A Contribution to the Study of Fijian Haematozoa

With Descriptions of a New Species from Each of the Genera Haemogregarina and Microfilaria*

By MARSHALL LAIRD, M.Sc., Ph.D.

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CONTENTS

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SUMMARY

Only 8 (1.6 per cent.) of the 497 animals examined were found to be infected with haematozoa, 4 (9 per cent.) of the 43 species concerned being hosts. Two of the 4 species of parasites discovered belong to the Protozoa (*Haemogregarina salariasi* n.sp. and *Plasmodium pteropi* Breinl), the others to the Nematoda (*Dirofilaria immitis* (Leidy) and *Microfilaria mynah* n.sp.). Both protozoans parasitize indigenous animals, one of these, the fruit bat *Pteropus nawaiensis* (Gray) being restricted to Fiji, although its parasite, *P. pteropi,* occurs throughout the Indo-Pacific area. The other host for a blood protozoan, the blenny *Salarias periophthalmus* Val., is widely distributed among the islands of the tropical Pacific. Its parasite, *H. salariasi* n.sp., is systematically close to other bigeminate haemogregarines already described from blennies in other parts of the world. Both nematodes occur in animals which have been introduced into Fiji by the agency of man, the dog and the Indian mynah, *Acridotheres tristis tristis* (Linnaeus).

INTRODUCTION AND ACKNOWLEDGEMENTS

Very little is known of the blood parasites, other than those of man, of the tropical islands of the South-west Pacific. The studies discussed in the present account were undertaken with the object of shedding some light on the haematozoan fauna of Fiji.

With the exception of *Wuchereria bancrofti* (Cobbold), a causal agent of filariasis in man, and *Dirofilaria immitis* (Leidy), responsible for causing canine heartworm, both of which have long been known from the Fijian group, there is but one record in the literature concerning a haematozoan from an animal of these islands. We owe this record to Donovan (1920), who, in an account of simian malaria in India, mentioned finding *Plasmodium* in the blood of "the Fijian flying fox," but did not elaborate any further on this information.

I am indebted to Dr. J. H. Lawrie Newnham, of Suva, for sending me blood smears from the fruit bat *Pteropus nawaiensis* (Gray) in July, 1948, and for his many kindnesses during my visit to Fiji in May and June, 1949; and have pleasure in acknowledging the assistance of the Commanding Officer, Royal New Zealand Air Force Station, Lauthala Bay, throughout the course of this visit. Invaluable aid was also furnished by the Fijian Agricultural Department authorities. Mr. C. W. McCann, of the Dominion Museum, Wellington, kindly identified the reptiles from which smears were obtained.

MATERIAL AND METHODS

Peripheral-blood smears from domestic animals were obtained during visits to farms in the vicinity of Suva, in company with veterinary inspectors of the Fijian Department of Agriculture. Wild birds and mammals were secured by trapping and shooting, and some reptilian material was collected by local people in response to newspaper and radio advertisements. Some fish-blood smears were taken from specimens brought to the municipal markets at Suva, and others were secured by purchasing portions of the catch of Fijian and Indian fishermen at Lauthala Bay and Nandi. The great majority of the fish studied were collected at Makuluva Island, a few miles' launch trip from Lauthala Bay R.N.Z.A.F. Station, by poisoning coral pools with rotenone (5 per cent.).

Thin blood smears were made in the field, from the heart where possible, and air-dried on collection. On being brought back to the laboratory at Lauthala Bay, these were fixed in absolute methyl alcohol and stained with Giemsa. All the slides were left uncovered, and were searched for parasites on my return to New Zealand. The figures were drawn with the aid of an Abbé camera lucida at a magnification of 2,400.

Haemogregarina salariasi n.sp.

(Text-figure 1, Figs. 37–39)

This haemogregarine is described from an 8 cm. example of the blenny *Salarias periophthalmus* Val., collected from a coral pool at Makuluva Island on 11th June, 1949. Twelve other examples of this species, also 17 of *Salarias fasciatus* (Bloch) captured at the same place and time, were negative for haematozoa. The single infection recorded was an exceedingly light one, only three parasitized erythrocytes being present in the smear.

One of the infected erythrocytes contains a single haemogregarine, unfortunately damaged during the preparation of the smear. This parasite measures 8.1μ by 2.1μ in its greatest dimensions. It has a subcentral nucleus staining deep red, and light blue staining cytoplasm. There is no indication of the presence of a capsule. In both other cases (Figs. 38 and 39) two haemogregarines occupy each host cell. Those seen in Fig. 38 are recent products of schizogony. Longitudinal cytoplasmic cleavage has taken place, but the adjacent sides of the haemogregarines are still in contact except for a short distance at one end. The parasites are crescentic in shape, tapering to a point at either extremity, and at their greatest dimensions they measure 8.3μ by 1.0μ and 9.9μ by 1.3μ respectively. In both cases the cytoplasm is hyaline, and the nuclear chromatin is diffuse and scattered. The host cell is not distorted, and falls within the size range of normal erythrocytes (Fig. 37). Its nucleus is only very slightly displaced in a lateral direction.

The erythrocyte seen in Fig. 39 owes its distortion to the pressure of adjacent blood cells in the smear. It holds two gametocytes, which are enclosed in a reniform clear space in the host cell cytoplasm. This space possibly indicates the presence of a capsule, although a capsular wall is not in evidence. Each gametocyte is curved in shape, narrowed towards the end near which the nucleus is situated, and swollen towards the other. The cytoplasm, which is hyaline towards the swollen end of the body, is stained light blue on the proximal side of the nucleus. This latter structure is stained deep red, with blackish-red aggregations of chromatin. At the bluntly rounded narrow end of one parasite there are three intensely stained granules of extranuclear chromatin, while at that of the other there are two such granules. The gametocytes measure 7.7μ by 1.0μ and 8.3μ by 1.0μ respectively, at their greatest dimensions. Their nuclei measure 2.3μ by 0.8μ and 2.3μ by 0.6μ respectively, in each case occupying the full width of the body.

The haemogregarine of *Salarias periophthalmus* is systematically close to members of its genus already known from blennies in other parts of the world. It resembles *Haemogregarina bigemina,* described from the European *Blennius pholis* and *B. gattorugine* by Laveran and Mesnil (1901), in its general morphology and twinning habit, although the size of the mature gametocytes of *H. bigemina* (12μ by 1.5μ to 2.0μ) is greater than that of the equivalent stages of the haemogregarine under consideration. The study of further material may, of course, disclose a greater size range for the gametocytes of the latter parasite. Kohl-Yakimoff and Yakimoff (1915) described *Haemogregarina londoni* from *Blennius trigloides* at Naples. These authors figured two intraerythrocytic gametocytes of *H. londoni* which were surrounded by a cyst-like structure (their Plate IV, Fig. 7). Such a structure has not been recorded for *H. bigemina,* although, as mentioned above, there is a possibility that the gametocytes of the haemogregarine of *Salarias periophthalmus* may be encapsuled. This parasite, being known from so little material, may ultimately

prove to be identical with one of the previously described blenny haemogregarines. The possibility is enhanced by the fact that a variety of *H. bigemina* recently recorded from four New Zealand species of blennies (an account of this parasite being in course of preparation) shows considerable diversity in gametocyte morphology and size. There is, indeed, a possibility that all blenny haemogregarines may eventually prove to be merely races or host-induced morphological variants of *H. bigemina*. Nevertheless, in the absence of copious material enabling full and satisfactory comparisons to be made with previously described species, it is considered the wisest course to assign specific rank, temporary though this may be, to haemogregarines from new blenny hosts in new localities. For this reason, the parasite of *Salarias periophthalmus* discussed above is designated *Haemogregarina salariasi* n.sp.

The type slide has been deposited in the collection of the Dominion Museum, Wellington (catalogue number Z16).

Plasmodium pteropi Breinl, 1913

(Text-figure 1, Figs. 1–36)

Plasmodium pteropi was originally described from the flying fox (fruit bat) *Pteropus gouldi* from Queensland, Australia. Although the report containing Breinl's description was published in 1913, it bears the date 1911 in its title. This discrepancy has caused some authors to fall into error and attribute the date of description variously to 1911 (e.g., Manwell, 1946) and even 1912 (e.g., Wenyon, (1926). Bhatia (1938) mistakenly gave West Australia as the type locality, and further stated that Johnston described *Plasmodium pteropi* as new in 1913, giving as the reference the page number of the description in Breinl's report. The error probably arose through the fact that Johnston collaborated with Breinl in these studies.

The earliest reports of plasmodia from fruit bats are those of Ziemann (according to Breinl, 1913) and Durham (1908), the latter author recording "a small malaria-like parasite" from the red cells of *Pteropus natalis* on Christmas Island, Straits Settlements. Mackie (1914), without knowledge of Breinl's paper, described as new *Plasmodium pteropi* from (*Pteropus edwardsii*) = *Pteropus medius* in Assam, India. Wenyon (1926) considered it probable that Breinl and Mackie were dealing with the same species, although neither the descriptions nor the figures of either author are full enough for a confident assertion on this point to be made. The parasite recorded as *Plasmodium pteropi* from the epauletted bat *Epomophorus gambianus* in Senegal, by Leger and Leger (1914), is stated by M. Leger (in a footnote to Rodhain, 1926) to be conspecific with *Plasmodium epomophori* Rodhain, 1926.

Donovan (1920) mentioned finding *Plasmodium* in the blood of the Fijian flying fox, without making it clear whether his material was obtained in Fiji. Wenyon (1926) listed the Javanese *Pteropus hyomelanus* as a host for *Plasmodium pteropi*, on the basis of an examination, by himself and Scott, of material from a bat which had died in the Gardens of the Zoological Society of London during 1925. Coloured illustrations of *Plasmodium pteropi* (?) in Wenyon (1926) were drawn from blood smears collected by Manson-Bahr from "the flying fox in Ceylon" (*Pteropus medius*?). Scott (1927) reported *P. pteropi* from *Pteropus medius*, in the Gardens of the Zoological Society of London. Manwell (1946) recorded *Plasmodium* from *Pteropus gouldi* and *Dobsonia moluccensis* from New Guinea, considering that the

parasites from the former host "probably belong to the species seen by Breinl (1911) in the same host, and named by him *Plasmodium pteropi.*" *Pteropus scapulatus* and *Pteropus conspicillatus* were listed by Bearup and Lawrence (1946) as additional Queensland hosts for *Plasmodium pteropi.* The host list and distribution of this parasite were further extended by McGhee (1949), who recorded it from *Pteropus geddiei* and *Pteropus eotinus* at Espiritu Santo, New Hebrides, and from an unidentified member of the family Pteropodidae at San Fernando, La Union, Philippine Islands.

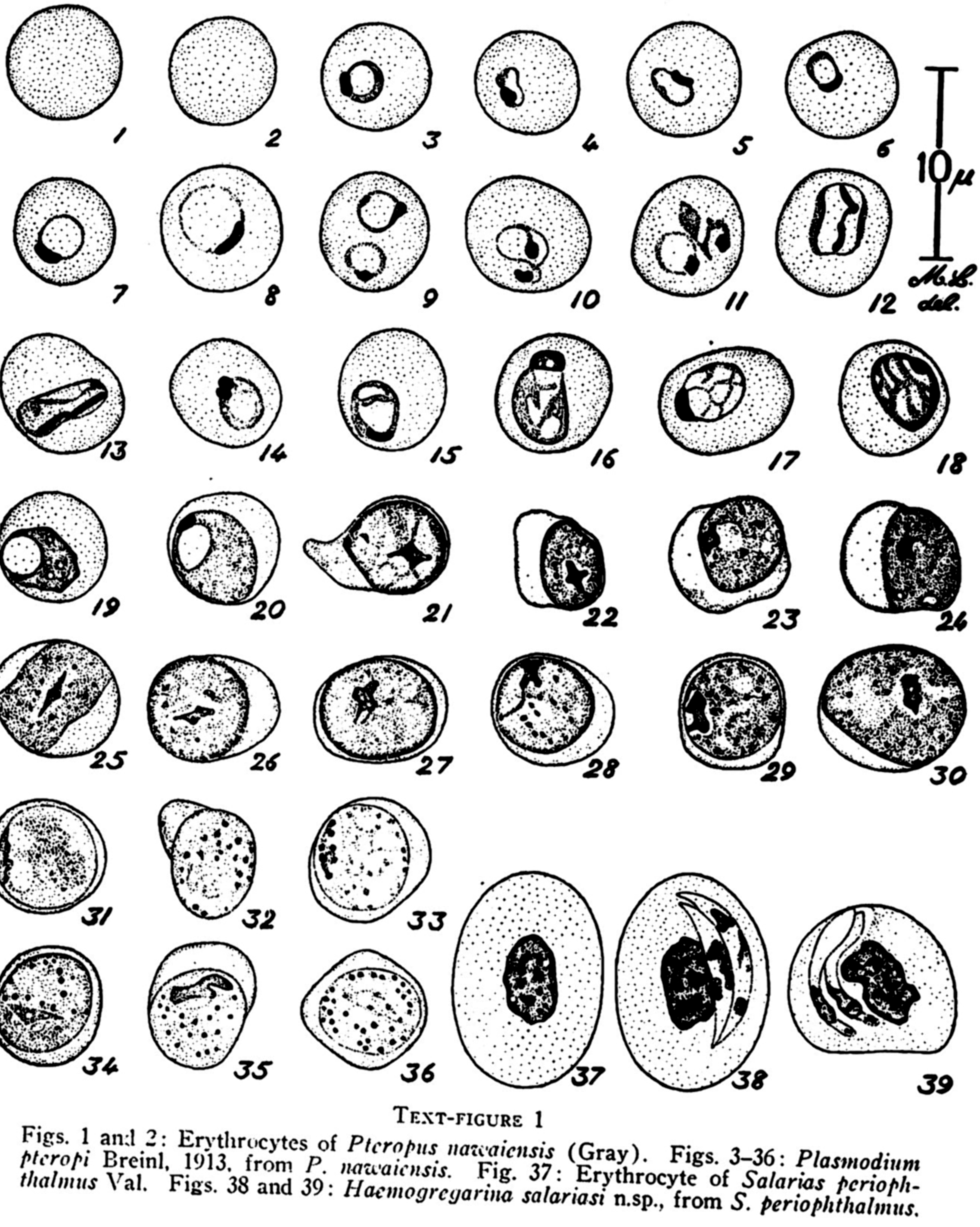
Breinl's description of *Plasmodium pteropi* consists of an account of the broad morphological features and the staining reaction with Giemsa. It mentions that the host cell is sometimes slightly enlarged, also that "the parasite, during its growth, replaces the cytoplasm of the red blood corpuscles, and finally the remainder of the blood corpuscle surrounds the parasite in the form of a thin pellicle." Breinl stated that gametocytes occur in fairly large numbers, and described and figured what he apparently took to be young schizonts. Mackie (1914) called attention to the fact that gametocytes were very numerous in his material, while young ring forms were not common. The last-named author's figures are not very informative, and, as Bearup and Lawrence (1946) suggested, his "schizonts," together with those referred to by Breinl, might well have been male gametocytes. Manwell (1946) described pigment-free, extracellular segmenters and schizonts from his smears of the peripheral blood of *Pteropus gouldi.* Neither Bearup and Lawrence (1946) nor McGhee (1949) found segmenters or exoerythrocytic forms in the blood or organs of the bats which they examined, although these authors studied a large number of infected specimens.

The present account is based on material from two heart-blood smears from a heavily parasitized mature example of *Pteropus nawaiensis* (Gray) shot in the lower reaches of the Wainimbuka River, Viti Levu, Fiji, during July, 1948. My own visit to this locality in May and June of the following year was a little too early in the season to allow of my obtaining more material from *P. nawaiensis.* The only bat from which I was able to obtain smears was another member of the Pteropodidae, the long-tailed fruit bat *Notopteris macdonaldii* Gray, 135 examples of which were shot in a limestone cave beneath the native village of Kalabo, a few miles inland from the mouth of the Nasinu River. None of these bats, which were representative of all ages, were parasitized by haematozoa. Fifty of the nycteribiids with which they were infested likewise proved negative for these parasites.

The cytoplasm of the signet ring forms of *Plasmodium pteropi* (Figs. 3–9) stains a very pale blue with Giemsa, while the nucleus, which is usually somewhat reniform in shape (Figs. 5–7), stains deep red. Appreciable hypertrophy of the host cell (Fig. 8) is very seldom apparent. More usually the size of a parasitized cell remains unchanged (Fig. 3, etc.), but sometimes (Figs. 4, 7, etc.) it is distinctly less than that of the smallest uninfected erythrocytes of the host (Fig. 2). Such a reduction in size of parasitized host cells is characteristically found in *Plasmodium malariae* infections (Wenyon, 1926). The diameter of the ring forms ranges from 1.9μ to 3.7μ, averaging 2.2μ, while the size of nuclei of the reniform type ranges from 0.8μ by 0.4μ to 2.2μ by 0.5μ. Double infections by small ring forms (Fig. 9) are common. The cytoplasm of two ring forms may fuse in such a way as to simulate early stages of schizogony (Figs. 10, 11). Partial nuclear fusion may also take place, giving rise to an appearance (Figs. 12, 13) strongly suggestive of the band forms characteristic of *Plasmodium malariae.* It is possible that the

parasites interpreted by Breinl and Mackie as young schizonts may in reality have been such fused ring forms. A thorough search of my material failed to reveal the presence of any schizonts whatever.

Growth beyond the signet ring stage may be initiated by a reduction in size of the vacuole associated with a broadening and slight vacuolation of the cytoplasmic ring (Fig. 14), or by the formation of anastomoses (Figs. 15–18). Some developing gametocytes (Figs. 19, 20) still preserve the large vacuole of the signet ring



TEXT-FIGURE 1

Figs. 1 and 2: Erythrocytes of *Pteropus nawaiensis* (Gray). Figs. 3–36: *Plasmodium pteropi* Breinl, 1913, from *P. nawaiensis*. Fig. 37: Erythrocyte of *Salarias periophthalmus* Val. Figs. 38 and 39: *Haemogregarina salariasi* n.sp., from *S. periophthalmus*.

stage, although their cytoplasm has increased very considerably in bulk. The fact that the nucleus of such forms is intimately connected with this vacuole suggests a likely origin of the vacuole associated with the nucleus of many older gametocytes (Figs. 22, 23, 33, 35, etc.). Rodhain (1926) stated that a similar clear area is associated with the gametocyte nucleus of *Plasmodium epomophori*. The cytoplasm of young macrogametocytes stains a deep greenish-blue and contains numerous small vacuoles (Figs. 22, 23, etc.). A varying number of rather fine pigment granules are present, the earliest stage encountered showing pigment being that illustrated in Fig. 19. These granules are of a dark golden-brown colour. The cytoplasm of erythrocytes containing older gametocytes is often apparent only as an uneven rather dark staining pellicle surrounding the parasite, as Breinl (1913) has already pointed out (Figs. 22, 23, 35, etc.). Rodhain (1926) remarked that gametocytes of *Plasmodium epomophori* completely replace the cytoplasm of the host erythrocyte, so that no trace of the outline of the cell is left.

Macrogametocytes of *P. pteropi* (Figs. 21–30) are usually round or more or less ovoid in shape. A few band forms (Fig. 25) occur, and these again call to mind the very similar forms of *Plasmodium malariae*. The cytoplasm of macrogametocytes of *P. pteropi,* unlike that of the equivalent stages of *Plasmodium epomophori,* often contains small vacuoles. The nucleus is compact, and stains densely. This structure is of irregular outline, and is often rather cruciform in shape (Figs. 22, 23, etc.). Both the cytoplasm and the nucleus of the largest macrogametocytes (Fig. 30) are lighter staining than in the smaller examples, the pigment granules are more apparent, and the cytoplasm is differentiated into light and dark staining areas. These facts suggest the possibility that such large forms may have been somewhat distorted during the smearing or drying operations. Macrogametocytes range in size from 4.4μ by 3.1μ to 7.6μ by 6.0μ, and average 5.4μ by 4.5μ.

Microgametocytes (Figs. 31–36) are also round to ovoid in shape. The cytoplasm takes a very light blue stain, finely diffuse pigment often giving large areas of it a light golden colour (central shaded area, Fig. 31). The nucleus is larger than that of the macrogametocyte, and is frequently marginal in position (Figs. 31, 33). Those microgametocytes which appear to be most mature have a triangular nucleus (Figs. 34, 36), which stains very light pink. Microgametocytes of *P. pteropi* differ markedly from those of *Plasmodium epomophori* in regard to the shape of the nucleus, that of the latter species being of regular round or oval shape (Rodhain, 1926). The cytoplasm scarcely stains at all, while numerous rather large pigment granules of a dark golden-brown colour are very conspicuous. Microgametocytes are less variable in size than macrogametocytes, ranging from 4.8μ by 3.8μ to 5.8μ by 5.0μ and averaging 5.3μ by 4.6μ.

The search for the vector of *Plasmodium pteropi* has so far proved fruitless. The uniformly negative results of Bearup and Lawrence (1946) and McGhee (1949) in their examination of ectoparasitic Nycteribiidae from fruit bats infected with *P. pteropi* do not support Manwell's (1946) suggestion that by analogy with the hippoboscid transmission of *Haemoproteus* such ectoparasites might prove to be the vectors. At all events the present record serves to eliminate *Anopheles* from the search, as mosquitoes of this genus do not occur in Fiji. Perhaps further studies aimed at the examination of day-biting jungle mosquitoes which are in a position to be able to bite the bats in their roosting places might be productive of more fruitful results.

Both the smears from *Pteropus nawaiensis* discussed in this account are in the author's private collection (catalogue numbers HP1 and HP2).

Dirofilaria immitis (Leidy, 1856)

(Text-figure 2, Fig. 2)

Dirofilaria immitis is widespread in Australia and in many of the islands of the South Pacific, although it is not yet established in New Zealand. Of nine dogs examined for this parasite at the veterinary clinic of the Department of Agriculture, Suva, during June, 1949, five proved to be infected.

The measurements of the microfilariae from the blood of these dogs compare favourably with those given by Mönnig (1934). Averages obtained from the measurement of ten examples are given below. The figures in parentheses are those quoted by Mönnig, from the records of various authors. The distance figures given in every case express the percentage of the total body length.

Distance of nerve ring from anterior extremity	21.4%	(21.4% and 22.8%)
Distance of excretory pore from anterior extremity	31.0%	(29.3% and 31.0%)
Distance of anal pore from anterior extremity	77.1%	(74.4% and 77.8%)
Distance of last tail cell from anterior extremity	91.1%	(90.9% and 92.0%)
Total length of body	223.3μ	(218.0μ–239.0μ)

The embryos of *D. immitis*, being unsheathed, stain very densely with Giemsa. Consequently, it is seldom possible to differentiate the excretory cell and the genital cells in examples from my Fijian material, although the other structural features of taxonomic significance and the cuticular annulations appear to advantage (Fig. 2).

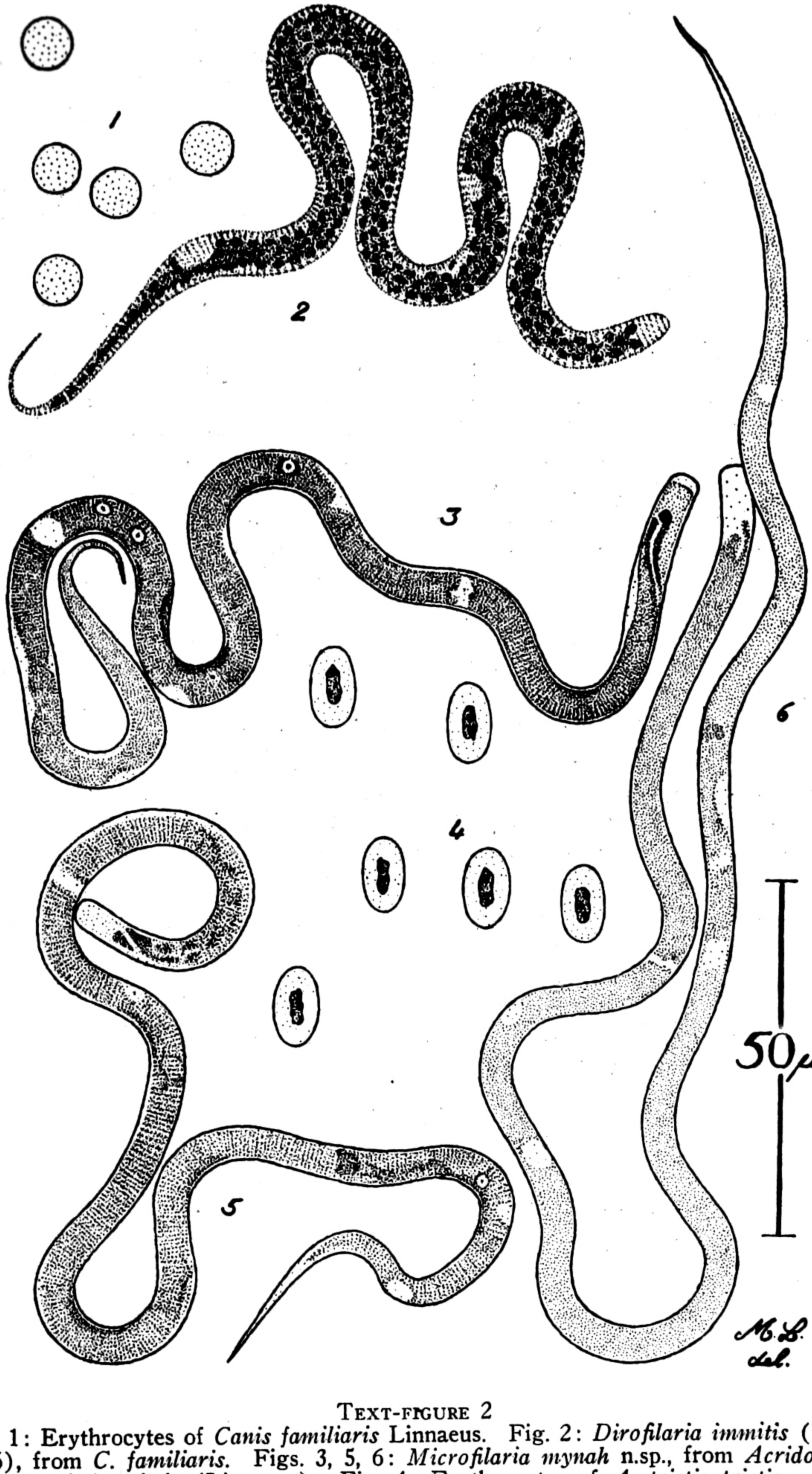
Among the mosquitoes listed by Del Rosario (1936) as known intermediary hosts for *D. immitis* are *Aëdes aegypti* (Linnaeus), *Culex fatigans* Wiedemann (Australia), and *Aëdes vexans* Meigen (Italy). These three species all occur in Fiji. Recent work (Summers, 1940, 1943) has indicated that fleas may play a more important role as vectors of *D. immitis* than has generally been realized. The species involved, *Ctenocephalides canis* (Curtis), *C. felis* (Bouché) and *Pulex irritans* Linnaeus are all found in Fiji. Pre-natal infection has also been known to occur (Augustine, 1938).

Microfilaria mynah n.sp.

(Text-figure 2, Figs. 3–6)

This parasite is described from the heart-blood of one of four examples of the mynah *Acridotheres tristis tristis* (Linnaeus), shot in the lower reaches of the Wainimbuka River, Viti Levu, on 15th June, 1949. The host bird has become well established in Fiji, having originally been introduced from India. *Microfilaria* Cobbold is used here in the sense of a collective name for young larval Filarioidea occurring in the blood of vertebrates. The infection was a moderately heavy one, a total of eight larvae being present in the three smears taken from the parasitized bird. No adult nematodes were encountered.

Microfilaria mynah is a very long, sheathed filarial larva, bluntly truncated anteriorly and tapering to a fine point posteriorly. The nuclear column stains light blue with Giemsa, appearing as a more or less homogeneous mass. Individual somatic cells are only occasionally distinguishable, towards the anterior extremity (Fig. 5). Cuticular annulations are readily apparent. Among the non-staining



TEXT-FIGURE 2

Fig. 1: Erythrocytes of *Canis familiaris* Linnaeus. Fig. 2: *Dirofilaria immitis* (Leidy, 1856), from *C. familiaris*. Figs. 3, 5, 6: *Microfilaria mynah* n.sp., from *Acridotheres tristis tristis* (Linnaeus). Fig. 4: Erythrocytes of *A. tristis tristis*.

portions of the body the nerve ring and the excretory and anal pores may always be distinguished. The excretory and genital cells (Fig. 3) can seldom be clearly seen. The average and range of the various dimensions of the examples studied are as follows, the distance figures given in every case expressing the percentage of the total body length:—

Distance of nerve ring from anterior extremity	21.3%	(20.1%–23.4%)
Distance of excretory pore from anterior extremity	29.4%	(27.3%–32.3%)
Distance of anal pore from anterior extremity	82.3%	(80.6%–83.8%)
Greatest breadth of body	5.8μ	(5.6μ–6.0μ)
Total length of body	320.5μ	(265.5μ–359.9μ)

Plimmer (1913) was the first to record microfilariae from the blood of *Acridotheres tristis*, the host having died in the Gardens of the Zoological Society of London. Beyond stating that the embryos of his parasite were long and thin, he published no further description. Mello (1936) described *Microfilarium acridotheris* from the same host in India. *M. acridotheris* is of much shorter length than *M. mynah* (90.0μ–120.0μ, as compared with 265.5μ–359.9μ). This fact is not necessarily of taxonomic significance, for the length of individual species of embryo filariae in the blood of birds often varies greatly. Thus Coles (1914) found the microfilariae in the blood of English blackbirds and thrushes to vary from 140μ to 400μ in length. However, *M. acridotheris* differs from *M. mynah* in that its anterior extremity is enlarged comparatively to the breadth of the body, whereas in the latter species the width of the body in this area remains uniform. Also, the posterior extremity, which tapers to a fine point in *M. mynah*, is either obtusely pointed or abruptly truncated in *M. acridotheris*.

The microfilaria of *Acridotheres tristis tristis* in Fiji cannot be identified with any of the avian species already described, the published accounts of many of which are in any case very incomplete, and differs from *M. acridotheris* Mello as outlined above. It is hence designated *Microfilaria mynah* n.sp., having the features set out in this account.

The type slide of *Microfilaria mynah* has been deposited in the collection of the Dominion Museum, Wellington (catalogue number Z200), while two paratypes are in the author's private collection (catalogue numbers NF1–2).

LIST OF THE ANIMALS EXAMINED FOR HAEMATOZOA WITH NEGATIVE RESULTS

TABLE I

(An asterisk * denotes a non-indigenous species)

Systematic position	Number examined	Locality
ELASMOBRANCHII		
Dasyatidae (Stingrays)		
Taeniura lymma (Forskal)	1	Lauthala Bay
PISCES		
Clupeidae (Herrings)		
Harengula punctata Rüpell	1	Lauthala Bay
Echidnidae (Morays)		

Systematic position	Number examined	Locality
Lycodontis picta (Ahl)	4	Makuluva Reef
Hemiramphidae (Halfbeaks)		
Hemiramphus erythrorinchus Le Sueur	3	Lauthala Bay
Sygnathidae (Pipefishes)		
Choeroichthys sculptus (Günther)	3	Makuluva Reef
Mugilidae (Mullets)		
Mugil vaigiensis Quoy and Gaimard	4	Suva
Carangidae (Crevalles)		
Trachinotus blochii (Lacépède)	3	Nandi
Leiognathidae (Pouters)		
Leiognathus fasciatus (Lacépède)	40	Nandi
Serranidae (Sea Basses)		
Serranus merra (Bloch)	18	Makuluva Reef
Lutjanidae (Snappers)		
Lutjanus marginatus (Cuvier)	3	Lauthala Bay
Lutjanus vaigiensis (Quoy and Gaimard)	1	Lauthala Bay
Pomadisidae (Grunts)		
Plectorhinchus orientalis (Bloch)	3	Makuluva Reef
Gerridae (Mojarras)		
Gerres oyena (Forskal)	24	Nandi
Mullidae (Surmullets)		
Upeneoides vittatus (Forskal)	2	Suva
Hepatidae (Tangs)		
Hepatus triostegus (Linnaeus)	14	Makuluva Reef
Hepatus elongatus (Lacépède)	4	Makuluva Reef
Scorpaenidae (Rock Fishes)		
Sebastapistes bynoensis (Richardson)	13	Makuluva Reef
Labridae (Wrasses)		
Halichoeres timorensis (Blecker)	2	Makuluva Reef
Callyodontidae (Parrot Fishes)		
Callyodon dussumieri Valenciennes	1	Makuluva Reef
Gobiidae (Gobies)		
Periophthalmus koelreuteri (Pallas)	7	Lauthala Bay
Blenniidae (Blennies)		
Salarias fasciatus (Bloch)	17	Makuluva Reef
Ostraciidae (Trunk Fishes)		
Ostracion sp?	1	Makuluva Reef
Tetrodontidae (Puffers)		
Tetrodon nigropunctatus Schneider	24	Lauthala Bay
AMPHIBIA		
Bufonidae (Toads)		
**Bufo marinus* (Linnaeus)	59	Lauthala Bay
REPTILIA		
Geckonidae (Geckoes)		
Gehyra oceanica Gray	9	Makuluva Island
Gonatodes kendalli (Gray)	2	Suva
Lepidodactylus lugubris (Gray)	4	Lauthala Bay
Peropus mutilatus Gray	8	Lauthala Bay and Makuluva Island

Systematic position	Number examined	Locality
Iguanidae (Iguanas)		
Brachylophus fasciatus Gray	2	Samabula, Suva
Scincidae (Skinks)		
Ablepharus boutonii (Gray)	2	Nandi
Lygosoma cyanurus (Gray)	1	Lauthala Bay
AVES		
Columbidae (Pigeons and Doves)		
**Streptopelia chinensis tigrina* Temminck	3	Wainimbuka River
Pycnonotidae (Bulbuls)		
**Pycnonotus cafer bengalensis* Blyth	4	Lauthala Bay
Muscicapidae (Flycatchers and Whistlers)		
Pachycephala pectoralis graeffii Hartlaub	1	Lauthala Bay
MAMMALIA		
Pteropodidae (Fruit Bats)		
Notopteris macdonaldii Gray	135	Kalabo Village
Muridae (Rats, Mice, etc.)		
**Mus musculus* Linnaeus	2	Lauthala Bay
Felidae (Cats)		
**Felis domestica* Brisson	1	Lauthala Bay
Suidae (Pigs)		
**Sus scrofa* Linnaeus	10	Tamavua, Suva
Bovidae (Cattle, etc.)		
**Bos taurus* Linnaeus	35	Tamavua, Suva

DISCUSSION

With the exception of a myxosporidian (*Hemeguya vitiensis* Laird, 1950), which was recorded from 12 of the 40 examples of *Leiognathus fasciatus* (Lacépède) examined, *Haemogregarina salariasi* n.sp. was the only protozoan found in the blood of marine fish during the present survey. The former parasite not being haematozoan (*sensu stricto*), it will not be considered further here. Thus, from the fact that only one (0.5 per cent.) of the 205 examples of 24 species studied was parasitized, the haematozoan fauna of Fijian marine fish appears to be a singularly poor one. This is emphasized by the results (as yet unpublished) of a recent survey of the haematozoa of New Zealand marine fish, in the course of which blood smears from 365 fish belonging to 45 species were studied. Fifty-six (15.5 per cent.) of these fish of 10 (22 per cent.) of the species concerned were infected with trypanosomes, and 35 (9.5 per cent.) of 8 (18 per cent.) of them were infected with haemogregarines. The overall total of the 365 fish parasitized by haematozoa was 81 (22 per cent.), 12 (26.5 per cent.) of the 45 species dealt with acting as hosts. However, the great majority of the New Zealand marine fish studied were of oceanic occurrence, and it was from species in this category that most of the blood parasites were described; while most of the Fijian fish from which smears were taken were reef- or shore-dwelling forms. Thus, although none of the few oceanic fish examined in Fiji were infected with haematozoa, perhaps a more comprehensive study might reveal the presence of these parasites.

Most marine fish from which haematozoa have been described dwell outside the tropics. There thus appears to be a possibility that the haematozoan fauna of marine fish is richer in temperate than in tropical waters. With the qualification mentioned above, the evidence from my surveys in New Zealand and Fiji supports this hypothesis. Nevertheless, in view of our present very patchy knowledge of this interesting group of parasites, and our almost complete ignorance of their vectors, it is too early to generalize. A map purporting to show the geographical distribution of marine fish haematozoa, constructed from the information at present available, would more truly depict the distribution of parasitologists interested in this group rather than that of the group itself.

Bufo marinus Linnaeus, a native of Central and South America, was the only amphibian studied. All the specimens handled, 59 examples of all ages, proved negative for haematozoa. In French Guiana this toad is parasitized by *Haemogregarina cayennensis* Leger (1918), *H. darlingi* Leger (1918a), and *Lankesterella minima* (Chaussat) (Leger, 1918a). In infections with any of these haematozoans, the natural parasite level is usually very low. Being aware of this, I examined the whole area of each of my *B. marinus* smears, using a x5 ocular and x97 oil-immersion objective. Had parasites been present, even in very scanty numbers, they would certainly have been detected. *B. marinus* has been introduced into many of the islands of the Pacific because of its value as an agent in the control of insects of economic importance. The stock originally imported into Fiji came not from America, but from Hawaii. It would be of considerable interest to learn whether or not any of the blood parasites which have been recorded from this toad in America occur today in Hawaii; for somewhere along the line of introductions the Fijian stock of *B. marinus* would appear to have become freed from haematozoans, possibly as a consequence of the absence of suitable invertebrate hosts from the new habitats.

No parasites were found in the blood of any of the 28 reptiles belonging to 7 species which were examined. Although this is rather surprising in view of the general prevalence of saurian haematozoa, particularly haemogregarines, in the tropics, too few reptiles were dealt with for any significant conclusions to be drawn.

Although the only example of the fruit bat *Pteropus nawaiensis* (Gray) studied was heavily infected with *Plasmodium pteropi* Breinl, 135 examples of the long-tailed fruit bat *Notopteris macdonaldii* Gray proved uniformly negative for this or any other blood parasite. *Plasmodium pteropi* characteristically has a high natural infection rate—at least, among adult fruit bats. Thus Bearup and Lawrence (1946) found a 100 per cent. infection rate for 25 adults of *Pteropus gouldi,* a 91 per cent. rate for 11 adults of *P. scapulatus,* and an 83 per cent. rate for 18 adults of *P. conspicillatus* in Queensland, Australia; while McGhee (1949) found a 100 per cent. infection rate for 92 examples of *P. geddiei* and *P. eotinus* at Espiritu Santo, New Hebrides. Twenty of the examples of *Notopteris macdonaldii* from which smears were examined were juveniles, while the remaining 115 were adults. Some at least of such a number might be expected to be parasitized were this species indeed a host for haematozoa. In contrast with his findings for fruit bats, McGhee (1949) failed to find any haematozoa in 100 examples of *Hipposideros cervinus* (Rhinolophidae). Whether this apparent species immunity in bats dwelling in close association with species heavily infected with *Plasmodium* has a biological or physiological explanation, poses an interesting problem for future investigation.

In the case of *Pteropus nawaiensis* and *Notopteris macdonaldii,* a possible explanation might lie in the predominantly forest-roosting habit of the former species as opposed to the cave-dwelling habit of *N. macdonaldii.* Should the vector of *Plasmodium pteropi* prove to be a day-biting forest mosquito, it would obviously not have access to *Notopteris macdonaldii* in the normal course of events.

LITERATURE CITED

AUGUSTINE, D. L., 1938.—Observations on the occurrence of heartworms, *Dirofilaria immitis* (Leidy, 1856), in New England dogs. *Amer.Jour. Hyg.*, 28 (3), 390–395.

BEARUP, A. J., and LAWRENCE, J. J., 1946.—A search for the vector of *Plasmodium pteropi* Breinl. *Proc.Linn.Soc.N.S.W.*, 71 (3–4), 197–200.

BHATIA, B. L., 1938.—Protozoa: Sporozoa. The Fauna of British India. Taylor & Francis, Ltd., London. i–xx + 1–497.

BREINL, A., 1913.—Parasitic protozoa encountered in the blood of Australian native animals. *Rep.Austr.Inst.Trop.Med.for 1911,* (Apr., 1913), 30–38.

COLES, A. C., 1914.—Blood parasites found in mammals, birds, and fishes in England. *Parasitol.*, 7 (1), 17–61.

DONOVAN, C., 1920.—Malaria of monkeys. At the foot of the Nilgiris. During the months of May and June, 1919. *Ind.Jour.Med.Res.*, 7 (4), 717–721.

DURHAM, H. E., 1908.—Notes on nagana and on some haematozoa observed during my travels. *Parasitol.*, 1 (3), 227–235.

FANTHAM, H. B., 1930.—Some parasitic protozoa found in South Africa—XIII. *S.Afr.Jour.Sci.*, 27, 376–390.

KOHL-YAKIMOFF, N., and YAKIMOFF, W. L., 1915.—Hämogregarinen der Seefische. *Zbl.Bakt.*, I Abt., 76, 135–146.

LAIRD, M., 1950.—*Hennegnya viticnsis* n.sp., a myxosporidian from a Fijian marine fish, *Leiognathus fasciatus* (Lacépède, 1803). *J.Parasit.*, 36 (4), 285–292.

LAVERAN, A., and MESNIL, F., 1901.—Deux espèces nouvelles d'hémogrégarines des poissons. *C.R.Acad.Sci.Paris,* 133, 572–577.

LEGER, A., and LEGER, M., 1914.—Sur un *Plasmodium* de la roussette du Haut-Sénégal et Niger. *C.R.Soc.Biol.Paris,* 77, 399–401.

LEGER, M., 1918.—Hémogrégarine de *Bufo marinus* L. *Bull.Soc.Path.exot.*, 11, 687–690.

————, 1918a.—Hémogrégarines de crapauds à la Guyane française. *Ibid.*, 788–791.

MCGHEE, R. B., 1949.—The occurrence of bat malaria in the New Hebrides and Philippine Islands. *J.Parasit.*, 35 (5), 545.

MACKIE, F. P., 1914.—Note on the parasite of bat malaria. *Ind.Jour.Med.Res.*, 2, 375–376.

MANWELL, R. D., 1946.—Bat malaria. *Amer.Jour.Hyg.*, 43 (1), 1–12.

MELLO, I. F. DE, 1936.—Further contribution to the study of the blood parasites of the Indian birds, together with a list of the hemoparasites hitherto recorded. *Jour.Roy.Asiatic Soc.Bengal,* Science 2 (2), 95–122.

MONNIG, H. O., 1934.—Veterinary Helminthology and Entomology. London, 1–402.

PLIMMER, H. G., 1913.—Report on the deaths which occurred in the Zoological Gardens during 1912, together with the blood-parasites found during the year. *Proc.Zool.Soc.Lond.*, 1913, 141–149.

RODHAIN, J., 1926.—*Plasmodium epomophori,* n.sp., parasite commun des rousettes épaulières au Congo Belge. *Bull.Soc.Path.exot.*, 19, 828–838.

ROSARIO, F. DEL, 1936.—*Dirofilaria immitis* (Leidy) and its culicine intermediate hosts in Manila. I. *Phil.J.Sci.*, 60 (1), 45–57.

SCOTT, H. H., 1927.—Report on the deaths occurring in the Society's Gardens during the year 1926. *Proc.Zool.Soc.Lond.*, 1927, 173–198.

SUMMERS, W. A., 1940.—Fleas as acceptable intermediate hosts of the dog heartworm, *Dirofilaria immitis. Proc.Soc.Exp.Biol.and Med.*, 43 (3), 448–450.

————, 1943.—Experimental studies on the larval development of *Dirofilaria immitis* in certain insects *Amer.Jour.Hyg.*, 37 (2), 173–178.

WENYON, C. M., 1926.—Protozoology. Baillière, Tindall & Cox, London. Vol. 2, ix + 779–1563.

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