bearing appendages already indicated in the embryonic band, and two much narrower ones following the former. The anal segment at first appears simple ; and in *Epeïra diadema* it is impossible to discover in it any trace of division. Nevertheless, by examining the sternal arcs we ascertain that the one corresponding to the anal segment is divided into three distinct pieces, which shows that this anal segment is here equivalent to three segments soldered together. This interpretation of the anal segment is not without interest, if we collate it with the fact, observed in *Pholcus* by Claparède, of the early division of the anal segment into three distinct segments. The fact observed in *Epeïra diadema* shows that this is perhaps general, and that this division, although rarely so early, none the less virtually exists.

This multiple value of the anal segment brings the number of segments of the entire abdomen to twelve, and that of the postabdomen to six ; and this agrees within a segment with the exact number of zonites in the abdomen of the Scorpions, and corresponds exactly for the postabdomen. The stage fig. 1, so like the king-crabs in the division of the body into two portions, would thus prove to come very near the Scorpions in the number of zonites in the different divisions.

This fact teaches us to compare this stage with the fossil forms of the Merostomata, which so often resemble passage-types between the Scorpions and the Xiphosura. Among the latter there is even a form (*Hemiaspis limuloides*) which seems to me to recall in a striking manner the stage which I have indicated in the Spiders: in it the body is in like manner separated into two divisions, of which the posterior contains ten segments, which are divided in the same way into six preabdominal and four postabdominal, the last of which is elongated into a style; it may also be noted that the first four preabdominals in this species present traces of an organization somewhat superior to that of the two following ones. This predominance of the first four preabdominals moreover appears to me to be a very constant fact, not only among the Spiders, but in the whole group Arachnida.

Metschnikoff has already shown that in the Scorpions they appear at the same time and before all the others, and that the formation of the ventral ganglia in their interior also greatly precedes that of all the others. Unfortunately we do not possess, with regard to the *Limuli*, data sufficiently complete to enable us to judge whether this is the case in the Xiphosura. Fig. 1 shows that at this period these segments in the spider occupy a considerable space and form more than half the tergal plate.

Besides the embryo proper (fig. 1), we have still to consider in this stage the vitelline part (figs. 2, 3), bounded all round by the nervous bands and the sternal plates (fig. 3). This now represents only an *annex of the embryo*, and on all accounts merits the name of *vitelline vesicle*; in fact, as in the fishes, it forms a sac surrounded by a delicate blastoderm, projecting from the ventral surface; it is bounded on all sides by the embryonic parts, and, in like manner, owes its origin to a displacement towards the ventral part of a nutritive vitellus too abundant to be entirely contained within the embryo. Thus this hernia of the nutritive vitellus through the sternal fissure, regarded by Claparède as constituting a mode of reversal (*retournement*) of a special nature differentiating the development of the Spiders from that of the other Arthropods, is due, according to me, solely to the presence in the Spiders of a *vitelline vesicle* exactly like that of fishes: it is, I believe, the first instance to which attention has been called in the Invertebrata*.

Leaving out of consideration this presence of the vitelline

* Except perhaps in the *Salpæ*.

vesicle, the entire evolution agrees absolutely with the development of the other Arthropoda, and consists essentially in the following phenomena:—1, formation of a continuous mesodermic band, and appearance of the sternal fissure dividing this band into germinative bands; 2, appearance of the nervous portion within the latter; 3, growth of the germinative bands towards the tergal region, then towards the sternal; 4, recurvation of the tail, and reversal &c.

Fig. 5 represents the boundaries of the vitelline vesicle. It commences immediately below the point of union of the two nervous bands—that is to say, a little behind the mouth in the Limuloid stage; but it nevertheless already presents a sensible flattening over all the rest of the thoracic region, and only becomes greatly inflated beneath the abdominal region, where it presents a thick projection: fig. 6 will assist in rendering this arrangement intelligible.

Passage to the young spider.—If we imagine exclusion to take place at this period, the thorax will be completed by the completion of the invagination of the œsophagus and the concomitant phenomena: the abdomen will close up by the growth of the sternal bands; and the sternal vesicle, which they compress on all sides, will be absorbed by degrees, and enter gradually within the embryo in proportion as the sternal plates grow over it so as to complete the zonites of the abdomen. There will thus be formed an organism analogous to *Hemiaspis limuloides*, while the vitelline vesicle will follow the ordinary course of absorption.

In the Spiders this is not the case. The new phenomena which rapidly intervene confuse this normal course; the sternal vesicle does not disappear by absorption, but it is covered up by the exaggerated development of the tergal plate, and is entirely enclosed within the embryo. For this purpose we see all the tergal plate, but especially the four large anterior segments, increase both in length and breadth; the tergal plate, at first confined to the dorsal surface, thus gradually encroaches upon the vitelline vesicle, which it finally surrounds completely, leaving free only a small oval space indicated in fig. 2 by the line *bv*, which will be covered up by the development of the sternal plates. At the period when this envelopment is effected, the invagination of the œsophagus and the constriction of the nervous bands have been completed, and the thorax is finally constituted; further, at the boundary of each of the first four zonites of the abdomen there is formed a double fold of the mesoderm, composed of flat cells, which advances into the mass of the nutritive vitellus so as to constitute a true diaphragmatic

partition, like those which keep the digestive tube of the Annelids in place.

We have already seen that at this epoch these four zonites had arrived at their maximum development, and played the principal part in the envelopment of the vitelline vesicle by the tergal plate; at the period when this envelopment is completed, the segments of the postabdomen still occupy only a small space in the posterior part, and the abdomen is almost entirely formed by the first four preabdominals, the diaphragmatic partitions of which divide the vitellus into four large digitate masses, recognized and well figured by Herold and especially by Claparède, but of which they did not understand the signification. The abdomen of nearly all spiders is thus almost entirely composed of these four extraordinarily developed segments, which at last shows us their signification.

At the same time that these various phenomena take place, the space left free (fig. 2, *bv*) by the tergal plate is covered up by the sternal plates. It is at this period that the limbrudiments of the first four abdominal segments disappear, and that the boundary between the dorsal and ventral halves of the body seems to disappear, to give place to an abdomen of globular form, in which the limit between the sternals and the tergals is no longer precisely indicated. We see that at the period of this disappearance the ventral pads (in consequence of the growth of the tergal plate) occupy a very different position (*bv*, fig. 2) than was assigned to them by Claparède at the same epoch: the distinction between tergal and sternal arches persists to the last in the Spiders; but finally, as we have seen, there is no proportion between the two pieces, the tergal pieces having grown out of all proportion, and the sternals forming only an insignificant part. The complete disappearance of the lateral pads is caused by a displacement of the last vestiges of the germinative bands. We have seen that these last continued hitherto to form a slight thickening on the edges of the tergal plate; at the period when the sternals increase to cover up the portion left free by the tergal plate (fig. 2, *bv*), this thickening quits the lateral region and unites with that of the opposite side to form a compact mesodermic mass of oval form, upon the median line and immediately within the space covered up by the sternals. From this thickening will be formed later on the whole of the straight abdominal part of the digestive tube, the excretory organ, the spinning-glands, and the genital organs. The spinnerets themselves originate at this period, in the form of pretty large elevations of the skin, situated at the posterior limit of the sternal plates: at first they only appear in

two pairs; the third smaller pair is not formed until later. The spinnerets at first occupy a much larger space than they afterwards do; subsequently they become more concentrated and rise into small and more definitely circumscribed mamillæ.

III. *The young Spider.*

The passage from the embryonic band to the young spider rolled up in the egg is therefore much more complex than as described by Claparède. It is during its progress that all the most essential phenomena of the internal development take place; and it consists, as we have seen, of two great periods—the passage from the embryonic band to the Limuloid stage, and the passage from the Limuloid stage to the young spider.

When this last stage is arrived at, the spider is constituted in all its most essential points, and already presents its definitive form. We can obtain a sufficiently good idea of the subsequent developmental aspects by consulting the figures given by Herold, who carefully studied this period. The most important phenomenon which occurs during it is the formation of the inner lamella, which is produced at the expense of the nutritive vitellus. Up to this time the vitelline masses retain an irregular arrangement. This irregularity persists in the masses of the centre, but ceases in those of the surface, which acquire a very regular arrangement at the period of the extension of the tergal plate. At the same time there appear between their boundaries trains of opaque granules; these trains rapidly increase in thickness, and soon present from place to place white spots recognizable as nuclei. These nuclei increase simultaneously with the granules. The latter represent the protoplasm, and speedily collect around the nuclei to form cells, which then begin rapidly to multiply and soon clothe the whole surface of the vitellus.

This appearance of the inner lamella is not without analogy with that of the blastoderm; and it would appear that, as Bobretzky has already indicated in *Palæmon* and *Oniscus*, the vitelline mass is twice active—once to form the outer lamella, and a second time to form the inner lamella. I do not think that we have here an immigration of blastodermic cells into the interior of the mass of the nutritive vitellus: I have never seen any thing that would justify such an assumption; and I rather incline to believe that the productive activity of the vitelline mass is not exhausted by the formation of the blastoderm, and that there remains in it sufficient to produce the nuclei which we see reappear in the trains of protoplasm.

The inner lamella thus produced is destined to form in the thorax the two pairs of cæca of the stomach, and in the abdomen the whole of the hepatic mass. The wall of the cæca of the stomach is formed at once by the simple fact of the appearance of a layer of cells at the surface of the two masses of nutritive vitellus (*cæ*, fig. 6); the vitellus which fills them is gradually absorbed. As regards the liver, the cells of the inner lamella begin by penetrating into the vitelline mass, at first skirting the diaphragmatic partitions and then the internal organs formed at the expense of the ventral mesodermic mass of the abdomen. In consequence of this penetration of the cells into the interior, the nutritive vitellus becomes divided into isolated fragments; and these are gradually absorbed in proportion as the surrounding endodermic cells multiply and take their place.

The liver and the two pairs of cæca of the stomach are therefore all developed at the expense of the inner lamella, while the straight tubular portion of the digestive canal, comprising the œsophagus, the sucking-stomach, the intestine, and the rectum, is developed at the expense of the two other lamellæ. The first two alone represent the endoderm; and it is evident that they only form a single part divided into two by the constriction of the thorax; in the Arachnida with an unpedunculated abdomen (*Chelifera*, Scorpions) they are not separated from each other.

Beyond this formation of the inner lamella I have nothing to describe, except some phenomena of detail which it would be tedious to enumerate here (differentiation of the ventral mesodermic mass of the abdomen, formation of the eyes, establishment of the circulation, &c.). The most important phenomena consist in the strong development of the peripheral musculature (*m'*, fig. 6), especially in front of the cerebral ganglia. At the commencement the internal organs, nervous masses, stomach, &c., are closely applied to the skin, from which they are separated only by a thin layer of mesodermic cells; the chelicerae are then still immediately anterior to the cerebral ganglia; and the anterior triangular plate of the thorax, which may still be distinguished even in the adult, evidently corresponds to the cerebral ganglia. Subsequently, when the thin mesodermic layer which clothes these organs has become developed into a powerful musculature, the internal organs are displaced inwards, and become greatly separated from the skin, which renders the relations of the divisions of the body to the internal organs more difficult of recognition. The chelicerae depart far from the ganglionic masses; and an entire long anterior portion seems to be added

to the cephalic portion: further, the muscular thickening at this point is such that the correspondence of the anterior thoracic plate and the cerebral ganglia is entirely masked. In the abdomen the peripheral musculature is represented by three groups of muscles (dorsal, ventral, and lateral)—the first formed at the expense of the mesoderm which surrounds the dorsal vessel, the other two at that of the ventral mesodermic mass.

A last fact which deserves to be mentioned is the considerable number of ganglionic masses of the thoracic region. The nervous bands, in dividing, form, not only the five pairs of large ganglia which persist in the adult, but also three or four smaller pairs applied to the lower surface of the peduncle and which are very visible shortly after exclusion; these are, no doubt, ganglia of abdominal segments which have concentrated themselves towards the thoracic region.

In conclusion, I may notice some interesting retrogressions which take place towards the close of the passage to the adult, such as the degeneration of the four diaphragmatic partitions, of the dorsal portion of the peripheral musculature of the abdomen, and of a considerable part of the nervous system.

EXPLANATION OF PLATE IX.

Fig. 1. Limuloid stage, seen from the back.

Fig. 2. The same, seen in profile. *l*, labium; *lc*, cephalic lobe; *b*, mouth; *vo*, sternal vesicle; *bv*, limit of the extension of the tergal plate.

Fig. 3. The same, seen on the ventral surface, and showing the distribution of the mesoderm, as well as the limits of the vitelline vesicle. *l*, labium; *ob*, labrum and mouth; *bn*, nervous band.

Fig. 4. Section a little below the mouth. *ch*, chelicerae; *æ*, oesophagus; *mmm*, the three superficial parts of the germinative bands carried on in the movement of the oesophagus; *gn*, cerebral ganglia.

Fig. 5. Section at the level of the labium; the nervous bands, *bn*, are still adherent to the blastoderm. *ch*, chelicerae; *l*, labium; *gn*, cerebral ganglia; *m*, as in fig. 4; *bn*, nervous bands.

Fig. 6. Diagram of the musculature in the thoracic region (theoretical). *m*, central musculature; *m'*, peripheral musculature; *cd*, digestive tube; *gn*, ventral ganglia; *ex*, space in which the stomachal caeca will be formed.

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