
By

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In a memoir on "The Microscopic Organisms found in the Blood of Man and Animals," published in the 'Fourteenth Annual Report of the Sanitary Commissioner with the Government of India,' and which was, in great part, reproduced in the first three numbers of the 'Quarterly Journal of Microscopical Science' for 1879, a chapter was devoted to a description of certain flagellated organisms which I had found in the blood of rats. This chapter will be found in the January number at p. 109, so that it will not be necessary on the present occasion to do more than very briefly recapitulate what was given therein.

Having been directed to make certain inquiries regarding the nature of the, sometimes designated, "spirillum-fever" which prevailed in Bombay during the earlier part of 1877, I had occasion to examine the blood of a considerable number of animals, and in July of that year detected spirillum-like organisms in the blood of healthy rats. In some instances these were so numerous that the blood when examined under a high power seemed to quiver with life. On careful focussing it was ascertained that each organism consisted of a body-portion and of an extension of it in the form of a gradually tapering, long flagellum, the former average 25 μ in length by 1 μ in width, whilst the flagellum brought up the total length of the organism to about 50 μ or longer, for it was by no means certain that the whole length of the free end of the flagellum
was visible. They were found not to be very sensitive to reagents, as they continued, for example, to manifest lively movements in a weak solution of bichloride of mercury for eight hours, and an exposure of several minutes to chloroform vapour did not seem to affect them. A weak solution of ammonia did not affect them for some time, but a stronger solution of potash affected them at once. When a drop of blood containing them was placed on a slide arranged for the application of electricity, it was found that an interrupted current of such a strength as could not be comfortably borne by an individual was tolerated by these beings for several consecutive hours.

They were found in two species of rats—Mus decumanus and Mus rufescens—and in 29 per cent. of the animals examined. At that time I had not specially searched for these organisms anywhere except in Calcutta, nor had I found them in the blood of any animal except in that of the rat. I have since found them in rats at Simla, in the Himalayas, at an elevation of 7500 feet above sea-level, though as regards the blood of mice and of musk rats I have searched for them in vain both in Simla and Calcutta.

That they are, however, to be found in the blood of other animals has been demonstrated by Dr. Griffith Evans, the present chief of the veterinary department in Madras, who, in 1880, whilst examining the blood of horses suffering from a wasting form of disease termed “sura” in the Punjab, found that it frequently swarmed with organisms of this character. Dr. Evans further made the very interesting observation that in the blood of a couple of camels, suffering apparently from a disease allied to surra in the horse, flagellated organisms were present in one, and nematoid embryos, closely resembling those which I described some years ago as being found in the blood of man, the Filaria sanguinis hominis,1 in the other. I have elsewhere2 drawn attention to this parasite of the camel,

parents and embryos, and suggested that it might be called Filaria Evansi. I hope, however, to describe it at greater length in the next number of this Journal.

With the view of ascertaining whether these flagellated organisms could be transferred to other animals, Dr. Evans had injected some blood from a horse, in which these organisms abounded, into the subcutaneous tissue of a dog and of a bitch, and on examining their blood four or five days afterwards precisely similar organisms were found in the blood of the bitch, but not in that of the dog. This bitch had a suckling puppy about a couple of months old, and its blood also contained these organisms, although it had not been intentionally inoculated; though as regards the possibility of the puppy having likewise been inoculated from the horse it is to be mentioned that a little of the blood was given to the bitch to eat, and it is quite possible that the puppy likewise consumed some of this. Unfortunately, the blood of these animals had not been examined as a preliminary procedure, so that it cannot be definitely declared that the organisms had been derived from the blood of the horse. It is just possible that they may have existed in their blood previously, and, in this connection, it is to be borne in mind that as regards rats attention was drawn in my previous article to the circumstance that the blood of those caught in a particular room would be affected, "whereas the blood of rats in another part of the building would not contain them. The servants had ultimately come to recognise this, as, whenever they learnt that a particular rat's blood contained the desired organisms, they diligently endeavoured to secure the rest of the family," so that the possibility is not absolutely excluded that the finding of these parasites in the blood of the puppy and of its mother may have been a coincidence and not the direct result of the experiment; nor is it known to what extent the blood of horses and camels or other animals in this part of India may harbour these organisms or may have harboured them at that time.

These flagellated blood-parasites are not, however, limited to India, for in 1881 Wittich described similar organisms in the
blood of hamsters in Germany. Wittich’s experience coincided with my own as regards their being found in the blood of apparently perfectly healthy animals, though Dr. Robert Koch, instigated by the result of Wittich’s observations, found that the hamsters which he procured died, one within two days of being in captivity, and four others subsequently. It does not appear that the blood of these hamsters was examined during life, but after death it was found, in each case, to contain the organisms in question. No reference is made to the examination of other hamsters, so that it is not quite clear whether the animals died as a result of captivity or in consequence of the parasitism. As regards rats thus affected I have had them kept in a cage for weeks, and to all appearances in a state of perfect health. Both Wittich and Koch suggest that the parasites found by them in the blood of hamsters are in all probability identical with those found by me in rats in India; and Koch gives two micro-photographs of them which correspond very closely with the micro-photographs which were published by me in the above-mentioned Indian ‘Sanitary Report.’

What these organisms are and whence their origin is by no means clear, and as the suggestions which have been offered by various authorities regarding these points are so greatly at variance it seems highly desirable that every detail which can be collected concerning them should be placed on record. This is all the more to be desired, seeing that the question has arisen of their possible influence as a cause of disease.

I had every opportunity of satisfying myself that the parasite found by Dr. Evans in the dog is identical with that in the rat, as Dr. Evans brought the puppy to Simla in October, 1880, and very kindly made it over to me for observation. The accompanying sketch represents some of the forms assumed by these organisms as observed under a Prazmowski’s 1·5 mm. immersion objective. This, together with the following remarks made at the time, are copied from my note-book:

A drop of blood having been obtained from the puppy’s ear

1 ‘Centralblatt für die medicin. Wissensch.,’ vol. xix, No. 4.
2 ‘Mittheilungen aus dem Kaiserlichen Gesundheitsamt,’ vol. i, p. 9, 1881.
about 9 a.m. on the 26th October, it was found to contain a considerable number of these organisms in a state of great activity.

Their movements were so rapid that it was impossible to obtain a clear conception of their exact form. The slide was set aside and again examined at 4 p.m., when it was found that their movements were much more languid and less suggestive of spirilla than they were in the morning. It was at this time that the figures above reproduced were sketched. As the rapidity of the movements diminished there appeared to be a greater tendency to throw out flagellæ, and wave-like extensions of their substance seemed to originate at the thicker end and to pass along rapidly towards the flagellum. The plasma-substance appeared to be contractile along the whole length of the parasite, even to the very tip of the flagellum, and, frequently, an impression was conveyed, suggestive of the organism being flat or ribbon-like; consequently, when seen in profile they presented a much more attenuated aspect than under other conditions. Moreover, it is difficult to decide how much of the wave-like appearance above referred to is due to rapid
lateral prolongations of the protoplasm, and how much to the aspect which would be presented when this ribbon-like form undergoes rapid spiral contractions. In the above figures an attempt has been made to reproduce the most striking of these different appearances, and a couple of red blood-corpuscles have been introduced to indicate the relative size under the same magnifying power.

At 5 p.m. the organisms manifested signs of losing vitality, became more ribbon-like and pointed—almost, if not quite, 'lashed,' at the thicker end also; moreover, a clear space is observed at a distance of from 2 to 3 μ from the point highly suggestive of a vacuole. This is indicated in two or three of the figures. They averaged about 30 μ in length and from 1 to 2 μ in width at the thickest part.

At 8 p.m. only two specimens could be detected in the slide, one quite motionless, the other nearly so. One of these is carefully sketched at a in the engraving; a vacuole-like spot is observable at one part, and the parasite is granular almost along its entire length. Near this specimen a curved protoplasmic object was observed to alter its form very slowly, as shown at a, b, c. Its further changes could not be followed, as it was lost whilst its form was being outlined, but I have on two or three occasions observed objects of this character associated with these parasites, and sometimes think that they must represent either an earlier or a later stage of them than is ordinarily seen.

Further specimens of blood were obtained from the puppy on the 29th and 30th of October, but no organisms could be detected; on the 3rd November, however, it is noted that the organisms were very numerous in the blood, and that "the dog looks remarkably well."

Shortly afterwards the puppy was taken to Calcutta, and when examined on the 25th November no organisms could be detected in its blood. On the 3rd December, however, they were readily found. A specimen which was observed on this occasion may serve to illustrate a phenomenon which I have frequently observed in connection with like organisms in the
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rat. A slide of blood which had been kept in a moist chamber for twenty hours having been placed under the microscope, the eye was attracted by the way in which one of the parasites appeared to play with a red blood-corpuscle. It was watched for fully an hour, until, in fact, the field was disturbed by the evaporation along the edge of the cover-glass. Its movements were sluggish and just sufficient to slightly shift the corpuscle. It had not attached itself to the corpuscle by either of its ends, but at a spot about 8 μ from the point of the thicker end as shown in Fig. 2, a to d. Sometimes there appeared to be a slight interval between the corpuscle and the parasite (Fig. 2, a), and occasionally even a greater interval than is indicated in the woodcut, but both parasite and corpuscle, nevertheless, continued to move in unison, as though some filamentous connection existed between them, which, however, was too delicate to be distinguished by the highest power which I possessed. At other times the organism appeared to be closely applied to the corpuscle, as though the latter were being embraced by two short lateral pseudopods, and the outline of corpuscle appeared as if squeezed (Fig. 2, b, c). At Fig. 2, d, the corpuscle is shown with the parasite immediately below it. No

Fig. 2.—a—d appearances presented by one of the flagellated organisms which had applied itself to a red blood-corpuscle. × 1000 diameters.

distinct flagellum could be detected extending from the thicker
portion of the parasite, though it was frequently observed to present a ribbon-like appearance.

Shortly after this the puppy got the "distemper," and was struck by one of the native servants, so that it lost the sight of the right eye. On the 15th January, 1881, several specimens of blood from its ear were examined, but not a single parasite could be detected. Further examinations were made on the 12th and 28th February, and again on the 24th March, but not a single specimen was found. The dates have been carefully recorded, as they may be of use to future observers; and the notes of observations in this instance have been made to subserve the double object of illustrating the more salient points in the microscopy of the parasite, and to give the exact history of this form of parasitism in the dog during a period of from four to five months.

There are, however, a few other points in connection with the microscopy of these organisms which it seems desirable to refer to as they may be of assistance to systematic writers in deciding their precise position in the animal (or, as some authorities may perhaps consider, vegetable) kingdom.

These supplementary details will be based on further observations which have been made from time to time, as opportunities offered, during the last three or four years, on the blood of rats, but more particularly on a series which were conducted for purposes of comparison whilst the organisms in the dog were being watched.

On January 30th, 1881, the following entry is made in my note-book: Examined the blood of five rats, and found flagellated organisms in two of them. One of the latter was a pregnant female, but this one, however, did not contain many specimens of the parasite, and none were found in the blood of its young. The blood of the other rat swarmed with the organisms.

As it had been found that the parasites were remarkably well preserved in a 0.75 per cent. solution of salt and water, half a Pravaz-syringeful of a mixture of the blood of this rat, and of the salt solution—one part to three—was injected into the
sub-cutaneous tissue of the thigh of a healthy rat, free from blood organisms, and which had been under observation for a fortnight.

The animal did not appear to be materially affected by this procedure, and on February 12th it is recorded: The rat continues to enjoy excellent health; eats and drinks freely. Not a trace of any organisms found in its blood, although the flagellated organisms which had been introduced into its tissues were found to be alive two days after the operation in what remained of the mixture which had been injected.

It would thus appear that these organisms are at all events not very readily transmissible by means of sub-cutaneous injection from one rat to another.

Nor have I succeeded in preserving them beyond two or three days outside the body. Attempts have been made to "cultivate" them in plain water, in sugar and water, glycerine and water, and in salt and water, as, also, in the blood itself, both with and without the aid of an incubator. But I could not satisfy myself that they multiplied; on the contrary, they seemed to degenerate after removal from the animal hour by hour. A weak solution of salt, as already observed, appeared to be a more favorable medium for retaining their vitality than any other which I have tried, and is a very convenient medium for studying the various stages of the disintegrative process.

**Fig. 3.**—Flagellated organisms from the blood of a rat preserved in a 0.75 per cent. solution of common salt. × 1000 diameters.
The different appearances which they presented as watched in such a solution are sketched at Fig. 3; from which it will be observed that the organisms present a striking resemblance to the more generally recognised forms of spermatozoa. On the third day the specimens figured were no longer recognisable in the fluid in which they were kept.

Whilst watching these particular specimens I was further able to satisfy myself that these, like the generality of flagellated organisms, moved with the lash in front—that is to say, in the direction indicated by the arrow which is placed alongside of the middle specimen in Fig. 4. Since this period I have frequently observed the same thing in other specimens, though it is scarcely possible to be sure of the direction of the movement until after the parasite has become sluggish. Moreover, they may also be observed to move with the thicker end forwards, but only for short distances.

![Fig. 4](image-url)

**Fig. 4.**—Different methods of attachment to foreign bodies observed in two specimens of the organisms from the blood of a rat. The arrow along the middle figure indicates the direction of progressive movement. $\times 1000$ diameters.

As already remarked, when describing the specimens from the blood of the dog, they seem to attach themselves to surrounding objects by means of some portion of the thicker end. The specimen sketched in the left half of Fig. 4 was observed to remain attached to a granular mass by the extreme point of its thicker end for a considerable time, whilst the remainder of the
parasite was seen to swing freely from $a$ to $b$ and from $a$ to $c$, the free end of the lash presenting a screw-like appearance. Another specimen was watched for half an hour whilst it remained attached to a granular mass in the preparation, but in this instance, as represented at the right half of Fig. 4, the parasite had fixed itself at a point about 3 $\mu$ from the end, and to swing itself, as from $a$ to $b$, from this fixed position. It will be noted that the part of the body by which the parasite attaches itself here corresponds with that represented as having been attached to the red blood-corpuscle in a previous figure. In this instance, also, the lash was observed to manifest incessant screw-like movements, the movement apparently commencing at the tip of the flagellum and proceeding rapidly upwards until the point of attachment to the granular mass was reached, and here it stopped abruptly.

Many attempts were made to demonstrate the presence of another flagellum at the opposite end, but without any satisfactory result. In preparations made by drying a film of the affected blood on a cover-glass both ends of the parasite are often seen to be very pointed, but in all cases a distinct flagellum could only be made out at one end. When a solution of gentian-violet is added to such a slide the parasites are rapidly stained and present a granular appearance throughout, granules being frequently distinguishable as far as the extreme tip of the flagellum, as may be observed in Fig. 5. Occasionally the

![Fig. 5.—Action of gentian-violet on specimens of the organisms from the blood of a rat. $\times$ 1000 diameters.](image)

flagellum appears to be retracted, as shown in the sketch in the middle of the figure, and I have sometimes thought that such a
retraction of the flagellum could be observed whilst the organism was in a condition of extreme activity. The specimens in this figure were carefully outlined to scale by means of the camera lucida.

I am wholly unable to suggest any explanation for the presence of these flagellated parasites in the blood of animals. It will be recollected that they have now been observed in the blood of the horse, camel, and hamster, in addition to that of the rat; and, further, that they have been found in the blood of two dogs, but whether as the result of intentional inoculation or otherwise must for the present be left undecided. As regards the season in which they may be detected, I find that there are entries in my note-book of their having been seen, at one time or another, in the blood of rats in nearly each month of the year.

For some time I was inclined to think that they might be the spermatozoa of some parasite hidden in the tissues of the animal, a view which strongly forced itself upon me some years ago, in 1878, by having accidentally observed a large number of spermatozoids escaping from the reproductive pore of a fragment of taenia which I had found while dissecting a rat. The "head" of the taenia was not found, so that the entozoon could not be identified with certainty, but it probably was a portion of Tænia microstoma or some closely allied species. My notes run as follows:—The segments having been placed on a slide spermatozoids are seen to escape from the genital pore of nearly every one of them. For a few moments after their escape they presented, with amazing exactness, the characters of the spirillar organisms found in the blood of rats, but which were not present in the blood of this particular specimen. It seemed, however, that the water in which the taenia segments were mounted and into which they escaped was not suitable to their preservation. They rapidly underwent changes of form, and almost before half a dozen of them could be sketched disintegrative changes set in, and the previously active flagellated organisms were transformed into quiescent, filamentous shreds. It has not been considered
necessary to reproduce the sketches of them which were made, seeing that both as to size and form they are so very like several of the figures in the woodcuts already given. The organisms found in the blood of rats, however, are by no means so sensitive to the action of water as this.

Leuckart, in his recently published review of the additions which have been made during 1876 to 1879 to the literature of low forms of animal life, suggests that it is doubtful whether these rat organisms should not be relegated to the class of organisms described by Dr. Gaule as being present in the blood and spleen of frogs and termed by him “Cytozoa” rather than to the flagellata. Readers of this Journal will recollect that Dr. Gaule was under the impression that these “Cytozoa” (also described by him as “Würmchen”) were the result of certain changes which took place in the blood-corpuscles and other cellular elements of frogs. Professor Ray Lankester, however, in the number of this Journal for January, 1882, has shown that such an inference is wholly erroneous, and has, I think, very satisfactorily demonstrated that Gaule’s Cytozoa are “independent parasitic organisms”—that they represent, in fact, the young stage of a Sporozoon. It is not quite clear to which view of the nature of these “Cytozoa,” to Gaule’s or to Lankester’s, Leuckart refers in the paragraph above cited.

In his recently completed ‘Manual of the Infusoria,’ Mr. Saville Kent, on the other hand, has placed the blood-organism of the rat amongst the Flagellata, and has named them Herpetomonas Lewisi; at the same time he points out that it is possible that further research “may possibly demonstrate their identity with the discharged spermatic elements of the minute nematodes, micro-filariae, or other metazoic endo-parasitic forms known to flourish amid the same surroundings.”

1 ‘Bericht über die wissenschaftlichen Leistungen in der Naturgeschichte der niederer Thiere,’ ii Hälfte, 1883, p. 775.