THE ANNALS

AND

MAGAZINE OF NATURAL HISTORY.

[SIXTH SERIES.]

"..... per litora spargite muscum,
Naiades, et circùm vitreos considite fontes:
Pollice virgineo teneros hìc carpite flores:
Floribus et pictum, divæ, replete canistrum.
At vos, o Nymphæ Craterides, ite sub undas;
Ite, recurvato variata corallia trunco
Vellite muscosis e rupibus, et mihi conchas
Ferte, Deæ pelagi, et pingui conchylia succo."
N. Parthenii Giannettasii Ecl. 1.

No. 61. JANUARY 1893.

I.—*On some Points in the Morphology of the Arachnida (s. s.), with Notes on the Classification of the Group.* By R. I. Pocock, of the British Museum (Natural History).

[Plates I. & II.]

Since it is generally admitted that the ancestor or ancestors of the Arthropoda must be sought for in animals resembling the Annelidan worms in the complete segmentation of the body, it seems clear that a species in which the metamerism is highly developed is, *cæteris paribus*, more primitive than an allied form in which it is obscurely manifested. The two common decapod crustaceans, the crab and the lobster, furnish a good example of the truth of this maxim, the latter animal with its gangliated nerve-chord, its long, segmented, and limb-bearing abdomen, being unquestionably more nearly related to the primitive form or ancestor of the Decapoda than the crab. Consequently in tracing the phylogeny of this group of crustaceans we should conclude that the Brachyura are the descendants of the Macrura, and that as such they should occupy a higher branch of a genealogical tree.

The truth of this, however, is so very obvious that the only excuse to be offered for its restatement is the circumstance that not all authors have borne it in mind in dealing with the

phylogeny of the Arachnida. This at least seems to be borne out by the phylogenetic tree of this group that was published by Dr. Thorell in 1877 *. From this tree it appears that the Scorpions branch off from the Pedipalpi, the latter from the Araneæ, the Araneæ from the Opiliones, &c., almost the lowest branch of the Arachnid trunk being assigned to the Acari.

Perhaps, so far as complexity of structure is concerned, a Scorpion stands higher than a sheep-tick, so, no doubt, does an active free-swimming lobster rank above a sluggish Maioid crab. Nevertheless no one would probably on these grounds place the Maiidæ in a phylogenetic tree at a lower level than the Astacidæ. But the reasons that lead us to consider the Macrura nearer than the Brachyura to the ancestor of the Decapoda point also to the conclusion that of all Arachnids the Scorpions most resemble the primitive type; for in these animals the metamerism of the body is more fully expressed than in any other order of Arachnida, all the twelve somites of the abdomen being well developed with dorsal and ventral representatives, the anterior six of them bearing permanent or transitory appendages; furthermore, the nerve-chord is furnished with a series of ganglia and the heart is divided into a greater number of chambers.

Considering, then, on these grounds the primitiveness of the Scorpion's structure, we may imagine that the immediate ancestor of all the Arachnida was constructed somewhat as follows †:—The body was composed of eighteen somites, the anterior six of which were provided with large appendages set apart for locomotion and the prehension and mastication of food; the terga of this cephalothoracic region were fused to form a single shield or carapace, supporting a submedian and a cluster of lateral eyes on each side, and the ventral surface of the carapace, at least in its posterior half, was protected by a sternal plate. Each of the succeeding six somites bore a pair of small ventral appendages, and the generative aperture opened upon the sternal area of the first of these somites. The posterior six somites had lost their appendages, were probably narrower than the rest, and constituted a limbless caudal termination to the body, the last of them being furnished with a single plate, articulated above the anal aperture.

The Scorpions have departed from this hypothetical type in the following particulars:—The otherwise useless posterior

* Actes Soc. Ital. Sci. Nat. xix. p. 86.

† *Cf.* in this connexion Prof. Lankester's definition of the class Arachnida in Quart. Journ. Micr. Sci. xxi. p. 647 (1881).

five somites are converted into the so-called tail; the posterior four pairs of appendages of the abdominal region have disappeared in connexion with the development of the lung-books, the second pair become the tactile sexual organs or pectines, and the first in all probability constitute the genital operculum *. Moreover the generative aperture has moved forwards between the coxæ of the last pair of cephalothoracic limbs, and the enlargement and ingrowth of the coxæ of this region have more or less obliterated the sternum.

The Arachnida which structurally come nearest the Scorpions are the Pedipalpi. There are three existing very distinct types of this order, *Thelyphonus*, *Schizonotus* †, and *Phrynus*; the first-named being the most Scorpion-like of the three may advantageously be considered first. Great, however, as is the superficial likeness between this genus and a Scorpion, the differences are in reality very considerable. In the first place the whole abdomen is immensely reduced in length by the shortening of the somites along the longitudinal axis, the three posterior alone being abruptly narrowed to constitute a small tail-like support for the filiform multiarticulated telson; in the second place a deep constriction separates the cephalothorax from the abdomen. But more important than all this is the disappearance of the two posterior lung-sacs and the obliteration of the sternite and appendages of the second abdominal somite by the enlargement and backward extension of the sternite of the first, behind which the generative organ opens. Moreover this first sternite, in addition to obliterating the second, encroaches largely upon the third and fourth, reducing them to narrow chitinous bands, the result being that the pulmonary sacs that are situated in the third and fourth somites open in front of their sterna, or, as it is usually expressed, behind the first and second sterna ‡.

* I am not aware that the evidence of the appendicular nature of the genital operculum is absolutely conclusive.

† A name proposed by Thorell to replace *Nyctalops* of Cambridge, which was preoccupied.

‡ This at least seems to me to be the probable nature and extent of the changes that have affected this region and these parts of the body. I do not see otherwise how to account for the anomalous position of the aperture of the pulmonary sacs behind the first and second sternites, when these sacs belong to the third and fourth somites.

If this view and the one expressed below as to the derivation of the Araneæ from the Pedipalpi is correct, it seems that the two abdominal sternites of the spider *Liphistius* and the opercula of the lung-sacs of the Mygalomorphæ are the homologues of the first and second sterna of the Pedipalpi. In this case the anterior lung-sacs belong to the somite that is represented by the second sternite in *Liphistius* and by the second pair of

Schizonotus presents a strong general likeness to *Thelyphonus* in the form of the body, structure of limbs, &c. The telson, however, consists of a single short segment, and the carapace being rather shorter, has left a larger space between its hinder border and the first abdominal tergite; but this area, otherwise unprotected, is covered by a single or a paired sclerite, which may be either a special development or one of the original cephalothoracic tergites. In any case the result of this segmentation of the carapace is the power to flex the two posterior somites in a vertical plane, the joint being situated between the fourth and fifth appendages. There appears usually to be a single pair of respiratory stigmata situated behind the first sternite, as in *Thelyphonus*. The posterior pair that are developed in *Thelyphonus* appear to be functionless, but upon the third, fourth, and fifth sterna (morphologically the fourth, fifth, and sixth) close to the posterior margin and behind the muscular impressions a pair of dusky patches are visible. These appear to be some internal organs seen through the semitransparent cuticle, and I believe they are the homologues of the three posterior pair of lung-sacs of the Scorpion *. In one species described by Dr. Thorell—*S. Cambridgii*—two eyes are present; but most interesting of all is the disappearance of the respiratory stigmata and the fusion † of the first two sterna of the abdomen, which leaves only ten for this region. This species is of interest in connexion with the possible derivation of the *Solifugæ* from this group.

The third group of Pedipalpi—the Phrynidæ—are of interest inasmuch as in all the characters that they depart from the Thelyphonidæ they approach the true Spiders or Araneæ. The whole body is very much shorter than in the

---

opercula in the Mygalomorphæ, while the posterior lung-sacs belong to a somite which has no free sternite. This view is entirely opposed to Macleod's hypothesis respecting the derivation of the lung-books of the spiders.

* These structures have not, I believe, been previously noticed, but they are certainly visible in both the specimens of this genus that I have seen. For affording me an opportunity to examine these examples I am indebted to the kindness of the Rev. O. P. Cambridge, who with great liberality sent to me the types of the two species he has described. That named *tenuicaudata* is referable to the so-called genus *Tripeltis* of Thorell, having the posterior cephalothoracic tergite paired.

† Dr. Thorell's words describing this feature are "... *nec limitem inter scuta ventralia* 1*m et* 2*m, nec spiracula certo discernere potui*" (Ann. Mus. Genov. xxvii. p. 560, 1889). This author ascribes only eleven terga to the abdomen. I cannot but think, however, that he overlooked the first small tergite, which is present in the two specimens seen by me.

Thelyphonidæ and wider. The telson has disappeared. The shortness of the abdomen is brought about by the reduction in size of the three posterior somites, the terga and sterna being represented by very short, closely approximated, transverse sclerites. Moreover the anterior two tergites are also much smaller than in *Thelyphonus*. The increase in the width of the cephalothorax is accompanied by a recession of the coxæ, especially of the fourth and fifth appendages, from the middle line, leaving a membranous space between the anterior and posterior sternal pieces; this membrane is chitinized from distinct centres. Furthermore, the coxæ of the second pair of appendages are freely movable, and not fused, as in *Thelyphonus*.

The Araneæ or Spiders agree with the Phrynidæ in having a distinct constriction between the cephalothorax and abdomen, in having the coxæ arranged radially round the sternum, those of the second pair being freely movable as maxillæ; in having two-jointed mandibles and normally eight (median and lateral) eyes. Moreover in lower forms there are two pairs of lung-sacs, as in *Phrynus*. Again, although a marked difference between the two groups is the absence of segmentation in the adult Spiders, yet it is interesting to note that during their embryonic condition the ventral surface of the abdomen seems at one time or another to be divisible into eleven sternal areas, as in the adult *Phrynus*. The first of these is apodous and represents probably, I think, the genital sternite; the second, third, fourth, and fifth bear a pair of appendages each, while the last six are without appendages, as in the Scorpion. The anterior two pairs of appendages disappear in connexion with the formation of the breathing-organs; the fate of the posterior two, however, is quite unlike anything met with elsewhere in the Arachnida, for they take on the form of dwarfed limbs and constitute the spinning-mammillæ, which, with their appropriate glands, are the most characteristic features of this group. Their presence constitutes the greatest structural break between the Spiders and Pedipalpi. In the higher forms of Spiders the posterior lung-sacs are replaced by tracheal tubes. In the lowest, i. e. *Liphistius*, the upper surface of the abdomen is furnished with a series of nine tergites, the posterior of which are very much reduced in size, as in *Phrynus*, and the spinning-appendages retain their primitive position close behind the lung-sacs.

Another order of the Arachnida, namely the Pseudoscorpiones, also seems to me to be tolerably nearly related to the Pedipalpi. It is not unusual to associate this group with the Scorpions, as Mr. Cambridge has done in his article in

the 'Encyclopædia Britannica;' but it is difficult to find grounds to justify this classification.

In the form of the cephalothoracic appendages, especially of the second pair, there is certainly a close similarity between the Scorpions and the Pseudoscorpiones; but in the structure of the abdomen the difference between the two groups is very great. But the same cannot be said of the abdomen of the Pedipalpi and the animals now under discussion; for the two groups resemble each other in the absence of the pectines and in the presence of only two pairs of respiratory stigmata. Moreover, in such a form as *Garypus litoralis* the same number of somites can be made out in the abdomen as are seen in this region in the Pedipalpi, namely twelve. Furthermore, there is the same inequality in the number between the tergites and sternites, the former being one in excess of the latter *. From the posterior somite forwards the dorsal and ventral sclerites correspond plate for plate until the third tergite and second sternite are reached. Here the correspondence ceases, there being but a single genital sternite for the first and second tergites, exactly as in the Pedipalpi. The stigmata are situated in the third and fourth abdominal somites, but they have taken up a more lateral position than in the Pedipalpi.

In some other forms of this group one of the tergites has disappeared, so that the abdomen is described by systematists as being furnished with only ten of these plates. Moreover the sterna similarly may be reduced to nine.

So far as the embryological history of these animals is concerned, it is especially interesting to note the presence of four pairs of provisional appendages attached to four of the anterior segments of the abdomen. In the absence of evidence to the contrary it seems justifiable to conclude that these appendages are the exact homologues of the four pairs seen in the Araneæ, a group which we have seen to be apparently nearly related to the Pedipalpi.

The next group to be considered is the Opiliones. The animals of this order agree with the Pseudoscorpiones in the tracheal nature of their respiratory organs and in the absence of a "waist" between the cephalothorax and abdomen. This last feature has led to very remarkable results in the forward migration of the generative aperture between the coxæ of the posterior limbs, in some forms even to a position just behind

* The last somite has not, so far as I am aware, been previously recognized as such. It is, except in distended specimens, almost entirely concealed inside what is apparently the last, namely the eleventh, but which is in reality the last but one.

the mouth. This procession of the abdominal sternites is accompanied by the obliteration of the anterior pair of tracheal stigmata with the sternite that supported them. The remaining stigmata are situated on the first free sternite, and their presence fixes this plate as belonging morphologically to the fourth somite *. Since, however, there is an immense range in structure within the Opiliones, especially touching the number and distinctness of the segments of the abdomen, it is not always easy to compare the somites with those of the Pedipalpi or Chelonethi.

In *Stylocellus*, however, a genus in which the segmentation of the abdomen is well developed, there are nine distinct tergites and eight sternites, and since the presence of the stigmata on the first sternite points to it morphologically as the fourth, we have almost the full complement of somites from the fourth backwards. Moreover, between the last tergite and sternite there is a single anal sclerite which may represent the twelfth tergite. The first free tergite has no free sternite to correspond to it; it appears to belong morphologically to the third somite, since it immediately precedes the tergite that covers the sternite upon which the tracheal organs open. In this case the dorsal elements of the first two somites have disappeared, and on the ventral side the first three sternites appear to be represented in a general way by that part of the intercoxal area of the cephalothorax which lies behind the generative aperture.

In most forms of Opiliones, however, the segmentation of the body is less well expressed than in *Stylocellus*. This genus appears in this respect, as well as in the small number of supernumerary maxillary sclerites, to be one of the most primitive of the order. In the higher forms the abdomen is much more reduced in length, and even when distinct tergites and sternites are strongly developed, as in *e. g.* the *Laniatores*, their number may fall as low as five; while in others, such as *Phalangium*, the segmentation is represented merely by folds of the integument, the tergal and sternal plates being undeveloped. This reduction in the number of the dorsal and ventral plates is brought about by their fusion with each other or with the cephalothorax.

That the Acari are nearly related to the Opiliones seems evident from a comparison between the two orders. For, as Dr. Thorell says, "from the Acari the Opiliones are scarcely in all cases distinguishable by any other external character than the structure of the abdomen, which, in the Opiliones, is

* If the third, it is not easy to explain the disappearance of the second pair of stigmata.

evidently segmented at least at its posterior end" *. Some of the free-living Acari, *e. g.* the Trombidiidæ and Holothyridæ, with their pediform, claw-tipped palpi and chelate mandibles, bear so strong a resemblance to *Stylocellus*, that with an example of this genus in hand it is impossible not to think that the Acari are descended from the Opiliones †.

As for the Solifugæ, their position is not so clear. They seem to show affinities with the Pedipalpi through the Tartarides (Schizonotidæ) and also with the Pseudoscorpiones, as Simon long ago suggested ‡.

In the first place the carapace, instead of consisting of a single shield, is usually described as being divided into three distinct sclerites, the posterior two of which are regarded as the tergites of the posterior two somites of the cephalothorax.

The rest of the body, the abdomen, consists of only ten somites, the tergites and sternites apparently corresponding exactly in the first nine, while the last is a single plate perforated mesially by a vertical slit—the anus. The generative aperture is, as usual, situated upon the ventral surface of the first, while the second and third bear the apertures of the tracheal breathing-organs.

It is thus clear that these Arachnida fall into the same section as the Pedipalpi, Araneæ, Pseudoscorpiones, Opiliones, and Acari, inasmuch as they are all devoid of the pectines which are so characteristic of the Scorpions. So, too, does it seem likely that the first sternite corresponds to that of the Pedipalpi, Araneæ, &c., in which case it will represent, according to our theory, the first enlarged abdominal sternite of the Scorpion. Then the two following sternites bearing the apertures of the breathing-organs will belong to the third and fourth somites respectively, and the breathing-organs will correspond in number and position with those of the Pedipalpi and Pseudoscorpiones. In this case one of the somites has disappeared behind the fourth. In all probability the missing one is the twelfth, and we can imagine that it has vanished from view inside the eleventh, almost exactly as in the Pseudoscorpiones. Then the eleventh somite will resemble that of the last-named group in consisting of a single plate,

* Bih. Sv. Vet.-Akad. Handl. xvii. no. 9, p. 8 (1892).

† In an interesting paper, recently published in vol. xxiv. of the Journ. Linn. Soc., Zoology, my friend Mr. H. M. Bernard has advanced reasons for showing that the Acari are derived from the Spiders. Without now venturing to discuss in detail the views put forward in this paper, I will merely say that in my opinion the conclusion arrived at would have been nearer the truth if the word "Opilionid" had been substituted all through for "Araneid."

‡ 'Les Arachnides de France,' vii. pp. 9, 10 (1879).

which results from the fusion of the tergite and sternite. The other missing tergite is, I suspect, the first.

Concerning the Palpigradi, an order established by Thorell for the genus *Kœnenia* of Grassi, I can say very little, never having had the good fortune to examine a specimen of this group. This curious form seems to lie somewhere between the Pedipalpi, especially the Schizonotidæ, and the Solifugæ. As in the last the abdomen is said to consist of ten segments, but the last three are narrowed to support an antenniform telson as in *Thelyphonus*. Moreover, the cephalothorax appears to be segmented very much as in the Solifugæ and Schizonotidæ. Unfortunately nothing is known of the breathing-organs of *Kœnenia*, except their reputed absence; so it is impossible to speculate further as to the true affinities of this genus.

Respecting *Gibbocellum*, the systematic position of which is a matter of debate, I can suggest nothing new. It is no doubt referable either to the Opiliones or Pseudoscorpiones, and probably to the former.

So far the structure of the abdomen has alone been considered. The cephalothorax it is not now my intention to touch upon, and the homologies of the segments of the appendages have lately been fully discussed by Gaubert. Without either accepting or rejecting the opinion of this author on the subject of the homology of the so-called *patella* of the limbs, it may be interesting to state that the segmentation of the second pair or palpi is not to my mind satisfactorily explained on the hypothesis that this segment results from the subdivision of the *tibia*. For throughout the class of Arachnida—setting aside some aberrant groups—the palpi curiously enough, considering the general plasticity of the limbs, present the same number of segments—namely six. This similarity in the number would lead one to think *à priori* that the separate segments are numerically homologous each to each throughout the class. So far as the Scorpiones, Pseudoscorpiones, Solifugæ, and Pedipalpi are concerned, there can be very little doubt upon this point. But according to Gaubert this is not the case with the Araneæ and Opiliones; for according to this author the fourth segment or *tibia* of the palp of e. g. *Phrynus* is homologous to the fourth and fifth—the *patella* and *tibia*—of the palp of a Spider or an Opilio. But if this is so, the last two segments of the palp of *Phrynus* are represented by a single segment in the two other groups. That such a double dissimilarity has arisen, I am not at present prepared to believe.

These considerations, coupled with the great resemblance

between the fourth segments of the limbs in *Thelyphonus* and *Scorpio*—segments which, according to Mons. Gaubert, are not homologous, that of *Thelyphonus* being a *patella* while that of *Scorpio* is a *tibia*—seem to me to be serious obstacles to an otherwise plausible theory.

So far as the mandible is concerned, there is not much that need be repeated here. With the possible exception of some Acari, the greatest number of segments for these appendages is three. Three are found in the Scorpiones, most Opiliones, and the Palpigradi; the basal one, however, has disappeared in the Pedipalpi, Araneæ, Pseudoscorpiones, and some Opiliones. The Solifugæ, too, are usually said to resemble the Araneæ in having two-segmented jaws; but in reality they appear to have the primitive number, namely three; the basal one, however, has hitherto never been recognized, on account of its fusion with the cephalic shield. It is, nevertheless, a more or less distinctly defined sclerite to which the rest of the jaw is articulated.

A further peculiarity in the mandibles of the Solifugæ is the inferior position of the terminal segment or fang with respect to the apophysis of the penultimate segment, to which it is opposable. Also in the male there is a peculiar process on the penultimate segment. Peculiar processes are also found on the same segment of the mandible in both sexes of the Pseudoscorpiones; the movable dactylus, too, is almost inferior. Mainly on these two points of similarity, Mons. Simon has expressed the belief that the affinities of the Solifugæ are with the Pseudoscorpiones—an hypothesis which is further supported by the absence of a cephalothoracic sternum and a close similarity in the number of abdominal segments.

Another system of organs, which no doubt, if more were known of their structure, would throw light upon the affinities of some of the orders of Arachnida, is the eyes.

The ancestral form we believe to have been furnished with two sets of visual organs, which differed in structure and mode of development. These median and lateral eyes are well shown in the Scorpiones, most of the Pedipalpi, and most Araneæ. But there is a marked tendency in many of the 'higher' forms to the disappearance of some or all of the eyes. In the higher Opiliones the median only are retained. This also appears to be the case in the Solifugæ. In the Pseudoscorpiones, on the contrary, the median seem to have disappeared and one or more of the lateral often retained. But until the histology and embryology of these organs has been worked out in this group, in the Acari and in *Stylocellus*,

their true systematic importance cannot be understood. For it is most interesting to note that *Stylocellus*, which is a true Opilio, possesses *two* eyes on each side of the carapace, one raised upon a tubercle, the other at the base of the tubercle. This last eye has disappeared in the closely allied genus *Pettalus*, which thus resembles the higher Opiliones in being furnished with only two eyes, but whether or not they are homologous to the two eyes of a *Phalangium*, I am not able to say. If they are not, the fact will constitute a radical difference between the Sironidæ (*Siro*, *Pettalus*, *Stylocellus*), constituting Thorell's suborder Anepignathi, and his Laniatores and Palpatores. Certainly the two eyes of *Pettalus* from their position strongly call to mind those of the Pseudoscorpiones and of the unplaced genus *Gibbocellum* of Stecker. But until the exact nature of all these eyes has been determined by a study of their development and minute structure, no very great taxonomic value can safely be placed upon them.

Having thus passed in review the most important external organs of the Arachnida, it seems to me that the best characters for the classification of the class are to be found in the abdomen.

The following grouping of the orders of Arachnida will serve to show briefly my present views as to their affinities:—

A. The embryo provided with six pairs of abdominal appendages, the second of which persists in the adult as the pectines. The adult with four pairs of abdominal breathing-organs in the form of lamellar tracheæ; the abdomen very long, the posterior five segments compressed to form a flexible tail; the post-anal sclerite furnished with two poison-glands; viviparous..... Subclass **Ctenophora.**

Order 1. SCORPIONES.

B. The embryo not provided with more than four pairs of abdominal appendages, the second of which are never retained as external organs in the adult. Not more than two pairs of abdominal breathing-organs. Post-anal sclerite usually absent and never provided with poison-glands; abdomen much shorter, with at most the three posterior segments narrowed to form a tail, usually oviparous..... Subclass **Lipoctena.**

a. Cephalothorax and abdomen separated by a deep constriction; the first abdominal stomite or its remnants covering the apertures of the generative organs and of the first pair of respiratory stigmata. The breathing-organs, except in some of the Arachnomorphous spiders, in the form of lamellar tracheæ; with

rare exceptions, there are eight eyes arranged in median and lateral groups ..... **Caulogastra.**
Order 2. Pedipalpi.
3. Araneæ.

B. Cephalothorax and abdomen not separated by a deep constriction; the first abdominal sternite not acting as an operculum to the anterior abdominal respiratory stigmata. Breathing-organs in the form of tubular tracheæ. Usually a single pair of eyes, rarely two pairs.

a. A pair of respiratory stigmata between the fourth and fifth cephalothoracic appendages. The posterior two cephalothoracic somites not covered by the cephalic shield. The posterior legs with a series of racquet-shaped tactile organs on the two basal segments; the trochanter of the two posterior pairs of appendages bisegmented, &c. ..... **Mycetophora.**
Order 4. Solifugæ.

b. No stigmata between the coxæ of the fourth and fifth appendages. The cephalothorax covered by a continuous shield. The posterior legs without racquet-shaped tactile organs, and the trochanters of all the legs undivided &c. ..... **Holosomata.**
Order 5. Pseudoscorpiones.
6. Opiliones.
7. Acari.

This classification differs considerably from that proposed by Prof. Lankester in his article "*Limulus* an Arachnid" already mentioned. This author united the Scorpiones, Pedipalpi, and Araneæ in a group termed Aerobranchia, while the Solifugæ, Pseudoscorpiones, Opiliones, and Acari constituted a corresponding group, Lipobranchia. This terminology, however, does not allow for the fact that nearly all the higher Araneæ are partially or wholly Lipobranchiate.

Moreover, although the Opiliones, Pseudoscorpiones, and Acari were placed in the same section of the Class, it appears from the genealogical tree published in the paper referred to above that these three orders have had an independent origin, the Acari being an offshoot from the stem of the Araneæ, the Pseudoscorpiones from that of the Scorpiones, and the Opiliones from the Solifugæ. If this be so, it is not easy to see upon what grounds the Lipobranchia can be considered a natural group.

As for Dr. Thorell's genealogical tree, enough has already been said to show how materially this author's opinions differ from my own. It may be added, however, that the Solifugæ are removed from the Arachnid phylum and attached to that of the Hexapoda and Myriopoda, a view which to me is quite unintelligible.

* * * * *

It now remains to be seen if any beneficial results can be ascribed to the structural modifications that we have endeavoured to trace right through the Arachnida, starting with the Scorpiones and ending with the Acari.

At the outset of this article it was concluded upon morphological and embryological grounds that the ancestor of the Arachnida was an animal composed of 18 distinct somites, which were divisible into three categories, composed of 6 somites each. The appendages of the anterior six were of large size and were set apart as organs for locomotion and for prehension and mastication of prey; those of the succeeding six were of small size, the posterior four of them disappearing in connexion with the development of four pairs of abdominal breathing-organs. The six somites of the last category were without appendages, and constituted what may be termed a caudal termination to the body. Now it seems perfectly clear that an Arthropod of this description would be most unfitted for terrestrial life on account of the clumsiness of its build. In fact, being forced to drag along a long, trailing, heavy, legless abdomen it could not be otherwise than sluggish, and would consequently find no little difficulty in gaining a livelihood by the capture of other terrestrial Arthropods, which, if not otherwise protected, are usually characterized by extreme activity. It would consequently be an undoubted benefit to our hypothetical ancestor if the caudal termination to its body could be either dispensed with or turned to some account.

The latter end could be without difficulty attained by the lateral compression of the segments, which would confer considerable flexibility upon them. Moreover, since, as we have seen, the last segment was furnished with a post-anal, probably pointed, sclerite, it seems clear that a formidable weapon of attack and defence might be thus constituted. But its greatest use would probably be to put a speedy end to the struggles of prey that had been seized by either one or the other of the prehensorial limbs. In this capacity its efficiency would be greatly increased by the development of a poison-gland in the telson. A concomitant advantage in the development of this "tail" would be a loss in the weight to be dragged by the limbs owing to the decrease in the size of the segments.

In some such manner as this we may imagine that the group of Scorpiones has been evolved. But it does not seem probable that any other group of Arachnida has been derived from them. For it appears hardly likely that any variations tending to the obliteration of so useful an organ as the "tail"

would be preserved. But we can without much difficulty imagine that the rest of the Arachnida are the descendants of our hypothetical ancestral form ; but the line of their evolution is quite different from that taken by the Scorpions.

The disadvantage that this form would be under from the great and useless development of its posterior abdominal segments has already been pointed out, and we have seen that the difficulty has been overcome in the case of the Scorpions by the conversion of these segments into a light and easily carried, flexible, destructive tail. But clearly another method of dispensing with this cumbrous caudal prolongation would be its suppression by the shortening of the whole abdomen along its longitudinal axis. At first it would still retain its full complement of segments, namely twelve, and the last of them would be furnished with the telson. But owing to the loss of flexibility in the abdomen, this telson would be of no use as an organ of offence or defence. Where it is retained, as in *Thelyphonus*, *Schizonotus*, and *Kœnenia*, it functions merely as an organ of touch, being studded with tactile hairs, and to add to its efficacy in this respect the posterior segments of the abdomen are narrowed to form a movable supporting stalk for it. In *Schizonotus* it retains its original form as a single sclerite either cylindrical or cordate in shape, while in *Thelyphonus* and *Kœnenia* it is a long multiarticulated flagellum. In these three cases greater range of movement is conferred upon this instrument, and its utility is thereby increased, by the increase in the flexibility of the abdomen brought about by the constriction between it and the cephalothorax. Furthermore in *Schizonotus*, in which the organ is very short, we find still greater flexibility results from the secondary constriction which marks off the posterior portion of the cephalothorax from the anterior. The result of this double constriction is that the abdomen can be flexed right over the cephalothorax.

In the Pseudoscorpiones and Opiliones the telson has entirely disappeared. There is consequently no great need for mobility in the abdomen, and no constriction appears between it and the cephalothorax. These two regions of the body are thus perfectly continuous throughout their width, and there is nothing to prevent the two regions from fusing. In the Opiliones, as we have seen, this takes place to a very great extent, the result being a decrease in the length of the body, which no doubt can thereby be carried with considerably less effort by the legs. In this connexion it is interesting to note that when the body is relatively large in this group, as in

e. g. *Trogulus* and *Stylocellus*, the legs are short, robust, and presumably stronger; but when the body is smaller, owing to a decrease in its length, as in *Phalangium*, the legs are extremely long and thin; so that I think there can be very little doubt that in this last-named form and its allies the body is shortened and lightened that it may be raised more easily upon the long stilt-like limbs.

The structure of the Opiliones and Acari is most favourable for shortening by the concrescence of the abdomen with the cephalothorax, for not only is there no constriction between these two regions, but the wide space that separates the coxæ of the posterior walking-legs allows of the forward migration of the anterior abdominal sternites beneath the lower part of the cephalothorax. In the Pseudoscorpiones and Solifugæ, however, the concrescence cannot take place to the same extent, owing to the union in the middle line of the coxæ, this union forming an impassable barrier to the forward movement of the genital aperture.

In the Pedipalpi, as we have seen, as also in the Araneæ, no fusion between the cephalothorax and abdomen is possible, owing to the constriction between them. So that in *Phrynus*, where the body is much shorter than in *Thelyphonus*, we find that the shortening of the abdomen is brought about by the reduction in length of the anterior and posterior somites.

In connexion with the cephalothoracic limbs there is much of interest to note.

In the Scorpions, in which the body is very heavy, and in which the large prehensorial chelæ have to be carried aloft to act as clumsy organs of touch, it is not surprising that four pairs of limbs are required for purposes of locomotion. The Pseudoscorpiones also have heavy prehensile and tactile chelæ; so, too, in this group there are four pairs of walking-legs. But in the Pedipalpi, in which the body is lighter than in the Scorpiones, it seems that three pairs of legs are sufficient for locomotion, for the third pair of appendages fulfil the much needed function of antennæ. So, too, do many Spiders use this same pair of legs as feelers and move with comparative freedom on three pairs. The same is true of the Solifugæ. In both these groups, moreover, there are no heavy palpi to be carried, and it must be a distinct advantage, so far as agility is concerned, for the mandibles to be adapted for seizing and killing prey; for these appendages, although enlarged for the purpose, must be very much lighter and more easily carried than the unwieldy prehensorial palpi of the Pedipalpi, Scorpiones, and Pseudoscorpiones.

So far as internal organization is concerned, it is interesting to note that the great development of the abdomen in the Scorpions is correlated with a serially gangliated nervous chord, a many-chambered heart, and four pairs of breathing-organs. In all the other Arachnida in which the abdomen is shortened, and its muscularity diminished, the nervous chord is simplified by the disappearance of the ganglia, the chambers of the heart are reduced in number, and the two posterior breathing-organs atrophy.

It is evident that in the Scorpions the posterior region of the abdomen is the seat of great muscular activity. To repair the muscular tissue and to absorb its waste products a rich supply of blood is required, and the oxygenation of this blood will be more efficiently performed by four pairs of lung-sacs than by fewer. But in all other Arachnida the abdomen is little more than a vehicle for carrying generative and alimentary glands, so that, seeing that in the Scorpions four pairs of lungs are sufficient, it is not surprising that the rest of the Arachnida have been able to dispense with two pairs.

Again, with regard to the position of the apertures of the breathing-organs, it has already been pointed out that in *Thelyphonus* and *Phrynus*, which retain the so-called lung-books, these apertures lie in front of sterna of the somites containing the lungs. A beneficial result of this arrangement is that the sterna in front of the apertures form movable opercula to them, so that they can be opened and closed at will. In the Araneæ, where the terga and sterna mostly atrophy, we find the remnants of these sterna retained as the opercula. In the higher Araneæ (Dipneumones) the posterior pair of pulmonary sacs are replaced by tracheal tubes, the apertures of which in most forms take advantage of the continuity of the integument of the lower surface of the abdomen to migrate to its hinder end in the wake of the spinning-appendages.

In the Solifugæ the apertures of the abdominal tracheæ are very small. In most forms, e. g. *Solpuga*, they are visible on the surface of the sterna, but in *Galeodes* they have moved posteriorly until they lie behind the sterna and are thus capable of being closed. This, as well as the small size of the stigmata, must be an advantage to an animal living in desert countries, where sand would be liable to block the breathing-tubes.

Another interesting point in connexion with these animals is that a second pair of breathing-organs occurs on the ventral surface of the cephalothorax behind the coxæ of the fourth appendages, as if to compensate for the small size of the abdominal stigmata. The apertures of these organs must

be less likely to get blocked by sand than those of the abdomen, owing to their being removed away from the surface of the ground, and only very much exposed when the coxæ between which they lie are separated by the movement in the vertical plane of the posterior half of the cephalothorax.

In some Pseudoscorpiones, too, the stigmata have also changed their position, but instead of moving backwards as in the Solifugæ they have migrated externally from the sternal plates to the lateral membrane of the somites. In this situation they are much more freely exposed to the air and much less likely to be blocked by sand or earth or other foreign bodies.

In the Opiliones the stigmata of the remaining pair of breathing-organs retain their position in the middle of the sterna of the somite to which they belong.

From what has been already said concerning the affinities of the orders of Arachnida, it will be seen that the replacement of pulmonary sacs by tracheæ has taken place independently at least twice—once in the Dipneumonous Spiders, and once in *e. g.* the Pseudoscorpiones. This fact goes a long way towards weakening the evidence of affinity between the Opiliones and Pseudoscorpiones, not to mention the Solifugæ, on the grounds of similarity in their breathing-organs. For the replacement may have been independently brought about in the three cases. But however this may be with regard to the three orders just mentioned, the fact that these tubes have been developed twice in the same group bears very strong evidence as to their efficacy as breathing-organs. They must in fact be better adapted for their purpose than the lung-book tracheæ. Perhaps the following considerations may throw some light upon the matter. It seems that an Arachnid furnished with tracheal tubes, such as *Galeodes*, must be considerably lighter and consequently more agile than one, like a Scorpion, which possesses pulmonary sacs. The loss of weight will be due to two causes : firstly, to the fact that there will be a much greater supply of air inside the body, owing to the ramifications of the air-tubes through the tissues ; and, secondly, to the fact that the blood will be reduced in quantity, for there will no longer be need for a rich supply of it, since the oxygen will be carried directly to all parts of the body by the branches of the tubular tracheæ.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Diagram to show fundamental plan of Arachnid structure. I.–VI., cephalothoracic appendages; *c*, carapace; *m*, median, and *l*, lateral eyes; 1–12, abdominal somites; *t*, telson; *x*, anus; α–ζ, abdominal appendages; *g*, generative aperture.

Fig. 2. Semi-diagrammatic figure of a Scorpion. Lettering as in fig. 1. α, genital operculum; β, pectines; 3′–6′, sterna bearing the four pulmonary sacs which correspond to γ–ζ of fig. 1. (N.B. The coxæ of the posterior two cephalothoracic appendages have been omitted so as to show the genital operculum and the pectines.

Fig. 3. Fig. of a *Thelyphonus*. Lettering as above. *w*, waist or constriction between cephalothorax and abdomen; 1–4, anterior four tergites of abdomen, represented on the ventral side by three sternites, 1′–2′, 3′, 4′; 10–12, posterior three abdominal somites forming the movable stalk for the antenniform telson.

Fig. 4. *Schizonotus*. Lettering as in fig. 3. *c*′, supernumerary cephalothoracic tergite.

Fig. 5. Diagram of *Phrynus* to show the absence of the telson and the reduction in size of the posterior abdominal tergites and sternites.

Fig. 6. Diagram of the anterior five abdominal somites of *Thelyphonus* or *Phrynus*, to illustrate the hypothesis that explains why the pulmonary sacs of the 3rd and 4th somites open behind the 1st and 2nd sterna. 1–5, abdominal somites; *op*, sternum of the 1st (? 2nd) forming the operculum of the anterior pulmonary sacs and of the genital orifice; p^1, anterior, p^2, posterior pulmonary sacs.

Plate II.

Fig. 7. *Liphistius desultor*, to show the persistence of most of the abdominal tergites and of the two anterior sternites. The 1st tergite forms the dorsal plate of the abdominal pedicle, and the 12th the dorsal plate of the anus. Similarly the 12th sternite persists as the ventral plate of the anus. The appendages marked ϵ, ζ in fig. 1 persist as the spinning-mammillæ, m^1, m^2.

Fig. 8. Diagram of one of the Mygalomorphous Araneæ to show the disappearance of the external segmentation, the persistence of parts of the sterna as respiratory opercula (s^1, s^2), and the migration of the mammillæ to the posterior end of the abdomen.

Fig. 9. Diagram of a Dipneumonous Spider (*Dysdera*), to show the replacement of the posterior pulmonary sacs by a tracheal tube (s^2).

Fig. 10. Diagram of another Dipneumonous Spider (*Epeira*), to show the migration of the tracheal tubes to the hinder end of the abdomen.

Fig. 11. Diagram of one of the Pseudoscorpiones (*Garypus*), to show the terga and sterna of the abdomen, also the presence of the stigmata in the 3rd and 4th somites and the single generative sternite (*g*) corresponding to the 1st and 2nd tergites.

Fig. 12. *Stylocellus javanus*, one of the Opiliones, showing the disappearance of the anterior abdominal somites (after Thorell; slightly modified). 3–12, the tergites; 4–11, sternites; *s*, stigma on the 4th sternite.

Fig. 13. The same from below (also slightly modified from a figure given by Thorell).

Fig. 14. *Gonyleptes* (an Opilio) to show the fusion of the anterior 4 (? 5) abdominal tergites with the carapace and the 4 (1–4) free tergites and 5 (1′–5′) free sternites.

Fig. 15. The same from below, for comparison with fig. 14.

Fig. 16. *Holothyrus* (one of the Acari), for comparison with fig. 13, to show the jointed, chelate mandible, and pediform palpi I., II. (after Thorell). *a*, anus; *g*, position of genital orifice.

Fig. 17. Diagram of one of the Solifugæ, to show the segmentation of the carapace, the basal segment of the mandible (*b*) fused to the cephalic shield, the position of the stigmata on the 2nd and 3rd (morphologically, I think, the 3rd and 4th) segments of the abdomen, and (*s*) the position of the cephalothoracic stigmata.

N.B.—Where I have taken the liberty of utilizing figures published by Dr. Thorell, I wish it to be understood that I have tested their accuracy by an examination of actual specimens.

II.—*Descriptions of Thirteen new Species of Terrestrial Mollusca from South Africa.* By James Cosmo Melvill, M.A., F.L.S., and John Henry Ponsonby, F.Z.S.

[Plate III.]

This, our sixth contribution on the subject, we present in fulfilment of our promise (Ann. & Mag. Nat. Hist. 1892, vol. x. p. 237) to deal with new forms of *Ennea* and *Pupa*. We now describe four of the former genus and seven of the latter.

1. *Helix* (*Pella*) *strobilodes*, sp. n. (Pl. III. fig. 1.)

H. testa obtecte umbilicata, conica, tenui, sordide alba, epidermide sericco-cornea contecta; anfractibus sex, supra angustatis, infra ad basin rapide accrescentibus, paullum ventricosis; apertura lunari; peristomate tenui, simplici, apud umbilicum triangulatim reflexo.

Long. 7·75, lat. 5·50 mill.

Hab. Tharfield.

A somewhat conical, close-whorled shell, with simple mouth and narrow umbilicus, allied to *H. Loveni*, Krauss.

Two specimens.

2. *Helix* (*Patula*) *somersetensis*, sp. n. (Pl. III. fig. 2.)

H. testa aperte umbilicata, subconico-depressa, lævi, albo-cinerea;