Further Observations on Koenenia.

By

Augusta Rucker,
Instructor in Zoology, University of Texas.

(Contributions from the Zoological Laboratory of the University of Texas.)

With plates 21—23.

I. Historical Notes.

When I began work on the Texan *Koenenia* in the fall of 1900 I had expected to consider the internal anatomy only, thinking that the external specific characters had already been described, first by B. Grassi [1]); second by Hansen & Sörensen [2]); and third by W. M. Wheeler. [3]) Scarcely had I taken up this work when I perceived that Dr. Wheeler in discovering this Arachnid in Austin had had the good fortune to find an entirely new species. At the

1) B. Grassi, I progenitori dei Miriapodi e degli Insetti, Mem. V, Intorno ad un nuovo Aracnide Artrogastro (Koenenia mirabilis) rappresentante di un nuovo ordine (Microthelyphonida), in: Bull. Soc. entomol. Italiana, Anno 18, Firenze 1886, p. 153—172.

2) The order Palpegradi Thor. (Koenenia mirabilis Grassi) and its relationship to the other Arachnidee, in: Entomol. Tidsskr., p. 223—240, Arg. 18, H. 4, 1897.

3) A singular Arachnid (Koenenia mirabilis Grassi) occurring in Texas, in: Amer. Naturalist, 1900.

very beginning of a rather unsuccessful attempt to get a great number of specimens before giving the fixed character of the species. I observed that I had two distinct types in my collection. One set had prominent and peculiar appendages around the reproductive orifice while the reproductive appendages in the other set were not so prominent and did not possess papillae. In all other respects the animals were similar. I naturally concluded that I had both sexes of *Koenenia* and subsequent sectioning showed this to be true. These results, which I did not start out to get and which I happened to obtain, I included in a few notes on the internal anatomy.[1])

Again, in carrying out further investigations on the internal anatomy, together with observations concerning the variation of characters which might be considered specific, where only one or two specimens were to be had, I have obtained some very interesting results in quite another direction . . . the post-embryonic development, which may be expected to throw some light on the phylogenetic position of the *Koenenia*. I have likewise been able through study of the living animal, to verify some of my former results, which were arrived at by means of sections and whole mounts, and which have been unduly criticised by H. M. Hansen, in: The Entomol. Tidsskr., 1901. Something further can be added in regard to the habits of these animals and the best methods for collecting, when special fixing fluids are desired which cannot be handled on the field.

Before going further in my results, I feel that I must, in justice to myself and the work which I have undertaken, consider some of the criticisms made by Dr. Hansen in his paper "On six species of Koenenia". Dr. Hansen begins his six-paged Postscript by saying I had "kindly" sent him a copy of my separate and he would insert a review of it. He then quotes from my paper: "We have been more fortunate than Drs. Hansen & Sörensen in being able to distinguish the two sexes. It hardly seems possible that the males of Grassi's species could be so rare when they are so abundant in our species". That it was surprise on my part that the European observers had not been so fortunate as we were, and that there was no doubt entertained of Dr. Hansen's ability, goes without saying. No one could believe that a young worker in science, would be so presumptive as to doubt the ability of a man so renowned as Prof. B. Grassi, or of men who have done such meritorious work

1) The Texan Koenenia, in: Amer. Naturalist, May 1901.

as Hansen & Sörensen. Dr. Wheeler most kindly read and made many valuable corrections on my paper before it went to press and he saw no intended slur in the above lines; yet Dr. Hansen says "This mode of writing is, speaking gently, rather bold". Truly one is thankful that the gentleman restrained himself and only spoke "gently". Dr. Hansen certainly misunderstood my thought, or rather my English, for he adds "But if I should obtain new material with males and females of *K. mirabilis* (or any other of my species), I think to be able to distinguish the sexes."

However, from the very outset of Drs. Hansen's & Sörensen's paper I was so convinced that they had individuals of one sex only that I have kept a tabulated account of the sex of the individuals taken around Austin, thinking that I might, since material was more accessible to me, find that the males and females appeared at different times, which would explain the failure of the European collectors to find the males of these small creatures.

Dr. Hansen's criticism on points relating to the external anatomy need not be dwelt on at all since they will be taken up later, having been revised and corrected after diligent observations on a considerable amount of material. He goes further, however, and touches on the internal anatomy of this form on which he has not given any study as yet, and says, "In fig. 5, she has drawn 4 pairs of dorso-ventral muscles; without dissection I have been able to discern five pairs in *K. wheeleri* (which has three pairs of sacs)". If fig. 5 did not show all the five muscles, fig. 6 does, which is a drawing through the same region of the male; but fig. 5 does show all five muscles as any one can see who cares to take the trouble to look. Furthermore, on p. 629 of my reprint it is stated "Just as there is a pair of dorso-ventral muscles for each pair of lung-sacs (there are three pairs of sacs) there is also a corresponding pair for the reproductive appendages of each segment".

In regard to the digestive tract, Dr. Hansen writes, presumedly in great haste, "Miss R. mentions a pair of small diverticula from the thoracic and five pairs of large diverticula from the abdominal part of the intestine, and furthermore she writes: 'The intestine and the diverticula are invariably filled with food particles, which have the appearences of yolk granules'. Dr. Sörensen has asked me to state that at least as to the diverticula in the abdomen this is certainly incorrect (and I share his opinion). In his extensive treatise on the anatomy of Opiliones Laniatores [in: Naturh. Tidsskr.,

(3), V. 12. 1879] he has proved (p. 170—171) that the four pairs of large diverticula in Op. Laniatores are glands and not besides reservoirs for food". Undoubtedly the diverticula in *Koenenia* are glandular but certainly not more so than any other region of the mid-gut; this whole region from the oesophageal ring anteriorly to the hind gut posteriorly, presents the same glandular structure. Indeed, in *Koenenia* these simple diverticula in the abdomen seem merely to have been produced by the flattening of the mid-gut dorso-ventrally through the great development of the reproductive organs; and in the process of spreading, the intestine was constricted laterally at regular intervals by the dorso-ventral muscles. A most primitive condition is thus found in the digestive tract of *Koenenia* which, as we should expect, presents a still simpler condition in the younger stages, where the reproductive organs are not developed. It is such a simple arrangement for digestion that I was not at all surprised when I beheld food particles driven from the thoracic diverticula through the straight course of the intestine, into first one and then another of the abdominal diverticula. Dr. Wheeler and myself have seen this course taken by the food through the intestine in specimens that were brought immediately from the field into the laboratory. The condition of the intestine in *Koenenia* corroborates Bernard's statements concerning *Galeodes*, p. 359 [1]): "The distinction often drawn between the mit-gut diverticula in the cephalothorax and the "liver" diverticula in the abdomen is erroneous. As I have shown elsewhere the epithelium of these diverticula throughout the whole mid-gut is essentially similar and is throughout digestive in its function. The differences which appear in the epithelia of the cephalothoracic portions of the mid-gut and of the abdominal are not differences of kind: they are due to the fact that the latter have more food pumped into them to digest. The diverticula throughout the Arachnida are typically mere extensions of the digestive surface, and are nowhere converted into hepatic or pancreatic glands". Thus Dr. Hansen's concluding sentence, expressing the opposite of Bernard's view, "We think that the diverticula in question never contain food particles in any order of Arachnida" is proved to be untrue at least for the orders to which *Koenenia* and *Galeodes* belong.

Any of the above criticisms of Dr. Hansen might have been entirely ignored, since honest results will always speak for themselves

1) H. M. Bernard, Comparative morphology of the Galeodidae, in: Trans. Linn. Soc. London, V. 6, part 4, 1896.

but there are critical remarks that cannot be faced too squarely or met too boldly. When I wrote "A young Danish zoologist has recently found in Siam a distinct species of *Koenenia*, which Dr. Hansen is to describe", I was not aware that this bit of information was a secret existing between Dr. Hansen, the Danish investigator and Dr. Wheeler, not to be divulged until Dr. Hansen himself was ready to electrify the world with it. That it was contained in a letter was not impressed on my mind when I included it in my paper, and it might as well have been left out, though one would think that the chief merit of my paper lay in the news this extract contained, for Dr. Hansen writes, "But when the author publishes this extract from one of my letters as a contribution to the knowledge of the distribution of the order, it had been proper to publish more details from my letters to Prof. Wheeler and herself". I have never received a letter from Dr. Hansen. In one letter to Dr. Wheeler I remember he was so kind as to offer some suggestions about obtaining specimens of *Thelyphonus* which he thought should be studied in comparison with *Koenenia*. The only other letter to Dr. Wheeler of which I am cognizant I think would not improve any contribution sent out from the University of Texas; in fact I do not think it "would have been proper" to have published anything from it since it was consumed partially in telling what he was going to do and what he did not wish others to do; and partially in giving a list of animals to be collected here in Texas and sent to him . . . he did not say for the same reward that I have received for the *Koenenia* which I collected and gave Dr. Wheeler to send him, or for the same reward that Mr. Börner received for furnishing him the only perfect specimens of *K. mirabilis* which he has seen. There is only one reward to be had and which is always expected under such conditions, and that is the just consideration of results. When Dr. Hansen concludes his postscript by "Perhaps these critical remarks will be found a little too lengthy. But I have wished that the base which I hoped to have laid down for the systematic study of the forms of this difficult order should be as solid as possible in all respects", he seems not to understand that I too and scores of others have this interest at heart as much as he. We merely wish to do our part in laying the foundation, when the material at hand makes it most expedient for us to do so, but we do not feel equal to doing this without the goodwill, the aid, and the special direction of those more

skilled in such undertakings. In undertaking any piece of research not only just comments and careful criticisms are expected and desired; but even severe criticism born of the desire to help is invited. We who are comparatively new in scientific investigation realize the great need of such supervision and criticism as only the true scientists can give, who with DARWIN-like persistance and patience in their broad field of work have lost sight of the ego in the sciamus. May we always have guidance from such a source, but may we be delivered from criticism begotten of ill-will and suspicion.

II. Observations on the Behavior and Structure of the Living Koenenia.

Owing to a drought throughout Texas for over a year's duration, in all the collecting done only two *Koenenia* were found and I had to content myself with a study of *Thelyphonus* and *Galeodes*. Two genera of the Solpugida seem to thrive in the hot and dry places around Austin but not in such abundance as they occur in Brewster, Jeff Davis and other Counties of the Trans-Pecos. It was not till the 14th of March, 1902 after the very slight spring rains which occurred about Austin, that we succeeded in finding *Koenenia* again, and then after a continual search of a whole afternoon, in which two of us were engaged, we found only five *Koenenia*. These five specimens were taken along a gulley on the Whitis place within three blocks of the University. From this time on two of us have searched diligently whenever the conditions were favorable. Until April 13th, a month later, there were only slight rains in this locality and because of lack of surface moisture only a few *Koenenia* were found. Those that were taken came from Waller Creek, which did not dry up like the other streams in and around Austin because it was supplied with water from ponds on the State Insane Asylum grounds. Under these conditions a whole afternoon of collecting rarely revealed more than six specimens.

While collecting in this region of Waller Creek it occurred to me that I might take specimens alive to the laboratory and there observe them with the aid of the microscope. I could be sure then that I did not have to deal with the problem of shrinkage which seemed to be causing some misunderstanding. It was very easy to pick up the little animals on the point of a delicate brush and float them off into water in a half-filled bottle. When the water was

poured from the bottle into a stender-dish in the laboratory the *Koenenia* remained floating and were then gently picked up with a brush and placed in a glass cell by the side of a piece of moist filter paper, which was then covered over. With a number eight ocular and a three objective they could be observed to great advantage as they ran around. Often they would become quiet and remain so for an hour, thus enabling one to use the camera lucida in sketching them. When the animal was quiet for a long time there was no trace of life save a slight peristaltic movement of the intestine (while even this sometimes ceased), and a rythmic-pulsation on either side of the head near the origin of the second pair of appendages, or pedipalps.

Just what is the function of these pulsating bodies I am unable to say. They are in the region of and seem to be surrounded by the coxal glands. Sections through this region reveal almost nothing, so delicate is the tissue which is found there. In some of the living specimens examined, no clear line of demarcation could be made out between this pulsating area and the thoracic diverticula of the intestine, while in other regions the digestive tract stood out in great clearness and we were able to see particles churning around in its yellowish confines. I have followed with my eye food particles in their course from the thoracic diverticula, through the straight course of the intestine into the abdomen, where they were sent into first one and then another of the abdominal diverticula. These diverticula, it seems, vary in number as well as in size, for the anterior pair is sometimes absent or it is sometimes represented by one diverticulum and not by a pair. The camera sketch that I made of a female *Koenenia* shows this condition of the digestive tract. The ovary in the same specimen showed up large and clear. The sketch in which this organ is shown brings out the longitudinal furrow on the ventral side, made by the contraction of the ventral and dorsoventral muscles. This furrowed condition was most common in the living animal of both sexes. I have never seen the lung-sacs protruded in any but dead specimens. The testes do not show their paired condition in the living animal, in fact, it was difficult to make these organs out because of the minuteness of their structure and their failure to take stains. It is only with the use of Zenker's fluid, a mixture of acetic acid, corrosive sublimate and Müller's fluid and followed by Iron Haematoxylin and Orange G stains, that I have succeeded in observing the true state of affairs. The testes are more like

those of the *Galeodes* though on a small scale; they consist of very small, and much convoluted tubules. There is a pair of these testicular tubules, one on either side of the abdomen. The contents in the living specimens look not unlike the contents of the ovary, which consist principally of yolk bodies. But I do not wish to give any further notes on the internal anatomy of *Koenenia* until time permits me to study it extensively and in comparison with the corresponding organs in *Thelyphonus* and *Galeodes*, on which I am engaged. Likewise for comparison dissection should be made and sections had of all of the other orders of the Arachnida, which occur here so abundantly. For the present it will suffice to give some account of the occurrence and habits of *Koenenia* together with the specific and variable characters of the adult, with notes on the ontogeny.

Up to the present time so far as is known to me, it has been stated that *Koenenia* are always found under stones of a definite degree of moisture. That they are positively hydrotropic is evident from their disappearance during drought, and appearance only after a rain. They are likewise decidely positive in their stereotropic reaction, but the moisture stimulus must of a necessity be the stronger one. When there was only an irregular surface moisture the animals were found under the rough and porous Austin and Dallas limestone, which not only held the moisture perfectly but, in the crevices formed by their decay and splitting, afforded perfect conditions for *Koenenia* to take up their abode away from the light, which they shun as do the *Solpugida*. On picking up small stones the *Koenenia* immediately ran to the edge and down on the other side, which was now turned from the light. Dr. WHEELER who has most kindly collected a great number of the *Solpugida* for me tells me that they react in exactly the same way to light.[1]) It seemed plausible to

1) Hunger does not necessarily change *Koenenia* from negative to positive heliotropism, since its food is obtained underground; but in the case of *Galeodes* I believe it to be different, from observing their behavior in several instances. In our sitting-room a specimen of *Galeodes* was captured standing where the 16 power electric light shone full on it. That it was hungry was evident from the fact that as soon as it was captured, which was about 11, P. M. it attacked and ate a June beetle (*Lachnosterna fareta*) larger than itself. Nothing more was offered it that night but next morning it ate three flies and five leaf-chafers and then retired to a dark place under a piece of folded paper and remained quiet. Whenever it was dislodged from its resting place and exposed to the light it again sought the dark under the paper. Another specimen, brought

me that *Koenenia* made to react to these strong geotropic and stereotropic stimuli need not necessarily always be found under stones if the soil presented the proper hydrotropic stimuli. These animals undeniably leave the stones and go down through the soil when the ground becomes dry on the surface. I had never found them under these conditions, however, until the morning of May 13th. We had been having good rains about Austin and the moisture seemed equally distributed throughout the surface to a depth of several feet. I was expecting to find a great number of specimens and was disappointed on taking up stones to find nothing. On digging up a small trowel of dirt at random, I was surprised and delighted to see two of the little animals moving swiftly and gracefully around through the soil. Following this plan of searching we succeeded in a short time in capturing thirty-seven specimens; of these only five came from under the stones. For the few days that this small area was blessed with moisture *Koenenia* were found in the soil.

That the animals are affected by the rains and also by another stimulus due either to heat or to the conditions of the sexual organs at certain periods, the following table will show. The table was at first arranged to give the sexes so far as they could be determined when the animals were examined alive immediately after capture. Often the males when alive contract their reproductive appendages to a certain extent so that the striking contour, which they usually present in dead specimens, was lost. When it became so evident that the sexes always appeared together and when other forms began to appear I ceased to record the number of each sex, and gave my whole attention to the other forms. In all my collecting, however where more than two specimens were obtained I never failed but on one occasion to take individuals of both sexes, as the table (page 410) will show.

After the 19th day of May it again became too dry for collecting. A few specimens might have been obtained where the ground was not thoroughly dry but the heat was too great and the "red-bugs" too numerous for field work. These periodic droughts for the last two years have made a systematic collection for information on the life-history of *Koenenia* a hopeless task. That the appearance of these animals on the surface does not depend on the rainfall alone is shown from the fact that in April after a severe rainstorm which

in by a friend, who captured it on her dresser near a large window, at 8 A. M. behaved in the same way.

Time	No. taken	No. of males	No. of females	Undetermined	Stage I	Stage II	Stage Male	Stage Female
Nov. 1901.	2	1	1	—	—	—	—	—
1902								
March 14	5	2	3	—	—	—	—	—
„ 15	5	1	4	—	—	—	—	—
„ 16 h [1])	29	11	18	—	—	—	—	—
„ 21	6	4	2	—	—	—	—	—
„ 22	5	1	4	—	—	—	—	—
April 8	11	3	8	—	—	—	—	—
„ 9	4	0	4	—	—	—	—	—
„ 10	0	—	—	—	—	—	—	—
„ 12	9	7	2	—	—	—	—	—
„ 13 r [2])	—	—	—	—	—	—	—	—
„ 16	14	4	9	1	—	—	—	—
„ 17	5	1	4	—	—	—	—	—
„ 17	8	3	3	2	—	—	—	—
„ 21	1	—	1	—	—	—	—	—
„ 25	14	7	6	1	—	—	—	—
„ 26	9	3	5	—	—	1	—	—
May 1	7	2	1	—	4	—	—	—
„ 2, 3, & 4 r	—	—	—	—	—	—	—	—
„ 4	14 of both sexes			—	—	—	—	—
„ 5 h	91 „ „ „			—	—	31	—	1	—
„ 7	21 „ „ „			—	—	0	—	1	1
„ 8	57 „ „ „			—	—	28	1	1	—
„ 10	39 „ „ „			—	—	15	—	—	1
„ 13	42 „ „ „			—	—	12	—	—	1
„ 19	13 „ „ „			—	—	4	—	—	1

left the ground in such a condition that it was impossible to collect for three days, only fifteen specimens were to be had while in May they appeared in the greatest abundance.

At this time when specimens were easy to obtain I placed a number unharmed and whole, even to the flagellum, in a large open mouthed vial with a little moist soil and a few damp stones. I was thus able to observe them somewhat more closely as they darted about through the crevices, running from the light whenever they happened to appear in it. For a clearer view of them, I placed some of the specimens with moist earth in a very flat culture dish, with a secure cover. I was then able with a reading lens to observe the little creatures as they ran around gently waving their long delicate third pair of appendages, while using the pedipalpi as true walking members. Sometimes the flagellum was lifted high over the head,

1) h, indicates the results of a whole day's collecting.
2) r, indicates heavy rain fall.

and sometimes not only the flagellum but the abdomen would be bent back so that only the head and thorax remained parallel with the surface on which they walked. This gave the animal the ludicrous appearance of attempting to stand on its head. The *Koenenia* seemed very sensitive to the approach of other individuals of the some species. They would dart apart, when with the lens I could not see that they had touched, as if each had received a shock. The warning of approach must have been given by the delicate sensory hairs on the third pair of appendages, which are evidently extremely sensitive. Often when one of these little animals was running, the flagellum dragged, seeming to hug the soil. The long setae on the organ probably served them in making their position more secure. This was noticed most particularly when catching them with a brush; if the flagellum touched the hairs of the brush and lay parallel with the hairs, much shaking was necessary to dislodge the animal, while in several cases I have been forced to cut a few hairs of this brush and leave them with the *Koenenia*. These setae have more power of movement than one might suspect. On dropping a live specimen in a Syracuse watch-glass containing alcohol, I have seen the animal in its death struggles, throw the long plumulose setae down till they lay pressed for their whole length, save the bent area near the tip, against the flagellum. In this condition the flagellum sometimes breaks off and the hairs remain in the appressed position. Often, however, the hairs return to the normal position or are thrown far forward making anteriorly an acute angle with the flagellum.

While the animals were running about the motion of the chelicerae could not be observed but when a live specimen was placed under the microscope the movements of these appendages were extremely interesting. There was almost perpetual motion of the movable distal joint — as automatic as the avicularia of *Bugula* but much more rapid. Occasionally it would grasp one chelicera with the other very much in the manner of a person wringing his hands. There was another movement in which the two distal joints were drawn up under the mouth, and then to all appearances the comb-like hairs, projecting over the mouth from the basal joint of the chelicera, were drawn through the teeth of the claws. Up to this time I have not had the good fortune to see *Koenenia* use these appendages in obtaining food. The chelicerae like the corresponding appendages in the spiders, harvestmen, many Acarids and the *Solpugida*.

are organs for seizing, since they have not been supplemented by the pedipalps which function in this capacity for the other orders of the Arachinida. We may say that the chelicera in *Koenenia* represents the primative type of that organ as found in the *Solpugida*; for according to Pocock the definitely marked off area in the *Galeodidae* represents the rudiment of the proximal joint, which was present on the chelicerae of the ancestral form. These two distal joints in *Koenenia* are more like the corresponding appendages in *Galeodes* than in any other arachnid. In regard to the metamerism of *Koenenia* a study of the living animal leads one to claim for it a position nearer to the *Galeodidae* than to any other order of the Arachnida. Mr. Börner in his most interesting paper on *Koenenia* [1]) advances the theory that the thorax possesses three segments instead of two as was heretofore believed. He claims for the thorax the segment which carries the second pair of legs together with the segments that carry the two remaining pairs of legs. A number of times I have followed with the use of the microscope one of these little animals running along the edge of a piece of filter paper with its side turned toward me. Whenever this aspect of the living animal was presented the true segmented condition of the thorax was most evident. I succeeded in getting a sketch of one which became perfectly quiet in this position of the thorax and in the position, of which I have already spoken, where the abdomen is elevated so that its long axis is almost at right angles to the surface on which the legs rest. In this instance a full side view of the entire animal is not obtained, for the head is slightly turned so that a three quarters view of it appears. One could hardly believe from seeing the dead specimens that the living animal could assume such an appearance yet I have seen this a number of times and have called Dr. Wheeler's attention to this most convincing point in regard to the living *Koenenia*.

Not only does the thoracic region but also the head become clearer in studying the living animal. The true shape of the head of this delicate little creature is lost with the use of alcohol though the alcohol may be rather weak (not above 70 %). The beak of the thin carapace has its sides puffed out through osmotic pressure and the contraction of certain of the head muscles so that its edge presents a curve instead of an angle. The anterior sensory hairs in their natural

1) Zur äussern Morphologie von Koenenia mirabilis Grassi, in: Zool. Anz., Sept. 1901.

position are entirely covered by the beak while they lie in a line almost parallel to the long axis of the animal's body. The lateral sensory hairs arise not above but on the underside of the carapace which is more curved laterally. Their position is so very near the line of greatest projection that the tips extend from beneath so that they can be seen directly from above. Specimens first examined in this condition, when put in alcohol have a swollen appearance, so that the frontal hairs project upwards. This change is brought about by the elevation of the ventral surface of the beak, on which the organs are situated, due to a shortening and swelling of the anterior region of the head. The rounding off of the anterior head region and obliteration of the sharp line between the ventral and dorsal surface of the carapace, likewise, elevate the lateral organs till they appear above the carapace. This slight contraction was noticed in the few perfectly preserved specimens of *K. mirabilis* which Dr. Silvestri kindly sent me in exchange for specimens of *K. wheeleri*.

III. Variable and Fixed Characters.

From observations on the living *Koenenia* it is necessary to turn to the results obtained in the examination of many *Koenenia*, for information in regard to variable and fixed characters. It seemed highly probable to me that among animals of *Koenenia*'s position there would be many points of variation which might be taken for specific characters when only a few specimens were studied, as I had done in considering the various organs of *K. wheeleri*. During all my collecting as an active help, likewise in this direction, I was continually on the lookout for *K. parvula* which was the name I had given to a species, so far represented by a single specimen, the reproductive appendages and flagellum of which were described by Dr. Wheeler (p. 845).

By April 12th I had collected about seventy-five specimens, all undoubtedly belonging to the one species. Later collecting, as the above table shows, brought out variations so great in my material, variations that had been given by Hansen as specific characters, that I was at first inclined to think, on superficial examination, that I had not only one but several new species. Abundant material, with more careful examination and comparison soon proved to me that I had merely different stages of the one species, *Koenenia wheeleri*! Before describing these three developmental stages it would be best to record very briefly the specific characters of our only

Texan form, so far as known [1]), and to give the variations occurring in what have been thought to be the fixed characters of the species.

1. One of the first and most interesting characters that has hitherto been overlooked and which appears to be among the oldest phylogenetically and most permanent, since it appears in the youngest and oldest stages, is the segmental arrangement of the fixed number of setae on the cephalo-thoracic carapace. There are five rows of these, the 1st consisting of a pair just back of, to the outside of, and almost on a line with the base of the median sensory hairs. The second row, consisting of two pairs, is slightly arched and runs over the head on a line with the origin of the second pair of appendages. The third row consists of the same number and is parallel to the second row. The fourth row of three pairs of setae is parallel to the other rows and appears on a line half way between the third and fourth pairs of appendages. While the fifth row, consisting of two pairs, is parallel to the others and half way between the fourth and fifth pairs of appendages.

In connection with these fixed hairs of *K. wheeleri* it might be well to mention a peculiarity of the anterior sensory organs which seems to appear in no other species. This is a short bridge or Siamese-twin like connection between the two organs near their tip. Owing to the difficulty of seeing this connection except in most favorable specimens which have been flattened dorso-ventrally through cover-glass pressure, I cannot say of a certainity that such a condition always exists, though I am certain that these organs rarely ever become separated in the region where this bridge was seen to exist in other sensory organs. [2])

2. Another fixed feature is the very large hollow pair of setae on the outside of the third metatarsal joints of the first pair of legs. This hair has more the appearance of a large bifurcated seta with the rami glued together by a transparent jelly. The hair is flat and often slightly curled, its walls are heavily chitinized and seem to be marked with peculiar pits and minute hairs. This is

1) Shortly after this paper was sent to the publisher I received a number of specimens of a new species of a *Koenenia* which was taken in in Bonham, Texas. This species I have described in a paper, entitled A new Koenenia from Texas, which is soon to appear in the Quarterly Journal of Microscopical Science.

2) Later examination of these organs in a glycerin preparation revealed clearly one pair of these sensory organs which were not connected near the tip.

larger than any spine of *K. mirabilis* and is by far the largest seta found on *Koenenia wheeleri*. This too is found on the youngest stage of our species, though it may be easily overlooked from the fact that its flat surface is often applied close to the appendage.

3. The position of two groups of setae, which are arranged in a line diagonally across the ventral surface of the proximal joint of the chelicerae, is another characteristic of *Koenenia wheeleri* which occurs in the earliest known stage. The first and most anteriorly arranged of the two groups consists of three rather stiff, blunt setae which are delicately plumulose and project across and under the mouth. The second group consists of two larger and one very small and more pointed setae which possess for almost their entire length on their inner side a line of secondary hairs. These setae likewise project forward and diagonally under the mouth.

4. The terminal joints of the chelicerae represent a condition which to judge from the description given by Dr. Hansen of other species, must be entirely characteristic of the Texan form. This is the arrangement of the teeth on both the movable and fixed joint.[1]) After examining the largest specimens to be had in glycerine, in KOH, and then stained and mounted in balsam, I feel satisfied that the true state of affairs is revealed in the results given below. Looking down on the chelicerae from above, when they are stretched out, one sees a small row of denticles which begins near the level of the second tooth from the distal end and runs parallel with the eight large teeth, and merges into that row at its proximal termination, where on the fixed joint, the two ridges dwindle into a serration, that is continued further into the end near the spot where a seta is given off. On the movable joint this serration is absent and the two rows end with an obtuse angular projection. These denticles are not projections of the teeth but arise from a distinct ridge, which lies close against the base of the teeth. The alternating arrangement of the teeth and the denticles is quite evident and it is this that gives the zigzag appearance to the teeth when looking straight down on them.

5. In those specimens which I have examined for this purpose I have always found six hairs on either side of the labrum arising from the edge, projecting over the mouth and overlapping the

[1]) In my previous paper I had thought that the row of denticles on the movable joint were not denticles but the reflection of light from the hollowed bases of the large teeth.

labium. The outermost of these hairs, sometimes but not usually, stands off by itself while the other five arise close together in a line. These hairs are just half the length of the corresponding hairs in *Koenenia mirabilis*.

6. The arrangement of the three pairs of hairs on the ventral surface of the fourth and fifth segments of the abdomen is characteristic and unvarying in the adult of our species. These hairs are usually much longer in the males than in the females. They are likewise longer and more slender than the hairs of the ventral region of either the fourth or fifth segments of *K. mirabilis*.

7. The four lateral sense organs, first correctly described by HANSEN, are characteristic of our Texan species alone. That these four hairs appear only in the adult may perhaps account for the fact that there is a retardation sometimes and only three put in their appearance. This happened in the type specimen, which I described in my former paper. It likewise happened in one specimen which was sectioned. In this case the organ could only appear to the most doubting Thomas as three circles pressed closely together. Another specimen had four hairs on one side and three on the other. It is very difficult to count the lateral sensory organs and I have not examined as many of the adult *Koenenia* for these variations as I have for other characteristics which can be made out on specimens without the use of KOH. That there are exceptions to the usual number of hairs is evident from the three cases mentioned.

8. The reproductive appendages were naturally left for the last since the specific characters were taken up in the order in which they appear ontogenetically. Eighteen specimens of each sex were cleaned in potassium hydrate and these with many glycerine and balsam preparations, together with fresh animals, were used in a re-examination of these appendages. I had not before laid very much stress on the exact number and arrangement of the setae over the region of the appendages since they were not so important as the structure of the appendages themselves and were probably not characteristic features, but to my surprise I found not a single exception to the fixed number of the setae and their regular arrangement. With this knowledge and cognisance of the fact from my former experience that the appendages are extremely difficult to make out, especially when one has only a few specimens, I have drawn these regions with the utmost care, believing that the drawings will tell more than pages of text. In the male the appendages of

the second segment consist of two pairs of large conical papillae, each terminating in a plumulose curved seta and four pairs of small papillae. These papillae are obliquely truncated and on the slanting end, but not at the tip, is a plumulose seta. Underneath these papillae and arising from the same segment is a pair of triangular plates. A section of these plates would likewise appear triangular with the inner edge slightly concave and irregular. The appendages are armed with five pairs of plumulose setae. The large and thick pair of appendages of the third segment present a broad and extended anterior surface and a very short posterior surface. These are armed each with five setae on or near their tips while a pair of small setae arise high up at the point where the appendages merge into the body wall. The rough edges of the posterior pair of appendages of the second segment and those of the third segment appear to possess partial perforations near their margin. There is a row of ten setae which arise on the ridge of the second segment from which the papillae project; anterior to this row, there is another one of only four setae.

In the female the appendages themselves are easily understood. The second segment becomes prolonged on the ventral side posteriorly into a triangular flap. This unpaired appendage possesses six rows of hairs, the rows themselves being arranged in pairs. Both of the uppermost row of four setae run in such a way as to form the sides of an inverted V. The middle rows consist of four setae each, which converge as they run down forming a V, minus a seta for the apex. The remaining rows, of three hairs each, follow fairly closely the edge of the appendage. This makes in all for this organ eleven pairs of plumulose setae, whereas in my formed paper I figured only nine pairs, yet Dr. Hansen says "the figure of the anterior genital lobe in the female is not correct, the essential fault is that too numerous setae have been drawn". The pairs of appendages for the third segment are very much like the corresponding ones in the male. They possess, projecting from their under surface, two pairs of setae somewhat larger than the other setae belonging to these appendages. From their sides, near where the appendages merge into the body-wall, there is, just as in the male, a pair of setae, one for either side.

Just the opposite to the definite condition found in the chaetotaxy of the reproductive appendages is the condition observed on the flagellum of *Koenenia*. This organ is liable to injury and

is easily broken and consequently more easily regenerated and more liable to variation. The flagellum is a little more complicated than one might think at first sight. With longitudinal sections of distended and contracted specimens, on which to make observations, the difficulty soon disappears. Macroscopically this appendage is seen to be made up of from seven to seventeen segments according to the indivual. Out of sixty complete flagella the number of segments was as follows.

1	flagellum	had	17	joints
37	flagella	„	16	„
10	„	„	15	„
5	„	„	14	„
1	flagellum	„	13	„
1	„	„	12	„
2	flagella	„	9	„
3	„	„	7	„

Thus sixteen is seen to be the number of joints which occurs oftenest in the flagellum, if we consider the first small segment a true joint, which it undoubtedly is. The cylindrical wall of this small segment is more heavily chitinized than any of the other segments of the flagellum. There is a thickening around its entire anterior rim, which thus has the form of a ring; on the upper surface this thickening is not confined to the edge but extends slightly forward and also backward for almost the whole length of the joint. In the edge of this thickening, in the mid-dorsal line, is a sligth groove into which fits the point of a chitinized plow-share-shaped projection which extends from the roof of the last segment of the body. This furnishes a pivot by means of which the heavy muscles situated in the last segment of the body, are able to raise the flagellum. The distal edge of this segment has smoother setae, two short ones on the dorsal and two longer ones on the ventral side. It has no whorl of plumulose setae as have all the other true segments. These plumulose setae are situated about one third of the length of the segment from the distal end. The second, third, fourth, sixth, eighth and tenth segments have in addition prominent smooth setae near their posterior termination. The terminal joint usually has near its apex a second whorl of plumulose setae. That there is great variation in the size of this joint and arrangement of the setae can be seen in an examination of the following table and of the figures of plate 22. The flagella of only adult specimens are considered in the table.

No. of flagella	No. of segments	Terminal segment		
		No. with 1 whorl	No. with 2 whorls	Irregular arrangement
1	17	1	—	—
37	16	5	31	1
10	15	3	5	2
5	14	1	3	1
1	13	1	—	—
1	12	—	1	—
2	9	1	1	—
3	7	3	—	—

In a perfectly relaxed flagellum as Dr. Hansen has already shown, subjoints are seen to occur at the proximal ends of all those joints that are preceeded by a joint with smooth setae. This appearance of the subjoint is produced by a thickened ring of chitin which marks off this small area from the remaining joint. I cannot see any reason, however, for believing that there is a further division, which Dr. Hansen considers as the apical subjoint. The figure of a section through the contracted flagellum as well as the other figures of the flagellum in Plate 22 will show that in *K. wheeleri* there is no such subjoint, unless the articulating membrane be considered as such. The smooth setae, however, belong to the more thickly chitinized wall at its line of union with this thin membrane; and I have never seen, in the most contracted flagellum, that these setae appear to originate as an inner ring. In more than two hundred specimens each with a portion of a flagellum, the breaking never occured in the region between the smooth and the plumulose setae of the same segment but always below the smooth setae in the thin membrane. When the flagellum is very much contracted the thin articulating portion of the wall is doubled back into the joint, since it is attached to the subjoint, which is pulled in by small muscles arising from the sides of the main joint and inserted on it. It does not seem possible in the contraction of a flagellum that this thin membrane could stand the strain of a pull so hard as to double in the comparatively thick chitinous wall on which the smooth setae arise. The remaining joints, which have not the proximal subjoint, flare out at their proximal end after fitting into the preceeding joint, to which they are attached. This membranous portion of the wall of the preceeding segment is attached along the line following the least circumference of the succeeding joint.

It would be a waste of energy to measure any, or all of the joints

of the flagellum for characters indicative of the species since these joints vary in length and thickness as do the joints of the head and thoracic appendages though to a much greater extent. The drawings of this appendage, which are all made to the same scale, would show the uselessness of such a procedure. The second joint in one flagellum is twice as long as thick while in another it is four times as long as thick. The difference is even greater in the terminal joint. All conditions of variation in size appear among these joints.

As variable, and more so, than the size of the joints in the flagellum is the number of short setae on the sternum of the cephalothorax of *Koenenia*. Sometimes twelve and never less for the adult, sometimes thirteen, sometimes fourteen, often fifteen, and sometimes sixteen hairs were present. These setae were arranged in a posterior (sometimes very irregular) row across the sternum. Anterior to this were two rows running posteriorly and slightly diagonally to form a V.

IV. Post-embryonic Stages.

When I began collecting for this piece of work I would have been very much surprised if I had been told that the above points laid down as characteristic of the species were more important than the three pairs of lung sacs, or the group of sense organs on each side of the head. I would have been still more surprised if I had been told that I could not recognize a younger ontogenetic stages of *Koenenia* when I was on the lookout for them at all times. To be sure they would be smaller, the number of hairs usually met with in the adult would not be present, and the reproductive appendages would be poorly developed. Yet the lung sacs, the stiff hairs on the third metatarsal joint and the lateral sensory organs would be present. However, if the metatarsal seta failed, the lateral sensory hairs and the condition presented by the lung sacs of the third, fourth and fifth segments would be evidence enough. Thus with implicit faith in these abdominal appendages as a guide for the younger stages of *Koenenia*, I continued collecting.

Material obtained on April 26th revealed a very active specimen which, because of its size, lack of certain hairs, the peculiar appearance of the reproductive organs, and the stiff seta on the third metatarsal joint, which did not fail, I believed to be a younger stage of the Texan *Koenenia* — but one glance at the condition of

the ventral surface of the sixth segment revealed the fact that no lung sacs were present. With all the reverence of a collector who has only one specimen of a new species, and is uncertain of obtaining others, I put it aside after making out all I could of its external characters without thoroughly ridding its exoskeleton of all its soft contents. A few days later in one afternoon I obtained four small specimens which the microscope revealed to be our long lost *K. parvula*, flagellum and all, and without a single lung sac, while the reproductive appendages seemed to surround two apertures, instead of one. On the heels of this discovery came another specimen of the type which had only two pairs of lung sacs, and several entirely new types. These last and larger specimens appeared entirely alike except for the reproductive organs, which had some striking differences. There was something suspiciously familiar about them when I set about to make a thorough comparison of all the new specimens. As soon as KOH was used on *K. parvula* a lack of the reproductive orifice was shown, the same happened for the first new specimen I found and then it was evident, without further examination at the time, that I had three different stages in the post-embryonic development of *K. wheeleri* of which in the last stage, I knew I was so fortunate as to have both males and females. Taking these up in the order in which they appear ontogenetically I will give a description of the three stages.

1. First known Stage (*K. parvula*).

About ninety specimens were obtained from Waller Creek, and in Pease Park, the first ones being taken in the former locality May 1.

Head. The anterior sensory hairs sometimes show the connecting bridge near their apex. Only one lateral sensory organ. The number and arrangement of the setae of the carapace the same as in the adult. The mouth shows the same condition of the labrum as seen in the adult, which is not a poor imitation on a diminutive scale of the labrum of a locust. The labrum possesses on the margin of each side three slightly curved setae, which in the closed mouth overlap the labium. The peculiar furrowed appearance across the labium which appears more pronounced in the adult, seems under the highest power of the microscope, to be produced by rows of the most delicate hairs. The sternum of the cephalothorax has only three setae arranged in an inverted V.

Chelicerae. These appendages have the row of teeth and

the row of denticles on the distal joints. The number of teeth is seven; the first tooth far outstrips the others in size; especially, is this the case on the movable joint which is strongly curved. The proximal joint possesses the two groups, consisting of three stiff setae and three comb-like setae on its ventral surface in a diagonal line.

Appendages. The remaining appendages are like those of the adult save the first pair of legs. In this appendage:

1. Second tarsus has one long sensory hair arising from a sac-like base on its upper side.

2. Fourth metatarsus has a long sensory hair on the upper side.

3. Second metatarsus has two tactile hairs, one on the upper and one on the outer or posterior surface.

4. The first metatarsal joint is lacking in the two tactile hairs which that joint possesses in the adult.

5. The tibia has one tactile hair on its upper surface near its proximal attachment.

6. The third metatarsal joint has on its outer surface and near its distal limit the large flat, hollow seta.

7. Bifurcated hairs present on both tarsus and metatarsus.

8. The metatarsus of the last leg has on its posterior surface a hollow stiff hair, slightly larger than the other setae of that joint. This seta is present throughout all the stages and in the adult.

Abdomen. On the ventral surface of the fourth, fifth and sixth segments there are no lung sacs or even any traces of these appendages on the chitinous wall. On the fourth and fifth segments, six small setae are found which complete the whorl of setae of those segments. On the sixth segment there are present four setae, or from their situation, one might say two pairs of setae.

Reproductive Appendages. On the ventral surface of the second segment of a live individual or of one killed with weak alcohol there is seen a slight projection of its posterior edge. This projection shows a slight bifurcation along its median line, while on either side but further forward are two pairs of setae. The third segment, likewise possesses an appendage of this character. Each of the two appendages, however, overlaps an aperture instead of surrounding the one orifice, yet it was this that, to a great extent, made me think it was not an immature stage of *K. wheeleri* but a sexually mature form. Treatment with potassium hydrate however, revealed a most surprising fact — these orifices were not openings for the emission of the reproductive contents but through them the lung

sacs were everted! Since there was no paired opening, as might be expected these sacs were not paired, yet their tips showed a bifurcated condition, which gave each sac the appearance of a pair of sacs with one mouth.

Flagellum. This appendage consists invariably of seven joints. The second, third and fourth only possessing a whirl of smooth setae. While the first small joint has the four smooth setae, with size and arrangement relatively the same as in the adult. All but this little first joint possesses a whorl of plumulose setae, and in this respect no variation occurs in the terminal joint. In connection with the consideration of this type of flagellum, it is well to speak of the three rather interesting cases of retardation of development, which came under my notice. At different times when collecting I obtained three unusually large adult *K. wheeleri* (one male and two females), which had only seven joints to the flagellum. These flagella conformed in every way to those of the first known post-embryonic stage, except in size.

2. Second Stage.

Only two specimens of this stage of *K. wheeleri* were obtained; the first was captured April 6th, even before I had taken a single specimen of the first stage. This individual had no flagellum, while the other one taken May 8th was perfect.

Head. Labrum with four pairs of setae projecting over the mouth. There are two pairs of lateral sense organs, while the number and arrangement of the dorsal cephalo-thoracic hairs are as in the adult. There are seven cephalo-thoracic sternal setae, four of which are in a transverse row, while the remaining three are anterior to these and in the position to form a V.

Chelicerae. These first appendages have the seven teeth and the regular arrangement of the denticles. The movable joint is not as much curved as the corresponding one in the first stage and its first tooth is not so large in proportion to the other teeth.

First pair of Appendages. These appendages which according to their position, are known as the first pair of legs, function entirely as pedipalps.

1. The second tarsal joint has one long tactile hair arising on its upper surface.

2. Fourth metatarsal joint with one of these tactile hairs on the upper surface.

3. Second metatarsus with two of these hairs which arise one on the upper and one on the posterior or outer surface.

4. The first metatarsus has only one tactile organ which is situated near its distal end on the anterior surface.

5. The tibia possesses one of these tactile organs on its outer surface and about one third of its length from the distal end.

6. The third metatarsal joint bears on its outer surface, near its distal end, the large flat and hollow seta.

7. Bifurcated hairs are present on both tarsus and first, second, and fourth metatarsus. I was able to distinguish on one specimen, which was particularly favorable, four bifurcated hairs, three on the inner surface and one on the upper surface of the terminal joint of the tarsus.

8. The metatarsus of the last leg has the hollow stiff sensory seta.

Abdomen. Two pairs of lung sacs are found on the ventral surface of the fourth and fifth segments of the abdomen. Eight hairs, instead of six, are present on both segments, but on the fourth they are crowded close together in two groups of four hairs each, which act as a protection over the slits of the lung sacs. In the fifth segments there are two groups, each of three hairs, which act for protection, while to the outside and in line with these is a fourth hair. The ventral surface of the sixth segment has eight hairs but no trace of lung sacs.

Reproductive Appendages. In reality these appendages first make their appearance at this stage, since the appendages which appeared in the preceeding stage were nothing more than slight flaps over the orifice of the lung sacs. There is very little to these external organs, for the second segment, simply a pair of small flaps with a papilla-like tip. These appendages possess two setae each, at the point where they have their origin from the body wall. The third segment has just underneath and on a line with these small triangular projections of the second segment, a pair of slight papillae — so slight that in a distended specimen they disappear — each tipped with a small seta.

Flagellum. Of this appendage a description must be given from observations made on only one specimen. The flagellum has twelve joints; the second, third, fourth, sixth, eight and tenth joints have the regular whorls of smooth setae; all of the joints, save the first, have the one whorl of plumulose setae. I was rather surprised

when I found this perfect specimen after having obtained several of the later stage which did not possess so many joints in the flagellum. The explanation is, probably, that the longer appendage, which was more liable to injury, had been broken and had only partly regenerated.

3. Last Stage.

Eight specimens in all represent the number of individuals in my possession which were on the treshhold of maturity. Three of these are males and five are females. The first one of this stage was taken on April 16th. On the day I captured this specimen I was hastily examining the material which I had just brought in and was tabulating it when I ran upon one individual smaller than the others, which sported a most curious flagellum. This appendage was made up of ten joints and the ninth presented a condition I have never seen before nor since, for it appeared made up of two fused segments. This was evidently merely an anomaly and represented nothing of importance. When I finished examination of this curious organ I turned to the body to which it belonged and found I was unable to obtain a clear view of the region of the second and third abdominal segments so I put it aside for later and more minute examination, assigning it in the table to the undetermined column. Later it proved to be an immature female of the last stage.

Cephalothorax. The labrum has five pairs of short curved setae. This is the number characteristic of *K. mirabilis*. Three pairs of lateral sense organs are present. In one individual there was an exception, for the right side had three of these sensory organs while the left bore only two. The arrangement of the dorsal cephalothoracic hair is normal. The sternal cephalothoracic setae are arranged in a transverse row of six (sometimes five), which is usually irregular near the mid ventral line, and two anterior rows, which are arranged to form a V with the seta of the apex sometimes merging into the transverse row at its region of irregularity. Five of the individuals of this stage of development had eleven setae, two had ten, and one had only nine.

The chelicerae, like those of the adult, possess eight teeth, and eight fairly good sized denticles, which on the fixed joint terminate in serrations.

The Appendages. Since all of the appendages outside of

the chelicerae[1] have been described so minutely by Dr. Hansen and since they do not possess points, apart from those dwelt on already, characteristic of the species, unless it be in the relative proportions of the joints (which I doubt), I did not give any space to them in enumerating the characters of the adult *K. wheeleri*. Every thing said about the appendages in the last stage represents the exact condition found in the adult.

First pair of Legs.

1. The second tarsal joint has one tactile hair on its upper surface and slightly posterior.

2. The fourth metatarsus joint likewise is in possession of one of these organs on its posterior surface.

3. The second metatarsus holds two of these organs on the the posterior surface. one being a little more ventrally situated than its fellow.

4. The first metatarsus advances one step beyond stage two and two steps beyond the first stage and carries two of these long tactile hairs on its upper surface.

5. The tibia has one tactile hair in its usual place.

6. The outer surface of the third metatarsus has the large hollow seta near its distal end.

7. Bifurcated hairs are present on the metatarsus and tarsus.

8. The metatarsus of the last leg has the stiff hollow seta.

Abdomen. The lung sacs are present on the fourth, fifth and sixth segments. Over the appertures of these sacs three plumulose setae (a portion of the segmental whorl) project. The third and fourth segments which in the adult possess three pairs of long setae, situated between the lung sacs, at this stage have only a single pair. The sixth segment presents the same appearance as is seen in the adult except there seems not to be as much of a grouping of the four pairs of setae in the region anterior to the lung sacs.

Reproductive Appendages. In the male the prolonged ventral projection of the second segment has become split at the tip dorso-ventrally and then divided symmetrically into a right and left portion. This gives the appearance at this stage of two pairs

1) I believe that Dr. Hansen who was the first to point out the two kinds of teeth on the fixed proximal joint of the chelicera is entirely mistaken as to the origin of the smaller teeth. These denticles are not branches of the teeth as he has figured them but arise from a distinct outer ridge.

of appendages. The anterior and broader pair has an irregular inner edge and is armed with three pairs of plumulose setae. It is this region with its irregularities which gives rise to the papillary appendages, while the short triangular and distinctly paired projections, with their two pairs of setae, form the long triangular pair of appendages. An inverted-shaped row of six setae extends over the breadth of the anterior appendage — about the line of its union with the body-wall. The appendages of the third segment at this stage are slight elevations that remind one of diminutive oyster shells or highly magnified grains of potato starch. At their outer limit each one possesses a seta.

The female appendages are much simpler and are surprisingly like the corresponding appendage of *K. mirabilis*. The ventral portion of the second segment is prolonged posteriorly and grooved in the mid-ventral line, giving a slightly paired condition to this organ. Two pairs of short stout setae, rather characteristic of *K. mirabilis*, are found on its posterior edge in the region of the groove. Higher up a pair of setae arise while still further anteriorly along the curved line between the appendage posteriorly and the body-wall anteriorly runs a curved row of six setae corresponding in number and position to those of the male appendage. The pair of appendages of the third segment is exactly like the corresponding pair in the male, even to the number and position of the setae.

Flagellum. Out of the collection of eight specimens, representing this last stage, four had perfect flagella, while one had ten joints of its flagellum which showed that it had been broken at the distal end of the tenth joint. These flagella represent the most varied condition in the number of joints and arrangement of setae of the joint. Because of the variation it seems best to give a hurried description of each flagellum of the specimens in the order in which they were taken.

1. Female. Flagellum 10 jointed, terminal joint with one whorl of setae; the ninth segment presented an anomolous condition of two fused joints each of which was equipped with a whorl of plumulose setae.

2. Male. Flagellum 9 jointed, terminal joint with two whorls. Seventh segment with a whorl of smooth setae besides the belt of plumulose ones.

3. Male. Flagellum, though broken between the tenth and eleventh segment, with normal arrangement of setae.

4. Male. Flagellum 9 jointed, terminal joint with one whorl, eighth segment without the whorl and with just two of the smooth setae on the upper surface, while the seventh segment had this whorl.

5. Female. Flagellum 12 jointed, terminal joint with the two whorls of plumulose setae and the other joints in every respect normal.

From this it is seen that very little definite information can be had in regard to this appendage of the last stage, until more material has been obtained. It has seemed probable that this caudal appendage would have nearly reached its limit in the number of joints for this stage just preceeding the adult, since in most respects the animal is in the condition of the adult.[1])

V. Conclusion.

In completing this piece of work on *Koenenia wheeleri* I would express my disappointment in failing to gain more information on its life history. This could not be done, because of the great gaps in periods of collecting which were due to lack of rains. Nothing can be done on the embryology until something further is known of their habits or until a suitable nest provided with proper food can be devised for keeping the animals indefinitely where they can live and breed as if unconfined. I believe, however, that a little information has been obtained in regard to the habits and especially in regard to the post-embryonic development of this interesting Arachnid of the order Microthelyphonida. This information, viewed in the light of the biogenetic law, will enable us to say which of the species of *Koenenia* has gone farthest in its development. From a study of the reproductive appendages it was seen that the female of *K. wheeleri* passed through a stage in which the adult female of *K. mirabilis* remains throughout life. From this fact we might perhaps expect the appendages of the still unknown male of *K. mirabilis* to be like those of the last stage in the male of *K. wheeleri*. It is with great interest I await the finding of this sex of the European species.

1) After this paper was sent to the publisher I obtained more material in further collecting, which furnished definite information in regard to the flagellum. On Aug. 5th, I took eight specimens of the last stage, three of which possessed perfect flagella. The flagellum in all three cases was made up of fourteen joints; the last or terminal joint was furnished with two whorls of plumulose setae.

K. wheeleri likewise possesses the greatest number of lateral sense organs. It is the appearance of the abdominal sacs in *K. wheeleri* and *K. chilensis* that is difficult of explanation. Why these organs should seem to be so absolutely essential in two species of a family when they do not even appear in the others is somewhat singular to say the least. That they are so essential to *K. wheeleri*, I take it, is shown from the fact that in the very small specimens of *K. parvula* they appear in the place of the reproductive appendages but function in their own capacity. When they are crowded out from these two segments they appear on the fourth and fifth segments and as the animal grows larger, to maturity, these appendages appear likewise on the sixth segment. If such organs are respiratory in function why should they not appear in all the other species, which live under the same conditions?

In conclusion I wish to thank Dr. Wheeler, under whose direction I was given courage to continue my work, for the aid so freely and untiringly given me, and for a collection of *Solpugida* made in the Trans-Pecos region. To my friend and co-worker, Miss Holliday, and to my friends, the Misses Rhine, I am greatly indebted for much of my material which was taken at a time when it was anything but pleasant to collect in Central Texas.

Austin, July 3, 1902.

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Description of Plate.

Plate 21.

Fig. 1. Ventral surface of the first known stage (*K. parvula*) of *K. wheeleri*. Camera drawing with No. 8 ocular and 3 objective, reduced one half. The three sternal cephalothoracic hairs are shown in their normal position. The abdomen shows the bifurcated lung-sacs, on segments two and three, thrown out on treatment with KOH.

Fig. 2. Ventral surface of the abdomen of the second known stage of *K. wheeleri*. Drawn on the same scale and with same reduction as Fig. 1. The lung-sacs are absent on segments two and three, which now possess very rudimentary reproductive appendages. Segments four and five at this stage possess the paired lung-sacs over each of which project three setae.

Fig. 3. Ventral surface of the abdomen of the third and last stage in the development of the male of *K. wheeleri* before the adult is reached. Drawing on the same scale and with the same reduction as Fig. 1 and Fig. 2. The lung-sacs now appear on all three of the abdominal segments as is the condition in the adult. Only one pair of the long hairs is present on the ventral surface between the lung-sacs of segments four and five. Segments two and three show prominent reproductive appendages with a great increase in the number of setae.

Fig. 4. Ventral surface of the abdomen of the third and last stage in the development of the female of *K. wheeleri* before the adult is reached. Drawn on the same scale and with the same reduction as the preceeding figures. The abdomen presents the same appearance, beyond the second segment as in Fig. 3 except that the ventral hairs between the lung-sacs are shorter. The reproductive appendages of segments three are quite similar, while segment two in this figure shows an appendage much like the female of *K. wheeleri*. Fig. 4 was not as much flattened through pressure as Fig. 3, which gives it a narrower appearance.

Fig. 5. Ventral surface of the abdomen of the adult female of *K. wheeleri*; drawn to the same scale and with the same reduction as the four preceeding figures. In all five drawing the transverse anal slit is shown on the ventral surface of the last segment of the abdomen.

Fig. 6. Side view of the appendages of the second and third abdominal segments of the first stage (*K. parvula*) (8 oc., 7 obj. 1/2 reduction). The appendages show a slightly swollen condition due to alcohol.

Fig. 7. Lateral sensory organ of the same stage (to the same scale).

Fig. 8. Frontal sensory organ of the same stage from an alcoholic glycerine preparations (to the same scale).

Fig. 9. Frontal sensory organs of the same stage from a specimen cleaned in KOH (to the same scale).

Fig. 10. Side view (8 oc., 7 obj., 1/2 reduction) of segments two, three and four of the second stage of the post-embryonic development of *K. wheeleri*.

Fig. 11. Cephalo-sternal hairs of same stage (same scale).

Fig. 12. Frontal sensory organs of *K. mirabilis* (8 oc., 7 obj., 1/2 reduction). Projecting from the tip of each organ was seen a delicate hair.

Fig. 13. Third left metatarsal joint seen from above (8 oc., 7 obj., 1/2 reduction) and showing the large flat hollow seta, which has a base not unlike that of the frontal sensory organs.

Fig. 14. Ventral view of appendages of second and third abdominal segments of the first stage (*K. parvula*) (1 oc., 7 obj., 1/2 reduction).

Fig. 15. Cephalothoracic sternal hairs of stage 3 (8 oc., 7 obj., 1/2 reduction).

Fig. 16. Reproductive appendages of the last stage before maturity of the male of *K. wheeleri* (1 oc., 7 obj., 1/2 reduction).

Fig. 17. Side view of reproductive appendages of adult male (1 oc., 7 obj., 1/2 reduction).

Fig. 18. Front view (a little to the right of the front) of the same appendages (1 oc., 7 obj., 1/2 reduction).

Fig. 19. a) Front view of the first appendage of the second segment of the same. b) Front view (appendages slightly rolled to the left) of the second appendage of the second segment which is paired. c) Front view of the appendages of the third segment of the male of *K. wheeleri*.

Fig. 20. Front view of reproductive appendages of the second and third abdominal segments of the last stage of the female (1 oc., 7 obj., 1/2 reduction).

Fig. 21. Front view of female appendages in the adult (to same scale).

Fig. 22. Side view of the same.

Fig. 23. Front view of the female appendages of *K. mirabilis* which have been flattened through pressure (1 oc., 7 obj., 1/2 reduction).

Figs. 24 and 25. Frontal and lateral sensory organs of third stage. KOH preparation (8 oc., 7 obj., 1/2 reduction).

Plate 22.

Fig. 26. Extended flagellum, balsam preparation, of an adult male *K. wheeleri* (1 oc., 7 obj., 1/2 reduction). Segments 1—10 inclusive are normal. The smooth setae are only drawn in one plane, except in the second segment. This flagellum lacks the regular joints 11, 12, and 13, which are like joints 5, 7, and 9, though somewhat narrower in the perfectly normal appendage.

Fig. 27. Flagellum of female *K. wheeleri* of the last stage (1 oc., 7 obj., 1/2 reduction). Cleaned with KOH. An air bubble was in flagellum and when cover glass was accidently dropped on it, the breaking took place as is shown in the figure. a) The articulating membrane which doubles in on contraction; b) the cuff that fits over the following subjoint; c) Seg. 7 is abnormal in that it has smooth setae, while seg. 8 is abnormal in that it has only two smooth setae.

Fig. 28. Flagellum of youngest known stage of *K. wheeleri*. The first joint is not shown as is the case also in Fig. 27.

Fig. 29. Last three joints of flagellum showing the usual termination (1 oc., 3 obj., 1/2 reduction).

Fig. 30. Terminal joints sometimes seen on a flagellum that has sixteen joints, which this one has (1 oc., 7 obj., 1/2 reduction).

Fig. 31. Terminal joint showing great size and irregular arrangement of setae (1 oc., 7 obj., 1/2 reduction).

Figs. 32, 33 and 34. Cephalothoracic sternal hairs present on different individuals of both sex.

Fig. 35. Section through terminal portion of the fourth joint and all of the fifth of a contracted flagellum. The camera was used as is the case in all the drawings and the utmost care taken with the aid of 8 ocular and 7 objective, to show the relative thickness of chitin and the manner of union of the joints (reduced 1/2).

Fig. 36. Section through joints 7 and 8 of a completely relaxed flagellum (8 oc., 7 obj., 1/2 reduction).

Fig. 37. The three proximal joints of a greatly contracted specimen (1 oc., 7 obj.).

Fig. 38. Posterior end of the abdomen showing the anus and the three proximal joints of the uplifted flagellum (1 oc., 7 obj., 1/2 reduction).

Fig. 39. Side view of last abdominal segment and first joint of flagellum. Through the chitinous walls of the two segments can be seen the plow-share-shaped thickening of the abdominal segment and the

ring-like thickening on the anterior rim of the first segment of the flagellum (8 oc., 7 obj., 1/2 reduction).

Fig. 40. Dorsal view of the same showing the dorsal transverse thickening from which the pointed piece of last the abdominal segment projects.

Fig. 41. Third metatarsal joint of the first stage, the chitinous wall of which being thin permits a clear view of the cnidoblast-like affair, from which the long tacticle hair projects.

Plate 23.

Fig. 42. Side view of cephalothorax to show segmentation and arrangement of its setae as well as the setae on the proximal joint of the appendages (1 oc., 7 obj., 1/2 reduction). Alcoholic specimen.

Fig. 43. Sketch of a live male *Koenenia* to show segmentation of the animal and the peculiar position often taken in which the abdomen is lifted almost at right angles to the cephalothorax (8 oc., 3 obj., 1/2 reduction).

Fig. 44. Mouth and a portion of the proximal joint of the left chelicera of the youngest known stage of *K. wheeleri* (8 oc., 7 obj., 1/2 reduction).

Fig. 45. Mouth of the stage just before maturity with the same magnification as Fig. 44.

Fig. 46. Distal joints of the chelicerae of the last stage before maturity. The same condition of these two joints holds for the adult (8 oc., 3 obj., 1/2 reduction).

Fig. 47. Dorsal view of a living and contracted specimen of adult *K. wheeleri* (8 oc., 3 obj., 1/2 reduction). Segmentation of the cephalothorax is quite pronounced.

Fig. 48. Dorsal view of a living and contracted specimen of the adult *K. wheeleri* (8 oc., 3 obj., 1/2 reduction). The segmentation of the thorax is here quite pronounced.

Fig. 49. Three quarters view of a living adult *Koenenia*. In this is seen the glandular portion of the intestine or the mid-gut area, which showed perfectly in this clear specimen (8 oc., 3 obj., 1/2 reduction).

Fig. 50. The abdomen sketched from a living animal in which the ovaries were well developed and quite pronounced.

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