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A PRELIMINARY NOTE ON THE IDENTITY, LIFE-CYCLE, AND PATHOGENICITY OF AN IMPORTANT NEMATODE PARASITE OF CAPTIVE MONKEYS

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In August 1936, two white-faced monkeys, *Cebus capucinus* (L.), of laboratory stock died within a few days of each other and at autopsy were found to be heavily parasitized with a species of spiruroid nematode. In the first instance, as observed at autopsy several hours *post mortem,* the parasites were generally distributed thoughout the alimentary tract and viscera. The stomach wall was perforated and a large encapsulated abscess affected nearly all of the visceral organs. Probably less than half of the worms were collected since much of the tissue was fixed for sectioning and pathologic study, yet of those collected, the following numbers were taken from the regions indicated; body cavity abscess 253, mouth and pharynx 131, esophagus 199, stomach 38, small intestine 19, liver 33, spleen 16, unknown 7, total 696. The second case, except for the peritoneal involvement, showed a similar picture and 502 worms were counted.

Since the date given above, at least twenty white-faced monkeys have succumbed to infection with this parasite, and, in addition, this same helminth, in less severe infections, has been encountered in the Canal Zone night monkey, *Aotus zonalis* Goldman, and in the Darien black spider monkey, *Ateles dariensis* Goldman.

IDENTITY AND MORPHOLOGY OF THE PARASITE

The parasite belongs to the genus *Protospirura* Seurat, 1914 (Spiruridae). On morphological grounds, particularly the position of the vulva, size of spicules, and structure of the anterior extremity, we consider it identical with *P. muricola* Gedoelst, 1916.

The morphology of the parasite is briefly as follows (figs. 1–6): Males 25 to 40 mm. long by 580 to 675 μ in greatest diameter. Females 40 to 70 mm. by 780 to 1200 μ in diameter at the vulva. Four submedian head papillae (fig. 3). Cuticle thick and transversely striated. Cervical papillae 315 to 350 μ from anterior end in males; 360 to 385 μ in females. Nerve ring 350 to 385 μ from anterior extremity in males; 410 to 470 μ in females. Excretory pore 490 to 535 μ from anterior end in males; 560 to 675 μ in females. Body gradually tapering toward the head end. Head 100 to 136 μ in diameter, slightly smaller in males than females. Mouth surrounded by two lateral trilobed lips, the lobes of each lip armed internally with anteriorly directed chitinized teeth (fig. 2), one on each lobe. The teeth on the middle lobes are large, terminal, and have two cusps each (fig. 1). The ventral and dorsal lobes of each lip are similarly armed, each having two internal cusps, one projecting antero-laterally and the other obliquely posteriorly into the buccal opening. Frequently this latter cusp is very much reduced. Usually there is also a smaller sharp tooth deeper in the vestibule, below the more anterior terminal tooth. On the dorsal and ventral aspects of the head are chitinized plates connecting the lateral lips just above the head papillae (fig. 2). The vestibule, in dorsal or ventral aspect, is chitinized and laterally compressed. It measures 130 to 136 μ deep in males and 145 to 150 μ in females. It is from 23 to 50 μ wide when viewed laterally in optic section. Esophagus long, consisting of muscular and glandular portions, the former about one-thirteenth as long as the latter, having an over-all measurement of about 5.5 mm. in males and 7 mm. in females. Anus, in females, 460 to 550 μ from posterior end; rectum well chitinized. Vulva posterior to middle of body, somewhat variable in position, but generally located so as to divide the body into anterior and posterior portions having a ratio of about 10 to 7. Eggs (fig. 4) oval, slightly flattened on one side, thick shelled, embryonated at deposition, measuring 53 x 40 μ. Male with broad, thick, caudal alae, decorated with irregularly interrupted longitudinal rugae. There are typically nine pairs of button-like caudal papillae (4 preanal, 5 postanal) and one unpaired papilla immediately preanal in position (fig. 5).

Some specimens, however, show as many as six pairs of preanal papillae and either four or six pairs of postanal papillae. Spicules unequal and alate (fig. 6); the left averaging 525 μ with broad wings, the right about 434 μ with narrow wings. Gubernaculum well developed, 134 μ long, triangular, and concave ventrally.

P. muricola of captive monkeys, described above, is atypical for the species in respect to its larger size and correspondingly greater measurements of body structures. Also, it differs from the typical form in the kind of host which it parasitizes. It appears, moreover, that this "primate strain" of the species may be more injurious to its host. With reference to size, Baylis (1928) states that males of *P. muricola* generally range from 15 to 20 mm. and females 20 to 30 mm. Mature specimens of this parasite in monkeys are about twice this size, although males up to 31 mm. were reported by Gedoelst (1916) and females up to 52 mm. by Tubangui (1931). In respect to kind of host, Baylis lists sixteen rodent hosts for this species and adds the statement that *P. muricola* is "probably the commonest nematode parasite of rodents in Nigeria" (p. 297). He also states that what appeared to be *P. muricola* occurred in the lemuroid, *Perodicticus potto,* this being the only previous record of the occurrence of any species of *Protospirura* S. S. (Chitwood, 1938) in primates. Concerning the pathogenicity of *P. muricola* for its usual rodent hosts, little is known, although it will be apparent from the discussion which follows that it is highly injurious to monkey hosts.

Perhaps the most striking aspect of what has been said above is the fact that, in the present report, we are dealing with a situation wherein a common parasite of rodents has become adapted to primate hosts in which it causes a serious disease. This may also be the most significant aspect of the present study since it suggests the importance of being alert to the possibility of similar endemic parasitisms arising in other animals and in man.

A NOTE ON THE LIFE-CYCLE OF P. MURICOLA OF CAPTIVE MONKEYS

The work of Brumpt (1931) which established that cockroaches are the vectors of *P. bonnei* Ortlepp, 1924, of rats, suggested that cockroaches might also be involved in the transmission of *P.*

muricola of monkeys. This probability seemed enhanced by the fact that cockroaches abundantly infested the animal houses and were a favored item of food to the white-faced monkeys. Accordingly, several cockroaches were caught in the vicinity of the monkey cages and examined for the presence of spiruroid larvae in the body cavity. Such larvae were readily found. They were not found, however, in cockroaches captured elsewhere.

The specific identity of these larvae with the worms from the monkeys seemed relatively easy to establish, especially since heavy infections in monkeys have invariably yielded worms of graduated sizes from immature forms of not more than 4 mm. in length to adult specimens of 65 mm. or more. There was noted at once a marked morphological similarity between the suspected infective stage (figs. 7 to 11) from the body cavity of the cockroach and the smallest worms (figs. 12 to 15) recovered from monkeys. Their identity has since been confirmed by comparing immature worms from experimentally infected mice, cats, and opossums with worms of similar sizes from monkeys, although it is not desired to report on this phase of the study until more data have been accumulated on the life-cycle.

The infective larvae to which we have referred (figs. 7 to 11) are 3.0 mm. long by 80 μ in maximum diameter shortly anterior to the anus. In the cockroach, they are contained within discoidal cysts having a diameter of 650 μ or more, although the larva is coiled like a watch-spring into a diameter of about 400 μ (fig. 21). The head bears four submedian papillae (figs. 8 and 9) and is structurally very similar to that of the adult. The vestibule is 25 to 27 μ deep, chitinized, and armed as shown in fig. 11. The esophagus is long, about 45 per cent of the body length, and divided into muscular and glandular portions. The intestine is simple and narrow with a few constrictions. The anus is about 80 μ from the posterior extremity. The cervical papillae are symetrically placed, about 110 μ from the anterior extremity. The nerve ring is about 145 μ from the anterior end, and the excretory pore about 190 μ. The genital primordium is located about 700 μ from the posterior end. The tip of the tail is characteristic, having a rosette of 10 to 12 papillae arranged in a circle as shown in figure 15. (This figure was sketched from a 3.5 mm.

larva taken from a monkey infection although it respresents well the tail of the infective larva, since the latter bears an exactly similar structural feature).

In the present epidemic only one species of cockroach, *Leucophaea maderae* (Fabr.),[1] appears to serve as vector (figs. 22 and 23). Both the adult and the nymphal stages are infected, although the incidence and intensity of infections are greater in the adult stages. Five other species of cockroaches have been captured along with the first named form, but no spiruroid larvae have been found in them.

The natural infection rate in the intermediate host is very high—about 96 per cent in adult cockroaches (130 positives out of 135 dissections)—while the number of cysts per cockroach is frequently several hundred, although the average number seems to be about one hundred. This high degree of infection is evidenced by the fact that one day's catch of 22 adult specimens of *L. maderae* was estimated by dilution count to have yielded 2460 cysts; another day's catch of 12 specimens, 1350 cysts; and a third day's catch of 12 specimens, 1250 cysts.

The cysts show a fairly definite localization in the intermediate host. Almost all of them are limited to the thoracic region where the principal sites of infection are the areas lateral to the esophagus and crop and at the bases of the large muscles of the fore-legs.

Prior to the instigation of preliminary control measures (viz. the trapping of cockroaches in baited, paraffined containers) conditions were ideally favorable for the continuance of this epidemic. The cockroaches fed upon monkey feces and other debris and, in turn, the monkeys readily ate the cockroaches. However, it is too early at present to evaluate the effect of a reduction in the number of cockroaches.

PATHOLOGICAL MANIFESTATIONS

Only one report concerning the pathogenicity of this parasite has been found in the available literature. Brumpt (1931) states, "malgré la présence d'un grand nombre de parasites, les rats ne

[1] The six species of cockroaches referred to in this study were determined by Mr. A. B. Gurney of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

montrent aucun signe clinique; il est donc permis d'affirmer que les actions mécaniques, prédatrices et toxiques exercées par ces vers sont trés faibles." (p. 352). In the white-faced monkey, however, under conditions of captivity, this parasite causes considerable damage resulting in the death of the animal. Unlike the infections in the rat, in the primate host the parasites are encountered not only in the stomach, but also in other locations, notably the terminal portion of the esophagus, the duodenum, and the peritoneal cavity. In the latter location they are usually very few in number and, as a rule, cause no injury to the tissues. An exception to this last occurred in one animal in which a perforation of the stomach wall had taken place and practically all the parasites present in the stomach had migrated into the peritoneal cavity causing, in combination with the bacteria, a peritonitis of considerable extent. In the esophagus and stomach the number of worms frequently becomes so great that a cast of these organs is formed when they are fixed intact. This condition is shown in figure 16. Also in the white-faced monkey, as in the rat, the parasite causes very little damage to the gastric tissues. Even when enormous numbers of worms are in the stomach, the mucosa shows little more than irritative changes which are evidenced by hyperemia and increased secretion, or, in some cases, by flattening and thinning of the mucosa as a result of pressure. We are impressed by the fact that it is outside of the stomach where the ability of the parasite to invade and cause destruction of tissue becomes manifest. The esophagus, particularly the terminal portion, is the seat of pronounced tissue changes. Here the parasite becomes an active tissue invader, threading itself in and out of the mucosa as pictured in figure 17. This repeated tissue invasion in combination with the pressure upon the tissues occasioned by the large number of parasites, results eventually in the destruction of almost the entire mucosal layer with replacement by a thick membrance composed principally of cellular débris and inflammatory cells (figs. 18 to 20). The submucosa is secondarily involved through bacterial invasion, while the more compact and resistant muscular layers remain apparently unchanged.

Briefly, then, the typical postmortem picture, in cases of severe infection, is an enormous number of worms concentrated in the stomach and esophagus, with pressure effects upon the entire mucosal surface, obvious mechanical blockage, rarely perforation, and with tissue invasion generally confined to the distal portion of the esophagus.

ABSTRACT SUMMARY

Preliminary data have been presented on a new and economically important nematode disease of captive monkeys. The parasite is described, and considered to be identical with *Protospirura muricola*, which is normally parasitic in the stomach of rats. Three monkeys (*Cebus capucinus*, *Ateles dariensis*, and *Aotus zonalis*) are recorded as new hosts for this parasite.

Most of the fatalities from protospiruriasis have occurred among the *Cebus* monkeys, whose dietary habits are especially favorable to the acquisition of heavy worm burdens. Normally, the worms live in the esophagus and stomach; rarely they were encountered in the duodenum and body cavity. Injury to the host is the result of obstruction, tissue invasion, pressure action, and secondary infection.

The cockroach, *Leucophaea maderae* (F.), serves as intermediate host. The infective larvae are contained in cysts which are found mainly in the thorax around the crop and at the bases of the large muscles of the first pair of legs. The morphology of this larva is described.

A reduction in cockroach population was suggested as a preventive measure.

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PLATE 1

MORPHOLOGY OF ADULTS AND LARVAE

FIG. 1. Lateral aspect of head of adult.
FIG. 2. Ventral aspect of head of adult.
FIG. 3. Anterior aspect of head of adult.
FIG. 4. Appearance of ova when deposited.
FIG. 5. Ventral aspect of tail of adult male.
FIG. 6. Spicules.
FIG. 7. Infective larva from cyst in body cavity of cockroach.
FIG. 8. Lateral aspect of anterior extremity of infective larva.
FIG. 9. Ventral aspect of same.
FIG. 10. Lateral aspect of posterior extremity of infective larva.
FIG. 11. Ventral aspect of one-half of head (one lip) showing tooth structure of infective larva.
FIG. 12. Lateral aspect of anterior extremity of 3.5 mm. specimen from stomach of white-faced monkey.
FIG. 13. Ventral aspect of same.
FIG. 14. Lateral aspect of tail of same.
FIG. 15. Free-hand sketch of rosette of papillae on tip of tail of same.

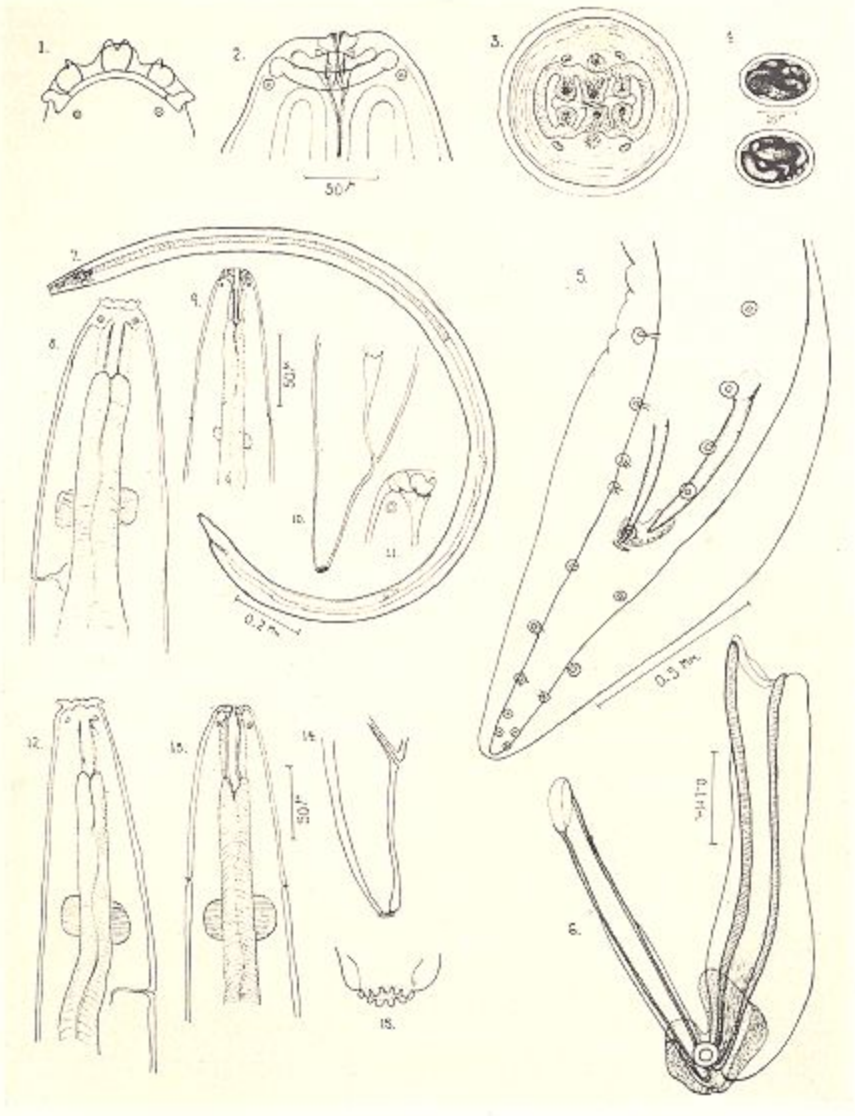
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PLATE 2

Pathological Manifestations

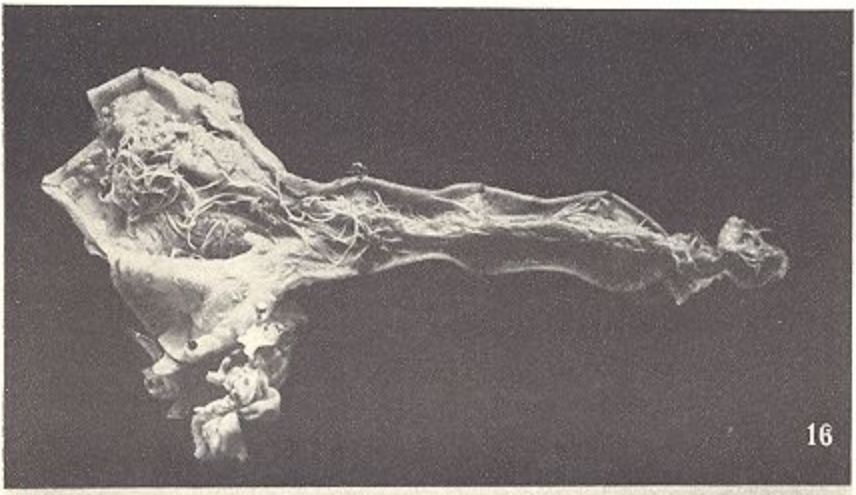
Fig. 16. Photograph of worms in esophagus and stomach of white-faced monkey no. 164-B as seen at autopsy.

Fig. 17. Section of esophagus of white-faced monkey no. 411-A. Early penetration of mucosa by worms. Apochromate 16 mm. Periplan 10. Camera length 20 cm.

Fig. 18. Section of esophagus of white-faced monkey no. 411-A. Small ulcer in mucosa resulting from penetration of type seen in figure 17. Apochromate 16 mm. Periplan 10. Camera length 20 cm.

Fig. 19. Section of esophagus of white-faced monkey no. 181-B. Almost complete destruction of mucosa and replacement by a thick layer of cellular exudate. Achromatic 32 mm. Periplan 10. Camera length 20 cm.

Fig. 20. A portion of figure 19 showing the cellular character of the exudate. In the lower portion of the photomicrograph a fragment of mucosa can be seen. Apochromate 16 mm. Periplan 10. Camera length 20 cm.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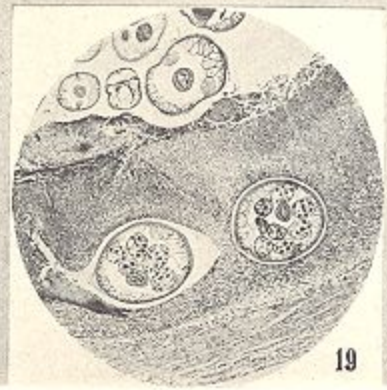
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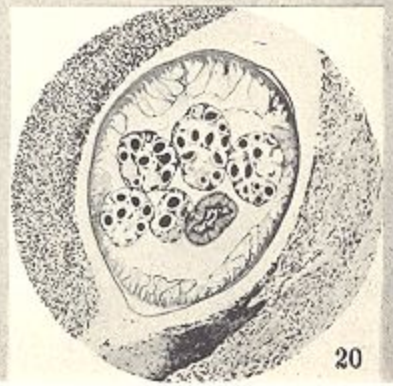
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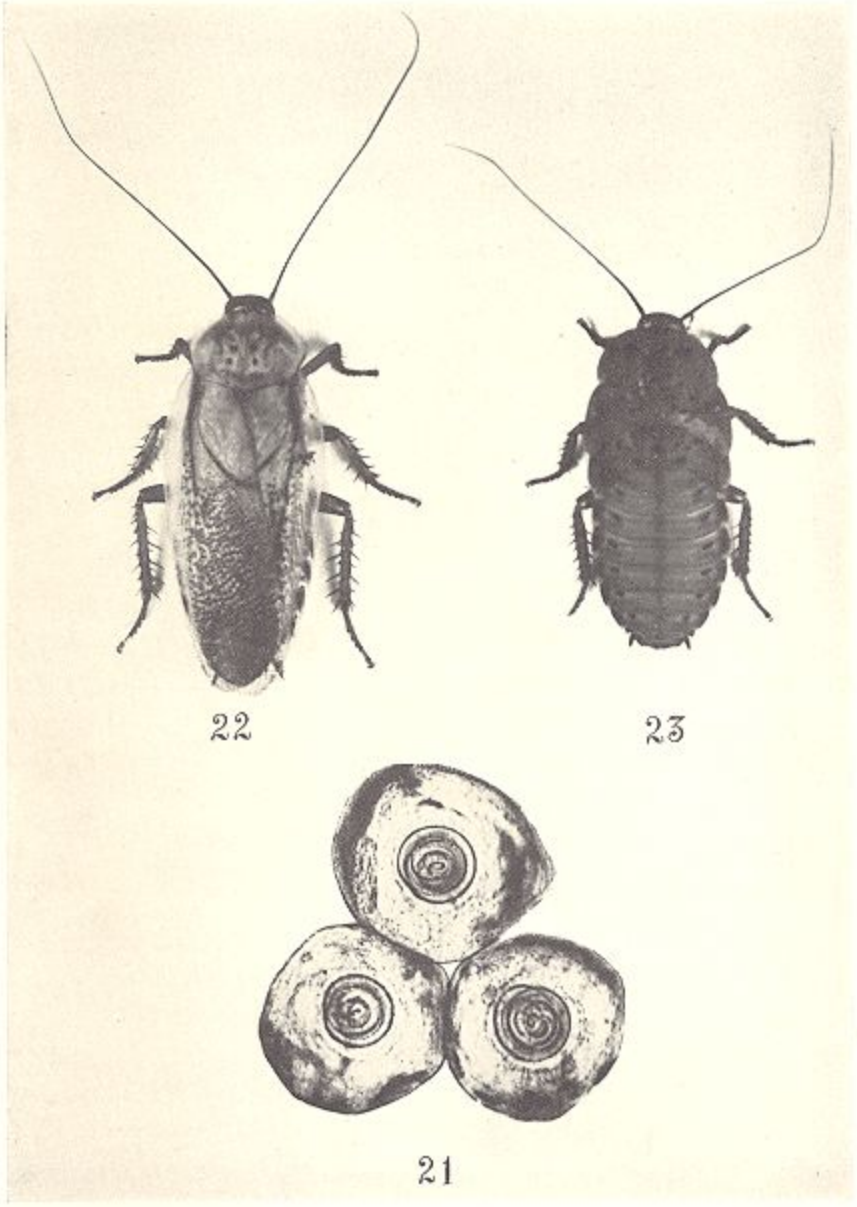
PLATE 3

VECTOR AND ENCYSTED INFECTIVE LARVAE

FIG. 21. Cysts from thoracic cavity of cockroach. Apochromate 16 mm, Ocular 4. Camera length 20 cm.

FIG. 22. The cockroach intermediate host, *Leucophaea maderae* (F.). Enlarged.

FIG. 23. A nymph of the same. Enlarged.



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