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parts of these regions. May this not indicate that certain physical influences have primarily induced the variations which have been developed into perfect adaptations?

2. May not heliotropism, or the retarding effect of light upon the formation of tissue, partly explain the greater development of the lower stamens, the shortening of the middle, and the abortion of the upper; and may it not also explain the upward curving of the styles and lower stamens in these plants?

3. May not the mechanical action of the insect have some connection with the obliquity of the *C. chamæcrista* flower, and the divergence of the styles and stamens? *C. chamæcrista* is like the typical form turned downward and to one side.

4. In these plants we have found a lack of bilateral symmetry, and we have found it attended with a regular exchange of sides, and that to accomplish a special purpose. Is this commonly so in plants thus irregular, such as the *Cannaceæ* and *Zingiberaceæ?*

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IS LIMULUS AN ARACHNID?

BY A. S. PACKARD, JR.

IN an article by Professor E. R. Lankester in the *Quarterly Journal of Microscopical Science*, for July and October, 1881, entitled "Limulus an Arachnid," the author, distinguished for his histological and embryological papers especially relating to molusks and Cœlenterates, takes the ground that Limulus, or the horse-shoe or king crab, "is best understood as an aquatic scorpion, and the scorpion and its allies as terrestrial modifications of the king crab," and on p. 507 he makes the following startling announcement: "That the king crab is as closely related to the scorpion as is the spider has for years been an open secret, which has escaped notice by something like fatality." While appreciating the thorough and critical nature of the learned author's work, especially observable in his excellent paper on the structure of Apus, we venture to assert that in regard to the systematic position of Limulus, Professor Lankester has mistaken interesting analogies for affinities, and has on quite insufficient and at times wholly hypothetical grounds rashly overlooked the most solid facts, and safe inductions from such facts, and arrived at very forced and it seems to us strange and quite untenable conclusions.

At the outset, it will be remembered that Limulus differs from

the Tracheates, including the Arachnids, in having no tracheæ, no spiracles, and no Malpighian tubes. It differs from Arachnids in these characters; also in having compound eyes, no functional mandibles or maxillæ, the legs not terminating, as is generally the case in Tracheates, in a pair of minute claws; while its brain does not as in Arachnida supply both eyes and first cephalic appendages. On the other hand, Limulus agrees with Crustacea in being aquatic and breathing by external gills attached to several pairs of biramous feet; in having a simple brain, which as in some groups of typical Crustacea (Branchiopoda, etc.), does not supply any of the appendages, while the structure of the circulatory, digestive and reproductive organs agrees with that of the Crustacea; and, as we have shown in our Embryology of Limulus (this journal for 1870), the development of Limulus is like that of certain other Crustacea with a condensed metamorphosis, the possession of an amnion being paralleled by that of Apus. In all essential points Limulus is a Crustacean, with some fundamental features in which it departs from the normal Crustacean type, and with some superficial characters in which it resembles the scorpion. The importance of these superficial characters Mr. Lankester exaggerates, and upon them with a number of suppositious, *a priori*, pseudo facts he constructs, by a process quite the reverse of the inductive method, a new classification of the Arachnida.

We will now briefly criticise some points insisted upon by Professor Lankester: and first on p. 510, as regards the ensheathing of the nervous cord by an actual arterial vessel. This is to be met with in a less marked degree in the insects (Lepidoptera) as well as scorpions. As regards the comparison of the nervous system of Limulus with that of the scorpion, the comparison and statement made in our second memoir, which Lankester sets aside, was based on a month's careful study and dissection of the nervous system, particularly the brain of the scorpion, while our author draws his inspiration from Newport's account and figures. The differences between the brain and thoracic ganglionic mass of the scorpion, and that of Limulus are not even correctly stated by our author. The brain of the adult scorpion, as we stated on p. 7 of our second memoir, sends off nerves to the simple eyes *and to the first pair of appendages;* in Limulus the brain supplies the eyes alone; the first pair of appendages being supplied from the

commissures, as in all Phyllopod Crustacea. Had Mr. Lankester examined for himself the brain of the scorpion, he would not have given the strangely incorrect account on p. 511. In the first place, the nerves to the first pair of appendages arise from the brain itself, as we have seen and as has been stated by other authors,[1] and not as Lankester says from the œsophageal collar. Moreover, as we stated, the brain is situated in the top of the head of the Arachnida, and not on the same plane as the œsophageal collar as in Limulus. In regard to the morphology (not the internal structure) of the brain, Limulus much more nearly approaches Apus and other Phyllopods than the scorpion and other Arachnida.

In discussing the external anatomy of Limulus, Mr. Lankester claims that between the sixth abdominal segment and the spine there are six segments. We venture to suggest that four of these segments are purely imaginary. Embryology, as we have indicated in our figures, shows that there are but nine segments in the abdomen of Limulus, the spine forming the ninth. Our author speaks of the "post-anal spine," when the anus is plainly situated in the base of the spine itself. It is a general law in the Arthropods that the anus opens in the terminal segment of the body. There are fifteen segments in the body of Limulus, as embryology abundantly shows. In order to compare the body of Limulus with its fifteen segments or arthromeres to that of the scorpion with nineteen, Mr. Lankester conjures up four additional segments, which are pure metaphysical inventions. The cephalothoracic plate or carapace is more than once styled a "sclerite." The author here (as usual) sets aside the embryological proof that the carapace is composed of the tergites of six segments, and allows, apparently as the results of his own independent observations (as if no one had previously *proved* it[2]), that

[1] Newport, whom our author quotes, expressly states that "immediately beneath the nerves to the eyes a large nervous trunk passes forwards, from the front of the brain on each side, to the small prehensile organs (*a*), which, in the scorpion, are modified antennæ." Balfour's embryological observations shows that originally the brain of the spider is a double ganglion; the two forming the adult brain; our embryology of Limulus shows that the brain is from the beginning a single ganglion.

[2] In a preliminary paper on the Embryology of Limulus Polyphemus, read before the Amer. Assn. Adv. Science, August 1870, and printed in the AMERICAN NATURALIST for October, 1870, which our author has apparently not seen, the six segments of the embryo Limulus when in the trilobite stage are figured, and the number of thoracic segments is stated in the text. This paper is a summary of the memoir printed in the Memoirs of the Boston Society of Natural History, and contains a general account of the embryology of Limulus, and appeared with figures over a year in advance of any other account of the embryology of Limulus.

the carapace may "be considered as representing six coalesced tergites." Partly on metaphysical grounds, and partly from the presence of moveable spines on the sides, which, however, are situated on the anterior limb-bearing segments of the abdomen, as well as on the 7th and 8th limbless segments, our author is encouraged in the belief that these four hypothetical segments really exist. We prefer the plain teachings of observed facts, which are capable of demonstration and proof, and would ask for better evidence than this article affords of the existence of such segments. We would also continue to regard the anal spine as the telson. Lankester's "telson" is made up of the consolidated thirteenth and fourteenth segments of the body *plus* the anal spine or fifteenth (or ninth abdominal) segment.

Our author sets out with the foregone conclusion that he "must" find in the "abdominal carapace" of Limulus the representatives of the twelve abdominal segments of the scorpion, and so with a method of his own he creates them out of his inner consciousness.

In like manner he feels compelled to offer a new interpretation of the scattered, individual, simple eyes of the scorpion, and attempts to show that after all they are compound eyes like those of Limulus, with the difference that in Scorpio they are "in a less compact form." Now the compound eye of Limulus, like that of the lobster or any other Crustacean or insect, possesses a common basally undivided retina, in Limulus a common undivided outer cornea, while the two simple eyes in Limulus have each a separate cornea, a separate retina, and each ocellus is supplied by a separate nerve arising independently from the brain.

In like manner our author labors to diminish the importance of the differences between the cephalothoracic appendages of the Arachnida and those of Limulus.

Professor Lankester then ventures, we think, somewhat hastily, to homologize the first pair of abdominal appendages of Limulus with a little triangular median sternite in the scorpion. Then he fancifully homologizes the comb-like organs of the scorpion with the second pair of abdominal legs of Limulus, and also homologizes the respiratory lamellæ with the "lamelliform teeth of the scorpion's comb-like organs." The author farther seriously attempts to homologize the four pairs of stigmata of the scorpion with the four last pairs of biramous respiratory feet of Limulus.

On the same principle the stigmata of any insect are the homologues of its legs. What will Mr. Lankester do with the gill-plates of the Eurypterida, which are not arranged, according to Woodward, like those of Limulus, but are placed like the teeth of a rake?

Another surprise is added to the already long list, by Mr. Lankester's discovery (of which he makes great account), of what he calls "parabranchial stigmata" in Limulus. He places them on the "sternal area of the segments," but his statements on the succeeding page, and his figures plainly show that these little muscular pits are situated at the base of the biramous abdominal legs. Is there an instance in nature of stigmata being borne on the legs? Is there the slightest possible reason for regarding these pits as stigmata? We are then treated to a long series of suppositions accompanied by a series of elaborate hypothetical lithographic drawings designed to "illustrate the hypothesis as to the derivation of the lamelliferous appendages of Limulus and Scorpio from a common ancestral form." The late appearance of the lamellæ on the feet of the embryo Limulus, should teach any naturalist of sound judgment that they are most probably very special and late differentiations of the appendages. Besides this, palæontology shows that in the Carboniferous period there were scorpions almost generically the same as the existing ones, and with them Bellinurus, closely resembling the Mesozoic and recent Limuli, which indicates that the latter type has always been a marine one, without any possible use for stigmata. Moreover, the Eurypterine Merostomata, with crustacean gills, flourished as early as the Lower Silurian period.

Passing over for want of space and time, the three or four pages of trivial criticisms of our own views by Professor Lankester, we are thus brought to the close of Mr. Lankester's article, and to his tabular view of his new classification of the Arachnida, one which is calculated at least to take away the breath of the ordinary systematist.

Any attempt at reasoning with our author, whose methods are so opposed to the inductive mode of scientific reasoning, and whose views are often founded on baseless hypotheses, would probably be fruitless. He is "surprised" that we should persist in believing that Limulus is a Crustacean.

We will in reply and to close this criticism, simply quote some

statements of the late Dr. Von Willemoes-Suhm, whose important discoveries have been overlooked by all writers on Limulus. Our attention has been called to them through Mr. E. Burgess by Professor Walter Faxon, who has kindly sent us the subjoined extracts from Von Willemoes-Suhm's Letters.

The first reference by Von Willemoes-Suhm was in the Zeitschrift für wissenschaftliche Zoölogie, XXIX, 1877, writing from Yeddo under date of May 7, 1875, he says: "I have in the meantime discovered in the Philippines that the Limulus living there develops from a free-swimming larva, viz., a Nauplius stage, a fact of great significance to the whole doctrine of crustacean development. The preliminary notice concerning it, which I soon send to the Royal Society, will soon come to your notice. Packard and Dohrn have had to do with an animal which, like the crayfish, has a condensed development." (p. CXXXII.)

A fuller statement is in a postscript to a letter written aboard the *Challenger* to Professor Kupffer, dated "Zamboanga, Mindaua, 4 Februar, 1875," printed in "Challenger-Briefe von Rudolf von Willemoes-Suhm, Dr. Phil., 1872–1875. Nach dem Tode des Verfasser herausgegeben von seiner Mutter," Leipzig, 1877, pp. 157, 158. I am indebted to Professor Faxon for the extract of which I give the following translation:

"I send you this postscript in order to forward early information that it has befallen to me to find on the surface of the water here, about five stages of development of *Limulus rotundicauda*, which does not, like the North American species, according to Packard and Dohrn, directly develop, but passes through a Nauplius stage, with one, afterwards with three eyes, wholly like a Phyllopod. A tail spine is present, but jointed above, and in this stage shows a parallel with Eurypterus. Packard's mode of development is a condensed one, and as would appear, his as well as Dohrn's and Van Beneden's generalizations on the position of Limulus are throughout untenable, in so far as they remove this from the Phyllopods *(Apus* and *Branchipus)*. They rather become closely allied through their common Nauplius with three pair of appendages; and a part of the 'Gigantostraken,' especially the Eurypteridæ, should be added to them."

"As soon as I reach Japan, I hope to also examine the Limulus there. The larvæ here are unfortunately very rare and difficult to isolate but I have good preparations of the most important stages. I hope to fall in with the northern species."