PARASITIC MITES ON MOSQUITOES.

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While making a collection of mosquitoes indigenous to the northern part of Nyasaland, I was struck by the frequency with which certain species appeared to be covered with minute red globules which on examination with a hand lens appeared to be eggs. Under the microscope, however, it was noticed that what had appeared an oval-shaped egg was in reality a small arthropod, resembling in general outline a minute tick. On gently detaching some of these with the point of a pin and examining with a low power, a feeble-moving six-legged creature was seen, laboriously crawling across the slide.

Dr. Balfour's article in the February number of the Journal of the Royal Army Medical Corps arriving at this opportune moment, I was spurred to take a greater interest in these small arthropods.

Finding that it was extremely difficult to make permanent preparations showing the essential details of structure, owing to their minute size and their habit of retracting the legs and mouth parts when dying, it appeared to be of more value to make accurate detailed drawings from the living insect and to study their life history with a view to throwing some light on their genus and species, as from Dr. Balfour's article I gathered that there must be a considerable variety of species of this type of mite which attacks mosquitoes. This must be my apology for writing an article on a subject I am so little qualified to investigate.

The following species of mosquitoes were found in this district:—

Anopheles costalis.
Anopheles (myzomyia) nili.
Anopheles (myzorhynchus) paludis.
Anopheles funestus.
Anopheles pharoensis.
Mansonia uniformis, var. africana.
Culex fatigans.
Culex tipuliformis.
Culex bitamiorhynchus.
Culex tigripes.
Culex decens.
Stegomyia fasciata.

They were chiefly collected in the houses of the Europeans stationed here and in my native hospital. The native huts were found to be of little use for collecting purposes owing to the smouldering wood fire kept con-
stantly burning, which creates an atmosphere intolerable to the European, and must make these huts completely mosquito proof.

Of the above list, *M. uniformis* is by far and away the commonest species, both indoors and out, being a ferocious feeder at all times of the day and night. Next in order of frequency comes *A. paludis*, which after sun-down is in almost as large numbers as the *Mansonia*. *A. costalis*, *C. fatigans*, *A. nili*, and *A. funestus* are frequently found, the rest being but occasional visitors. Many hundreds were collected alive and a systematic search for these little parasites was made, and the following approximate figures were obtained:

1. During the latter part of the rainy season, March, April and May:
   - *M. uniformis*, fifty per cent females, no males infected.
   - *A. paludis*, forty-five per cent females, no males infected.
   - *A. pharoensis*, ten per cent females, no males infected.
   - *C. fatigans*, one female only found infected with a single mite.

2. During the cold weather, June, July and August:
   - *M. uniformis*, five per cent females, no males infected.
   - *A. paludis*, two per cent females, no males infected.
   - The other species prevalent here were never found to be infected.

With reference to the apparent immunity of the males, it should be mentioned that the number of males examined was only a fractional part of the whole number, but in no case was a male found to carry one of the insects. Experimentally it was found impossible to persuade a mite detached from a female mosquito to take a permanent hold of a male *Mansonia*. This, however, was an experiment of little value, as it was found that they were loath to take a definite hold after once being detached, although it occasionally happened.

Much confusion was experienced until it was discovered that there were at least two very closely allied species present, and that they could be differentiated in their larval stage, when present on the body of the mosquito, by their size, colour, and often by their position on their host, as there were no structural differences present until development had taken place after removal from the mosquito. Both species presented much variability in size, but one, called for convenience, "the small brown species" was found never to exceed 350 microns in length of body, and was a deep red brown colour, while the other called "the large red species," was often found as large as 550 microns and in colour was a bright vermilion red. The former was always found attached to the thorax of the mosquito, most frequently between the coxa, but often just under the junction of the wing with the body, close to the second thoracic spiracle. This type of mite was never found attached to the abdomen. The latter or "large red species," which in an heavily infected mosquito always formed the higher percentage, was more frequently found attached to the abdomen, although the thorax was by no means immune to attack. In a typical heavily loaded mosquito a group of three or four small brown mites
would be found on the thorax, and ten to twelve large red mites attached to the lateral and ventral walls of the abdomen in rows. As many as seventeen of these little parasites of mixed species have been found attached to a single mosquito, while on the other hand it was not uncommon to find but a single passenger. The average ranged about six to eight per infected mosquito. Although very large numbers were examined, as mentioned above, the details of structure other than size and colour, appeared identical in the stage of development present while living on the mosquito, and therefore the following description will apply to both.

*In situ*, they appeared as egg-shaped bodies, either dark brown or bright red in colour, with deeply pigmented purple eyes and conspicuous mouth parts. In side view they had rather a grotesque appearance, owing to their snout-like rostra and stumpy legs. They were firmly
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anchored to their host by the attachment of their tarsal claws to the adjacent bristles, and by their claw-like pedipalpi to the surface of the mosquito's body. Careful examination of fortunate specimens showed that the tissues of the mosquito's body were pulled up towards the parasite by the action of the pedipalpi (fig. 1). Various attempts to kill and clear a specimen without the mite leaving its host were eventually successful, and one specimen was obtained which showed the hypostome driven a short way into the tissues of the body.

Removed from the host and examined with a higher power the following additional details could be made out.

The pigment of the body was not evenly distributed all over, being made up of numerous and varying sized globules which had an oily appearance when the body was crushed and were not soluble in xylol. These globules were also present in the legs. The eyes, four in number,
were composed of a large anterior pair, and just behind a smaller posterior pair. Both pairs were deeply pigmented with a deep purple finely granular pigment. On removal of this pigment the eyes appeared as simple ocelli, with clear shining lenses (fig. 2). The mouth parts consisted of three jointed pedipalpi armed at the tip with a formidable claw, and the last two segments being also armed with stout bristles (fig. 3). The two very long whip-like bristles as shown in figs. 2, 3 and 5 were very constant in position and size. Some of the other bristles appeared rather variable. The remainder of the mouth parts, which were extremely difficult to make out, appeared to consist of chelicerae armed at the tip with a fine hook and a bifid, finely pointed hypostome, which could be extruded or retracted at will, covered dorsally with a sheath split at its distal end.

The six-jointed legs ended in a trifurcate claw (fig. 4), of which the centre one was shorter and stouter than the lateral two and was frequently retracted back into the depression in the last segment, which caused it to be missed for some time. The bristles on the legs were rather variable in position and number with the exception of the long whip-like hairs on the second and third legs.

The body when cleared of pigment showed a clear shining chitinous surface seen well at the periphery, with a definite arrangement of short dorsal bristles, and two long posterior bristles, which latter were very conspicuous in all specimens. The ventral surface showed three pairs of shields, and the anal opening lying posterior in the medio-ventral line (fig. 5).

From their structure it was obvious that this was the larval stage, and experiments were performed to try and find out their further life history.

After careful removal from the mosquito some were placed on dry earth, others on moist earth, and again some on stalks of grass. All these died within a few hours, but if dropped off into water, it was found that they
remained floating on the surface, apparently lifeless, for a period of three to eight days, when moulting would take place and an eight-legged actively moving adult emerge, swimming about the bottom of the glass dish with great rapidity and vigour.

During the early months of the year a very small percentage gained the adult stage. On the other hand during the dry months of June, July and August, not only did a much higher percentage of mites, detached from the mosquito and placed in water, proceed rapidly to develop, often as many as a hundred per cent, but in addition they readily detached themselves from the body of their host as soon as it was dead. This had never happened in the earlier part of the year, forcible separation being necessary, otherwise the mite was enveloped in the general decomposition of its host. As the months proceeded this latter trait became more and more evident, the mites detaching themselves from the mosquito, within a few minutes of its death, and showing quite considerable pedestrian powers, travelling...
rapidly over a sheet of paper nine inches wide. If, however, they were not put in water within a short time, they shrivelled up and died. These small swimmers, when first developed, retained their larval distinctions of colour for about twenty-four hours, and then a distinct alteration in colour and appearance took place.

The "small brown" larvae developed into two distinct types, one dark reddish in colour with a body measurement of 350 microns, the other slowly developing into a light lemon yellow species with a similar body measurement. Barring the very marked difference in colour, no distinction in structure could be made out between these two and they will therefore be
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described together. The "large red" larvae developed into adults with a body measurement of 550 microns, and were a reddish brown colour, with marked structural differences as compared to the other two species. All three types after development had proceeded for a few days, lost the globular pigment from all the appendages, these latter becoming a translucent green colour, no pigment being visible microscopically.

Microscopic examination of these adult mites while still alive presented the following details and differences:—

(1) Small brown and yellow species (figs. 6, 7 and 8).

The pedipalpi had increased markedly in size and had become five-
jointed. The tip was still armed with a formidable claw, opposed by a stout bristle situated on a papilla at the root of the claw (fig. 8). Of the two whip-like bristles, the one on the second segment had disappeared, and the other had become much attenuated. The chelicerae were still present as fine hooks, while the hypostome appeared to consist of two symmetrical lancet-shaped blades, which could be extruded to a considerable distance, but were usually kept retracted and out of sight. All the legs, including the post-pair, now consisted of seven segments, all armed with trifurcate claws. The solitary whip-like hairs present on the second and third pair of legs in the larval stage had disappeared and were replaced by groups of swimming hairs on the fifth and sixth segments of the third and fourth pairs of legs. The number of these hairs did not seem to be sufficiently constant for classification purposes (fig. 7).

The bodies of these fully developed mites lose much of their egg-shaped appearance in side-view, being very much flatter and in shape can be likened to a non-engorged tick. The four deeply purple pigmented ocelli remain and could be seen to be slightly pedunculated, having a small but definite range of movement, but the scutum had become involved in the general chitinous surface of the dorsum, which in the lateral view had a definite sharply defined edge. The arrangement of the bristles is shown in fig. 7, the two conspicuous post-bristles being evident. Close to each bristle and partially connected to it, there is a circular pit, the function of this not being evident unless it is respiratory. The chief differences of the ventral surface are the arrangement of the ventral plates and the appearance of the genital pore. In addition there is a bilobed plate which appeared to be covered with multiple small perforations (fig. 6). No stigmata could be seen unless the peculiar pits found adjacent to each bristle are to be looked upon as multiple stigmata.

As stated above, these details of structure apply equally to both the small brown and small yellow species, the difference in colour being the
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only distinguishing mark, and after clearing in xylol differentiation being impossible.

(2) Large brown species (figs. 9, 10, 11 and 12).

This on account of its greater size was much more satisfactory to study. The massive pedipalpi were found to be composed of five segments, the first two segments being very short, the major portion being composed of the last three. The terminal hook was found to have been replaced by a triple claw as shown in fig. 9. The hypostome was easily demonstrable, and was seen to be composed of two stout straight Lancets, saw-edged on their median surfaces, the chelicere being tipped by small hooks (fig. 10).

The seven segmented legs differed from the preceding species in having double compound claws on the first three pairs of legs (fig. 11) and no terminal claws at all on the fourth pair, this latter ending in a pointed tarsus, adorned with some short swimming hairs, and on the median side with six stout, constantly present, bristles (fig. 12). In addition, the sixth segments of the third and fourth pairs of legs in this species have conspicuous attachments shown in fig. 12, which gives the appearance of very stout blunt bristles, slightly feathered.

The dorsal surface of the body (not figured), has nothing of note, and bears a general resemblance to the dorsal surface of the smaller species already described. The ventral surface shows a slightly different arrangement of plates, the bilobed? perforated plate being replaced by a very distinctive plate containing some? perforations and four disc-like structures, which in spite of their comparative large size did not yield any details when examined under a high power (fig. 10). The two post-bristles were still well marked and both dorsal and ventral bristles were found to have the peculiar little pits adjacent to them as described above.

What the future of these small water mites might be became rather a problem. A variety of fresh water animalcule was added to the dish which contained a large number of adult mites. These mites, although quick swimmers, are not capable of competing with the ordinary hydrachnidæ, which are so common in the stagnant pools, and in time they fell a prey

Fig. 9.
to some of the bigger types of predaceous water arthropods. They ignored slow moving organisms, but on adding the hairy larva of a species of dermestes to the Petri dish in which they lived, they attacked this with great ferocity, working their way between the hairs until every mite had disappeared from view. On another occasion I added a piece of the skin of the small black bat, to which I left a portion of flesh attached. This
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too appeared very attractive, but the hair side only was attacked, the mites again getting completely out of sight. The hairy object appeared to attract in virtue of its value as food, and not as a protective, as a small loosely twisted ball of grass, which would appear to supply good and attractive natural cover, was ignored.

As it seemed probable that, with such ferocious mouth parts and well-armed tarsi, living and not dead animal matter must be their natural prey, and as the hairy surface of the maggot and bat attracted so readily, it was deemed possible that they might ascend the legs of cattle or wild game and complete their existence on vertebrates. This, however, was disproved. Two or three mites were carefully removed from the dish in which they had undergone development, and put with some small drops of water on my arm. They continued to swim about actively in the drop of water, but

made no attempt to attach themselves either to the skin or to the hairs of my arm. As soon as the water had evaporated, however, they shrivelled up and died, and did not recover when replaced in water. Apparently they are not able to survive even for a few minutes out of water in their adult stage of existence. Up to date I have kept these mites alive for sixty-five days, without adding any food to the dish in which they originally developed, but allowing the water to go stagnant and adding a few pieces of grass to increase the development of small water organisms.

Copulation has never been noticed to take place between any of these species, but owing to periods of absence while travelling the district, accurate observation has not been possible. It appears probable, however, that these little parasites get attached to the mosquito, either when it is hatching out, or resting on the surface of the water, very early in their career, as some minute ones were found early in the season. I have never found a mosquito larva or pupa parasitized, but as the larva and pupa of
the *Mansonia* do not rise to the surface of the water this may account for
the heavy infestation of this particular species. I have searched the pools
carefully, and have never been able to detect in the sediment obtained
therefrom anything that bore any resemblance to the mite in question.
This would, however, be very difficult to do, if, as I believe, they get
attached to their host shortly after hatching, and while microscopic in size.
That they grow and develop on the mosquito can be proved by the fact that
very small ones knocked off fail to develop out in water, and that they are
definitely larger as the season advances. The mosquitoes caught locally
in the months of July and August must have hatched out during the rainy
season, as the breeding grounds are too far away during the dry weather to
supply new arrivals. Also the fact that the larger the larvae the higher the
percentage that will develop out when removed from the host, is confirm-
ation of this point.

No blood corpuscles were ever found in crushed specimens, and it seems
doubtful if their mouth parts are long enough to pierce to the mosquito's
stomach. I am inclined to think that they feed on the body fluids of the
mosquito.

Whether they do much damage to their host it is difficult to say. The
latter's powers of flight seem to be unimpaired, but the drop in the percentage
of infected mosquitoes as the season advances is suggestive. The mos-
quitoes in this district though not so plentiful as during the latter parts of
the rains, are prevalent during all months of the year, and no great less-
ing in numbers is noticed until the bush fires take place in September and
October. Infected mosquitoes kept in captivity did not survive many days,
but the method of keeping them was admittedly not ideal, and too much
weight must not be placed on this point.

It would appear that the mites, when fully developed larvae, detach
themselves when the mosquito returns to water and there develop into
the aquatic adult. Here they apparently feed on some water animal or
organism that is most probably covered with hair and remains constantly
submerged. The rest of their life history is at the moment a matter of
conjecture, but the water in which many of these mites have lived for some
considerable time is being kept in as near an approach to the natural
conditions as possible, and at the beginning of the rains in December next, it
is proposed to add mosquito larvae to it when it is thought it may be
possible to demonstrate the earlier stage of the life history if my suppositions
are correct.

With reference to the quotations in Dr. Balfour's interesting article
(Major Boyd's previously published article is unfortunately not to hand),
I do not think that the colour of the mites is due to blood ingested at
second hand, otherwise some pale ones would have been found, and what
is of still more importance, the adults retain the colour, either intact or
with alterations specific in character. It appears certain that the green
ones seen by Dr. Balfour in the Sudan, and by other observers in other
parts of the world, must be of a different species. The various biting flies which distinguish this country by their presence, and vary from *Tabanus biguttatus* to Simuliidæ, were examined for parasitic mites. Specimens of *Stomoxys niger* were the only ones to harbour mites visible to the naked eye. These however were entirely different and, as shown in fig. 13, were the larval stage of feathered mites.

Fig. 13.

Many ways of mounting these delicate specimens were tried, but the most successful method both for the larvae and adults was found to be as follows: The living insect is placed gently on a glass slide and covered with a small drop of water. A cover slip is gently let down, the drop of water easing the pressure and allowing the appendages to be extended. The slide is left for twenty-four hours when it will be found that the mite has died with extended legs as the water has dried. If the cover slip is
gently raised with the point of a pin the mite will be found adhering to the glass slide. Xylol can now be added and the specimen watched under the microscope until completely cleared and then mounted in Canada balsam. Absolute alcohol is not necessary if the specimen is left to dry for twenty-four hours as described above. Balsam mounted specimens, however, do not show the swimming hairs or finer bristles well, and for these the living specimens placed in glycerine to retard their movements are required.

The classification of these parasites is difficult. The larval stage has a very strong resemblance to the larvae of Trombidiidae.

Max Braun (translated by Sambon) gives as a definition of the Trombidiidae, "soft-skinned acarina with tracheae, and with two eyes usually pedunculated: they are often brightly coloured; chelicerae lance or claw-shaped; pedipalpi claw-like; legs composed of six or seven segments, with sctorial discs between the terminal ungues. Larvae six-legged."

With the exception that they have a third claw in place of an empodium, the Nyasaland mites agree with this definition, while the adults appear to resemble more closely hydrachnids.

I have a considerable number of specimens mounted permanently, and shall be pleased to send a selection to anyone who is interested in the subject and would care to have them.

I am indebted to the Principal Medical Officer, Nyasaland Protectorate, for permission to publish this paper.

[We are indebted to Dr. Andrew Balfour for the following observations on this paper.—Ed.]

"Captain Dye is to be congratulated on the careful observations he has made upon the mites infesting mosquitoes in Nyasaland. He has, to some extent, extended our knowledge regarding these arthropods, and his drawings appear to be the best illustrations of them which have hitherto appeared in medical literature.

"It may be noted that while the French author Dyé found, as Captain Dye has found, that only female mosquitoes were infested, the Sergents in Algeria observed mites upon male anophelines. Prior to Captain Dye's description, the fullest account of these small water mites was that by Dyé, whose work I mentioned in the paper to which Captain Dye refers. I there stated that Dyé divided them into three types, but that it was unnecessary to quote the details given in his paper. In the light of Captain Dye's observations, however, it may perhaps be well to append the following translation of a small portion of Dyé's paper. This has been kindly extracted for me by Lieutenant-Colonel Stammers, and its perusal would seem to show that the Madagascar mites of the first and second type, described by Dyé, are probably the same species as those to which Captain Dye has directed attention. It is true there are a few small discrepancies, but in the main the accounts agree, although Captain Dye's is much the more elaborate:—"
'First type. Top view globular in appearance—av. 335 μ long and 330 μ broad; small head, broadened transversely, apparently articulated and capable of movement; 4 eyes, 2 large ones lateral and 2 small ones submedian. Palps large with several (3 or 4) articulations, termination hook-like; on one of the joints is a long transversely placed hair. Buccal orifice apparently formed for suction; mandibles very short and hidden in the buccal orifice with two inferior lips disposed flat on the buccal orifice, which appears to open at the lower part. The 6 epimeres of the 3 pairs of legs distinct, the 2 first small and equal in size, the posterior pair larger. The free legs with five joints, some long hairs on the joints and short spines massive and squat; no swimming hairs. A claw, strong and recurved for each pair of legs with small accessory claws. No visible spiracles, no thickening on the dorsal surface. Colour clear. Interior of body indistinct. No trace of genital apparatus.

Seen from the side and attached to the mosquito the larva has a less globular appearance, being elongated in the longitudinal direction and measuring 358 μ long and 212 μ across. It appears to hold on to the body of the mosquito by its rostrum. This is firmly fixed in the tissues of the insect, which often tears itself in its endeavour to be rid of the parasites. In this position, at least when preserved in alcohol, the mite has its legs held against its body; they do not appear to come into connection with the body of the mosquito.

'Second type. Approaches very closely the former, but is less globular in form, the head is less enlarged transversely and is without the two long hairs. It seems to have a covering which may well be no more than the cast skin (moulr) of the transition stage from larva to nymph. This type shows almost constantly a blackish mass in its interior, which may be taken for a first essay at genital apparatus, but which in reality is only the residue of ingested food.

'Third type. Seems to be linked up by the largeness of the rostrum with the larva of hydrachna. Only one specimen was seen on a Mansonia.'