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H.M. Bernard M.A. Cantab. ^a

^a Huxley Research Laboratory, R. Coll. of
Science, South Kensington
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with all his ingenuity, has to make frames for constructing arches and circular buildings, and moulds for circular casts; his cement has to be brought from a distance and carefully manufactured, and he requires good sight and much aid to form his dwelling: whereas some of the most skilful and beautiful formations of these marine annelids are executed by creatures devoid of eyes and with a soft and delicate body, whose mortar is secreted by the glands of their skins, and whose inborn instinct enables them to dispense with all artificial aids in the construction of their homes.

II.—*The Endosternite of Scorpio compared with the Homologous Structures in other Arachnida.* By H. M. BERNARD, M.A. Cantab. (from the Huxley Research Laboratory, R. Coll. of Science, South Kensington).

[Plate III.]

SPECIAL interest has attached to the endosternite of *Scorpio* on account of its bearing upon the question of the relationship between *Scorpio* and certain near allies of *Limulus*. The external likeness between *Scorpio* and *Slimonia* taken alone might be merely a case of convergence; but their common possession of an endosternite seemed to many to establish beyond doubt that this resemblance was due to a direct relationship. The validity of this argument depends, however, upon it being shown that their respective endosternites are morphological equivalents. Indeed, it seems to me that the whole question of the assumed relationship depends upon the settling of this point; for it is hardly possible that two forms so related should possess analogous structures of fundamental importance in the organism which are not also homologous.

Considering, then, the interest attaching to the endosternites it is somewhat to be wondered at that no serious attempt* has been made to obtain a clear idea of their essential morphology in the only way this can be obtained, viz. by comparison.

The Arachnid which at the outset seemed to promise most light on this subject was *Galeodes*, in which the three posterior cephalothoracic segments remain unfused. This primitive feature could hardly fail to find some reflection in the structure of the endosternite.

* Cf., however, Lankester, "On the Skeleto-trophic Tissues of *Limulus*, *Scorpio*, and *Mygale*," Q. J. M. S. vol. xxiv., 1884.

Fairly good drawings of the endosternite in *Galeodes* have already been given by Modest Kittary* and by Blanchard†.

From both of these its essential nature can be made out. It is composed of two apodemes running in from between the first and second legs and meeting in the middle line under the gut. Fig. 1 (Pl. III.) shows the structure *in situ* and fig. 2 is a cross section showing that the junction of the two apodemes in the middle line is an interlocking apposition and not an actual fusion. Its nature as a fold of the external cuticle is also very apparent from the section. The thickness of the chitin of the fold is very irregular. Into its deeper parts (fig. 2, s) staining protoplasmic matter has penetrated, and similar protoplasmic matter binds the interlocking folds together. The hindmost ends of the structure are greatly expanded for the attachment of muscles.

With this key to the understanding of the morphology of the endosternite, by the kind permission of Prof. Stewart I examined the fine preparation of that of *Mygale* at the Royal College of Surgeons. The cephalothoracic segments of the Araneidæ, as is well known, are equally fused together, indication of their original separation being, however, distinct in the furrows on the dorsal wall of the cephalothorax. Instead of one pair of apodemes fusing in the middle line, such as is found in *Galeodes*, we here find four pairs meeting and fusing together (figs. 3, 4, and 5) ‡.

This is what we should expect, owing to the larger number of segments fused together. The eight apodemes further radiate from a common centre, thus repeating the curious radial arrangement of the segmental constrictions seen on the dorsal surface. Figs. 3, 4, 5 show the arrangement of these four pairs of apodemes and their place in the cephalothorax. Their principal attachments to the body-wall are now the points marked 1, 2, 3, 4 on the inner surface of the sternum in fig. 4. In very young spiders (just hatched) the original segmental constrictions running across the sternum, and now reduced to these points, are still traceable as clear lines running across the sternum.

* Bulletin de la Soc. Imp. des Naturalists, vol. xxi. (Moscow, 1848).

† 'L'Organisation du Règne Animal,' Arachnides, pl. xxv. fig. 9.

‡ There exist several drawings of both the dorsal and ventral aspects of this structure. The earliest which I can find is that of Wassmann ("Beiträge zur Anat. der Spinnen," Hamburg. Abhandlung. Bd. i., 1846). This was copied by Victor Carus in his 'Icones Zootomicæ,' Taf. xiii. Blanchard has drawings of it in his 'Règne Animal.' The latest, given by Lankester (*antea*, p. 18), is full of detail, but the conclusions which he draws from it are vitiated by his having mistaken the ventral for the dorsal surface.

The shape of the whole fused mass has been no doubt much altered by the action of muscles, but its essential nature as a fusion of metamerically recurrent apodemes cannot be mistaken.

On comparing the segmentations of the two Arachnids we have so far considered, we find that the apodemes forming the endosternite of *Galeodes* correspond only with the second pair of apodemes forming the endosternite of *Mygale*. The first pair in *Mygale* is now only represented in *Galeodes* by a small pair of chitinous plates attached by tendons to the cuticle and to the endosternite (fig. 10), and apparently carrying the proximal ends of the main ducts of the coxal glands.

The endosternite of *Phrynus* (fig. 6) is a broad crescent-shaped plate. It apparently only has one attachment to the ventral surface, and that is to the intersegmental membrane between the second and third pair of limbs corresponding with the first pair of apodemes forming the endosternite of *Mygale*; dorsally, however, it has four pairs of ligamentous attachments to the dorsal wall. These remind us of the endosternite of *Mygale*, and a comparison of the drawings seems to bear this out. If the endosternite of *Phrynus* prove ultimately to be homologous with that of *Mygale*, its sternal attachments, except the first, must have secondarily atrophied.

The endosternite of *Thelyphonus* (fig. 7) * is again of special interest, as it clearly follows the same type as that of *Mygale* and *Phrynus*. But inasmuch as the fusion of the segments shows no such radial arrangement as in the former, nor such longitudinal compression as in *Phrynus*, the various pairs of apodemes neither radiate from a centre nor form a short crescentic plate, but a long fenestrated framework.

On turning to *Scorpio* we find that the endosternite most resembles that of *Galeodes*. Fig. 8 is from a dissection of *Palamnaeus Thorellii*, Pocock, made in order to ascertain the exact points of attachment to its parent cuticle. The nerves to the first pair of legs are seen in front of these attachments, which thus correspond with the points of origin of the endosternite in *Galeodes*. Lankester describes and figures† a second pair of ventral attachments—"cornua or anterior tendons of the subneural process;" but this subneural process belongs to the "diaphragm" and not to the endosternite, as I shall presently show.

* I have borrowed this drawing by Tarnani from Schimkewitsch's recent paper in the 'Zool. Anzeiger' (July 1893), "Sur la Structure et sur la Signification de l'endosternite des Arachnides."

† Lankester, "On the Muscular and Endoskeletal Systems of *Limulus* and *Scorpio*," Trans. Zool. Soc. vol. xi. part 10 (1885).

The endosternite of *Scorpio* is somewhat complicated by the strong longitudinal compression of the thorax having caused it to fuse posteriorly with the "diaphragm" (figs. 8 and 11, *d*). This "diaphragm," like that of *Galeodes*, is the homologue of the great constriction between the sixth and seventh segments forming the "waists" of other Arachnids. In both *Galeodes* and *Scorpio* it is pierced by the dorsal vessel (*h*), the alimentary canal (*a*), and the nerve-cords (*n*), and in *Galeodes* by tracheæ (*t*). In *Galeodes* it lies some distance behind the posterior edge of the endosternite, there being no longitudinal compression of the thorax, and it also slopes from above backwards (*cf.* figs. 1 and 10). In *Scorpio* the secondary longitudinal compression of the cephalothorax, which is more marked than in other Arachnids, especially on the ventral surface, has caused the "diaphragm" to slope from above forward (*cf.* figs. 8 and 11). In fig. 8 the posterior edge given to the (shaded) endosternite is naturally arbitrary, as, except where it passes under the alimentary canal, it is fused with the "diaphragm." There seem to be four points of fusion. The ridges (*r*), caused by the dorso-ventral muscles *behind* the "diaphragm," have fused with the postero-lateral tendons (*t*) of the endosternite, to which the muscles themselves are now secondarily attached; and, further, the horizontal plate of the endosternite itself is attached by two processes (*e*) to the anterior face of the "diaphragm" which runs slantingly under it. Fig. 11 illustrates the relative positions of the endosternite and the "diaphragm;" it shows only the fusion of the plate of the endosternite with the latter, and is not intended to represent a true horizontal section. Fig. 9 is a transverse section (through the line * in fig. 11) of *Euscorpio* showing the endosternite with a portion of the "diaphragm" (Lankester's "subneural portion") which has been thrust forward under it by the ventral median portion of the seventh segment. With this portion of the "diaphragm" (*d*) so thrust forward, the extreme posterior ends of the endosternite (*e*) fuse on each side of the nerve-cord.

The figures which have hitherto been given of the endosternite of *Scorpio* really represent, then, a composite body, viz. the endosternite and the "diaphragm" fused together. This point is of great importance, as it seems to me to establish beyond question the complete distinctness between the endosternites of *Limulus* and *Scorpio*. In order to maintain the contrary it would be necessary to show that the endosternite of *Limulus* was once part of a "diaphragm," a "diaphragm" or waist being typical of Arachnids.

Histologically the endosternite proper of *Scorpio* shows its origin out of apodemes less plainly than does that of *Galeodes*. This origin out of cuticular folds is, however, clear in cross sections near their points of attachment to the body-wall between the first and second legs; in the other parts the originally simple chitinous folds still visible in *Galeodes* (fig. 2) have become changed, groups of cells having found their way in between the chitinous layers *. Full of interest is the marked difference between the cross sections of these original and ancient apodemes forming the endosternite, which have now become almost entirely detached from their parent cuticle, and the recent secondary apodemes forming the coxal endosclerites, which latter show their origin as cuticular infoldings at a glance. These structures are well developed in *Phrynus* and *Scorpio*, and they arise as an accompaniment of the longitudinal compression of the thorax which characterizes these two Arachnids. These apodemes remain continuously rigid with the posterior faces of the coxæ.

The endosternite of the Chernetidæ is now so specialized that it will be difficult to ascertain its exact origin; it appears to be due to a fusion of segmental apodemes from between the posterior thoracic segments, as it lies right back at the posterior end of the thorax †. It may perhaps be homologous with that of the Araneids.

Enough has now been said to show conclusively that the endosternites of the Arachnids are apodematus, and owe their origin and varying forms to the different methods and degrees of fusion and longitudinal compression of the cephalothoracic segments. In *Scorpio* this longitudinal compression of the thorax is so pronounced that the endosternite has fused with the diaphragm, and this has misled investigators into believing that they belong to one another as parts of one and the same structure.

We may, then, safely conclude from this comparative survey of the endosternites in Arachnids that *Scorpio* has not retained the original condition of the Arachnid thorax. But this is after all in reality nothing more than what we can learn from any comparative study of the Arachnids. We have, for instance, every degree of fusion and longitudinal compression of the first six segments, with *Galeodes* at one end retaining the largest number of segments unfused, and *Scorpio* at the other end with all the cephalothoracic segments closely fused and compressed.

* Cf. Lankester (*anted.*, p. 18) and Schimkewitsch (p. 20).

† Cf. "Notes on the Chernetidæ," Journ. Linn. Soc., Zool. vol. xxiv. p. 410.

It seems to me that, in order to answer the question, "Is *Limulus* an Arachnid?" we ought to compare *Limulus* with *Galeodes*! Indeed, I must here express a surprise, which I have long felt, that any serious attempt should have been made to establish relationship between two groups by comparing their specialized forms, practically ignoring the remaining representatives of the groups. And yet this is what has been attempted. The Merostomata and the Arachnida are supposed to be related because of the likeness between certain Eurypterids and *Scorpio*. *Scorpio* was clearly an Arachnid, and therefore related to other Arachnids, and *Limulus* was equally clearly related to the Trilobites. To attempt to build up an elaborate proof that *Limulus* must be related to *Scorpio* on the ground of their external and internal resemblance, while *Galeodes* on the one hand and the Trilobites on the other are but incidentally considered, can only lead to confusion*. The only scientific method of dealing with the question of the alleged relationship between *Limulus* and *Scorpio* lies first of all in the determination by comparative morphology of what is the essential diagnosis of the Arachnids and what is that of the Merostomata†.

Having seen that the endosternites of the Arachnids are apodematous structures due to fusion and compression of

* *Galeodes*, indeed, is often not even considered at all!

† I would here point out that it is still a matter of dispute whether the Pycnogonidae and Pentastomidae are or are not Arachnids. It seems to me that the only way to obtain a true insight into the essential morphology of the various groups of the Articulata is, by comparing all the available forms, to discover how the original undifferentiated condition of the segmentation of the ancestral form has been modified in each group. I have already endeavoured to do this for the Crustacea, with results which are in a way to being more rapidly confirmed than I ever expected. I am now engaged on a comparative study of the Arachnids, and I hope to find the clue to the original modification of their primitive segmentation. And here I should like to add that, although my friend Mr. Pocock's paper, "On some Points in the Morphology of the Arachnida" (Ann. & Mag. Nat. Hist., Jan. 1893) is of much service as a store of facts, the arguments which he bases upon them are not conclusive. He endeavours to show that all Arachnids *might be* deduced from a scorpion-like ancestral form. I have recently shown in 'Nature' (Nov. 16, 1893) that there is no necessity to assume the strict homology of the stigmatic segments, on which assumption much of Mr. Pocock's argument appears to rest, inasmuch as *all* the segments originally possessed tracheal invaginations. Further, it is not sufficient to take simply the *number* of the segments into account; the *fusions* of the segments are, if anything, even more important, those animals with the lesser number of fused segments being as a rule more primitive than those with a greater number. Judged by this standard, *Galeodes* or *Schizognathus*, and not *Scorpio*, is the primitive Arachnid.

the cephalothoracic segments, and later specialized for muscular attachments, let us for a moment look at the analogous structure in *Limulus*. Lankester* expressly tells us that "the inter-entapophysial ligaments which run on each side, right and left, along the dorsal surface of *Limulus*, passing from one entapophysis to the next, are of similar nature and origin to the entochondrites," *i. e.* to the endosternite. Further, we learn from Benham's researches† that these ligaments run on the *outer* sides of the entapophyses. These two facts, it seems to me, confirm the explanation of the endosternite of *Apus* and *Limulus* as derivations of the longitudinal muscle-bands given by me‡. A comparison between cross sections of *Apus* and *Limulus* leaves little doubt that these entapophysial ligaments are the structurally degraded homologues of the dorsal muscle-bands, which, as in *Apus*, once ran *outside* the dorsal attachments of the dorso-ventral muscles. In *Limulus* these muscles have lost their physiological significance owing to fusion of the segments, and have become ligamentous.

If these ligaments, then, are derivatives of the dorsal longitudinal muscle-bands, which seems to me in the highest degree probable§, then the endosternite, which, according to Lankester, is of exactly the same nature as these ligaments, must be a derivative of the ventral muscle-bands, as I have already maintained.

The endosternite of *Limulus* thus viewed must be homologous with that of *Apus* and not with that of the Arachnids, which had, as we have seen, an entirely different origin. Indeed the evidence which we have here obtained from this short comparative study of the endosternal system appears to be conclusive against the existence of any direct genetic relationship between *Limulus* and Arachnids.

The claims of relationship between the Trilobites, *Limulus*,

* Cf. *anteà*, p. 20.

† "Muscular and Endoskeletal System of *Limulus*," Trans. Zool. Soc. vol. xi. (1885).

‡ 'The Apodidæ,' Nature Series (1892).

§ I have carefully compared the musculature of *Apus* with Benham's detailed description and drawings of that of *Limulus*, and find that that of *Limulus* can be deduced from that of *Apus* (as I have before suggested) without difficulty. This derivation further avoids the necessity of assuming that any *important muscles* or *whole series of muscles* either of *Scorpio* or *Limulus* are new formations, which Lankester shows must have been the case if *Limulus* and *Scorpio* are nearly related. I might here also mention that histologically the muscle-fibres of Arachnids are totally distinct from those of Crustacea. *Limulus* has, it appears, Crustacean, or at least certainly not Arachnidan, muscle-fibres.

and the Eurypteridæ on the one hand and *Apus* on the other I have already elaborated in the book above cited, the main conclusion of which I am in a position greatly to strengthen by new points which have lately come to light. The position of *Scorpio* among the Arachnids will be further discussed in a work on *Galeodes* on which I am now engaged.

EXPLANATION OF PLATE III.

- Fig. 1.* The endosternite (shaded) of *Galeodes*, shown *in situ*. *l*, labrum; *p*, pedipalp; I., II., III., IV., four pairs of legs; T, stigmatic opening of trachea; *d*, diaphragm, sloping backwards; *h*, *a*, *n*, *t*, cardiac, alimentary, neural, and tracheal apertures in *d*.
- Fig. 2.* Transverse sections of the endosternite of *Galeodes*, showing its nature as two infoldings of the cuticle, joined by staining protoplasmic matter, but not fused, in the middle line. *a*, alimentary canal; *m*, massive elevator muscles of the pedipalps; *s*, space filled with staining protoplasmic matter.
- Fig. 3.* Dorsal aspect of the endosternite of *Mygale*.
- Fig. 4.* Inner view of the ventral surface of *Mygale*, showing the ventral points of attachment (1, 2, 3, 4) of the endosternite to the sternum (S). *p*, pedipalp; I., II., III., IV., four pairs of legs.
- Fig. 5.* Ventral aspect of the endosternite of *Mygale*, showing its sternal attachments uppermost. From a comparison of these figures the endosternite is seen to be composed of four pairs of apodemes (1, 1, 1), (2, 2, 2), (3, 3, 3), (4, 4, 4), radiating from a common centre, and further joined by a web-like expansion in the middle horizontal plane.
- Fig. 6.* Dorsal aspect of the endosternite of *Phrynus*. The preparation was accidentally destroyed before the drawing was completed; it, however, represents its general appearance. 1, 2, 3, 4, tendinous attachments, probably corresponding with the first ventral and four dorsal attachments of the endosternite in *Mygale*.
- Fig. 7.* Dorsal aspect of endosternite of *Thelyphonus*, after Tarnani (*cf.* last figure).
- Fig. 8.* Endosternite (shaded) of *Scorpio* (*Palamnceus Thorellii*, Pocock), *in situ*. *l*, labrum; *p*, pedipalps; I., II., III., IV., legs; *b*, brain, with nerves to *p* and I.; *d*, diaphragm, with *h* and *a*, cardiac and alimentary apertures through it, and *r*, ridges produced in it by the first pair of abdominal dorso-ventral muscles. The diaphragm is seen to slope forward under the endosternite.
- Fig. 9.* Transverse section through the line * in fig. 11, showing the points of fusion of the endosternite of *Scorpio*, with the diaphragm, *d*. *g*, genital operculum; *l*, anterior ends of the lips of the genital aperture. The diaphragm separating the sixth from the seventh segment has here been thrust forward by the genital aperture belonging to the seventh segment. *e*, posterior ends of the endosternite, on one side fused with *d*, on the other just before fusing, the section not being accurately transverse. *t*, tendons for attachment of muscle-bands, which slope backwards along the anterior face of the diaphragm (dorso-ventral muscles); *a*, alimentary canal; *n*, nerve-cords.
- Fig. 10.* Diagram showing the relative positions of the endosternite and

diaphragm (*d*) in *Galeodes* from the side. *h*, heart; *a*, alimentary canal; *n*, nerve-cords passing through *d*; *c*, small plates attached by tendons to the endosternite and outer cuticle (*cf.* text, p. 20).

Fig. 11. Diagram showing the relative positions of the endosternite and diaphragm (*d*) in *Scorpio*. Lettering as in fig. 10. The line of section of fig. 9 is also indicated.

III.—On the Elateridæ of Japan. By G. LEWIS, F.L.S.

THE first object of this paper is to describe as simply as possible the new species of Elateridæ brought from Japan by the writer in 1882; the second and minor object is to adjust certain synonymy, to revise some previous work on the fauna, and to note and reject species which have been erroneously introduced to the Japanese catalogue. The arrangement of Candèze has been followed as closely as possible, but in two cases I have given full rank to genera merged in others by Candèze. It is also to be noted that some of the species described are very similar to American and European forms, and others again resemble species from the islands and various countries of the Asian continent, yet after a careful examination it appears that only one or two are identical.

By the kindness of Mr. Godman I have had access to the collection made by the late Mr. E. W. Janson, and this has been of considerable assistance to me; the collection also in the National Museum has been of material aid, while the specimens returned to me by Dr. Candèze, after writing his paper on the Japanese species in 1873, are of course in my possession and are now amalgamated with the more recently gathered specimens.

Some species of Elateridæ are extremely local, remaining at times as a little colony in or near one tree for many generations, so that there can be hardly any doubt that the number of species yet to be discovered must be very considerable. *Athous desertor*, Cand., is a case in point; I found two or three specimens in a glen on Maiyasan, near Kobé, in 1871, and on returning there in 1881 I found a few more, and these are, I believe, the only examples known.

The localities given are selected to furnish some information regarding the distribution of the species at present known to me; but no names are given of places which are not registered in my itinerary and do not also appear on the map published with it in the Trans. Ent. Soc. Lond. 1883. Authors in describing species would do well to remember