Some Blood Parasites of New Zealand Birds*

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INTRODUCTION

Our previous knowledge of the blood parasites of New Zealand birds is summarized in Table 1.

TABLE 1

(An asterisk denotes that the host is non-indigenous.)

Systematic position of host	Common name of host	Parasite	Reference
AVES SPHENISCIFORMES			
Spheniscidae			
Megadyptes antipodes (Hombron and Jacquinot, 1841)	Yellow-crowned penguin	*Plasmodium relictum* (Grassi and Feletti, 1891) var. *spheniscidae* Fantham and Porter, 1944.	Fantham and Porter, 1944
PASSERIFORMES			
Turdidae			
**Turdus ericetorum* (Turton, 1807)	Song thrush	*Haemoproteus danilewsky?* *Plasmodium* sp.?	Doré, 1920
**Turdus merula* Linnaeus, 1758	Blackbird	*Haemoproteus danilewsky?* *Plasmodium* sp.?	Doré, 1920
Alaudidae			
**Alauda arvensis* Linnaeus, 1758	Skylark	*Haemoproteus danilewsky?* *Plasmodium* sp.?	Doré, 1921
Motacillidae			
Anthus novaeseelandiae (Gmelin, 1789)	Pipit	*Plasmodium* sp.?	Doré, 1920a

A survey of the haemotozoa of New Zealand animals carried out during 1947–48 resulted in the confirmation and amplification of these earlier records, with the exception of those concerning *Alauda arvensis* and *Anthus novaeseelandiae* from which no material was examined. In the following pages the results of this survey are discussed and host and parasite records new to this country are given.

MATERIAL AND METHODS

Birds examined for haematozoa were collected by trapping, by searching beaches after storms, and in the case of unprotected species, by shooting. Useful material was obtained from birds trapped by members of the Ornithological Society of New Zealand during routine banding work. Blood smears were taken from the birds concerned by pricking one of the superficial vessels of the leg, this method being used with large numbers of even small species such as *Zosterops lateralis* (silvereye) without causing them any ill effects. It should be made clear, however, that this method, although desirable in the case of rare and protected birds, is not productive of the best results. Some *Leucocytozoon* and *Toxoplasma* infections are liable to be overlooked unless smears are made from the heart blood, as is suggested by the fact that the only one of 124 specimens of *Zosterops lateralis*

found positive for *Toxoplasma* was the only specimen from which heart blood smears were examined.

During the 1947 shooting season, blood smears were taken from game birds by visiting shooters' camps in the vicinity of Lake Wairarapa. The discovery of a very light *Plasmodium* infection in an example of *Anas poicilorhyncha* (grey duck) led to the development of a small self-contained collecting outfit, numbers of which were distributed among the members of the various Acclimatization Societies in time for the 1948 shooting season in an effort to obtain more material of the haematozoan. Each set consisted of eight numbered slides, a spreading slide, and a glass rod for transferring blood from specimens to slide, packed together with a printed sheet for field notes and a printed sheet of directions in a small cardboard box. Although no additional positive slides were so obtained, and many of the slides returned to the laboratory were too dirty or too poorly prepared to be of use, sufficient usable smears (some 60 per cent. of the total of 640) were returned to recommend the distribution of collecting sets to interested laymen as a useful auxiliary to other collecting methods in haematozoan surveys.

Thin blood and organ smears were made on 3 in. x 1 in. microscopic slides, air-dried, fixed in absolute methyl alcohol, and stained with Giemsa. They were left uncovered and examined under a x5 ocular and a x97 oil immersion objective. All figures were drawn with the aid of an Abbé camera lucida at a magnification of 2,400, a x15 ocular being substituted for the x5 used in searching.

Haemoproteus danilewsky Kruse, 1890

Plate 1, Figs. 1–12

Members of the genus *Haemoproteus* Kruse, 1890, reproduce asexually in the endothelial cells of the blood vessels of the host. The only forms found in the blood are the gametocytes, which enter erythrocytes when young and develop within these cells. As the blood thus contains only sexual stages which must be taken up by an invertebrate host before further development can be undergone, it is impossible to investigate the susceptibility of various species of host to a particular species of *Haemoproteus* by means of inoculation (Wenyon, 1926). Thus many species have been described as new on the basis of their being found in a new host, although it is likely to prove eventually, by analogy with *Plasmodium* in birds, that many of these will fall as synonyms to some of the earlier described species of the genus.

Haemoproteus danilewsky was described by Kruse (1890) from the European grey crow *Corvus cornix*. Parasites inseparable from *H. danilewsky* on morphological grounds have since been described from other hosts. Coatney and West (1938) record the species from the American eastern crow *Corvus branchyrhyn-*

chos, and expand the original description, which was based on material stained with methylene blue, in the light of modern staining methods.

Doré's (1920) record of *Haemoproteus* (*danilewsky*) from *Turdus ericetorum* is now confirmed, after an examination of one of his preparations in the Victoria College collection and of fresh material. This latter material consists of a single lightly-infected preparation (averaging 1 parasite per 10,000 erythrocytes) from each of the species *Turdus ericetorum* (eight specimens examined) and *Turdus merula* (14 specimens examined). Both parasitized birds were shot at Mangere, 10 miles from Auckland, in July, 1947, and both had light infections of *Plasmodium relictum* (Grassi and Feletti, 1891). *H. danilewsky* is already known from *Turdus merula* in Europe (Cardamatis, 1909).

Doré (1920) recorded (*Halteridium*) = *Haemoproteus* from both the above hosts, the birds being shot at Kimihia, some 60 miles south of Auckland, in February, 1917. Approximately 5 per cent. of the birds examined were infected, the percentage of infected cells ranging from 5 to 12 per cent. Doré tentatively identified his *Haemoproteus* as *H. danilewsky*, and subsequently recorded what he considered to be the same species of parasite from *Alauda arvensis*. Of birds of this species shot at Kimihia in January, 1921, 3 per cent. were parasitized, some very lightly (fewer than 12 parasites per slide). Cardamatis (1909) recorded *H. danilewsky* from *Alauda arvensis* in Greece, while a further species, *Haemoproteus alaudae* (Celli and San Felice, 1891), had already been described from this host in Italy. Danilewsky (1889)*, Wasielewsky (1908)*, and Coles (1914) all list undesignated representatives of the genus *Haemoproteus* from *Turdus ericetorum* in various parts of Europe.

The younger gametocytes of *H. danilewsky* (Pl. 1, Fig. 2) have no pigment. Microgametocytes in my preparations range from 10.7 to 18.0μ in total length, and from 1.8 to 2.3μ (the approximate limit of the available space between the cell membrane and nuclear membrane of the host cell) in breadth at the nucleus. The cytoplasm is lightly vacuolated, and appears whitish-blue to pale blue with Giemsa, while the diffuse nucleus, usually central in position, stains pale pink. This latter structure may be ovoid (Pl. 1, Figs. 3 and 4) or irregular (Pl. 1, Fig. 6) in shape, but is more usually elongate, extending along one side of the parasite only (Pl. 1, Fig. 5) or occupying the full width of the body (Pl. 1, Figs. 7 and 8). The pigment granules are round to ovoid in shape and irregular in size, the number present ranging from 9 to 18 and averaging 14. Macrogametocytes range in total length from 10.2 to 23.0μ, and in breadth at the nucleus from 1.5 to 2.3μ. The cytoplasm is lightly vacuolated and stains deep blue, and the centrally placed nucleus is a compact structure round to ovoid in shape and staining deep

*According to Coatney, 1936.

pink. The pigment granules resemble those of the microgametocytes, and range in number from 11 to 20, with an average of 16.

Both microgametocytes and macrogametocyetes are typically C-shaped when fully developed (Pl. 1, Figs. 8 and 11). A few large macrogametocytes surround the host cell nucleus and almost completely fill the available space between the cell and nuclear membranes (Pl. 1, Fig. 12). The host erythrocyte does not show marked hypertrophy. Those cells appearing longer and thinner than the others in Pl. 1 (Figs. 7 and 9) are from a part of the preparation showing longitudinal distortion of erythrocytes as a result of the smearing process. The only case of double infection observed, in which the host cell contains a developing microgametocyte and a developing macrogametocyte, is illustrated in Pl. 1, Fig. 9.

H. danilewsky from *Turdus ericetorum* and *T. merula* agrees in all essentials of its morphology with the parasite described from *Corvus* by Kruse (1890) and Coatney and West (1938). In overall dimensions it is slighly smaller than the parasite studied by the latter authors, whose figure of 5.28μ for the greatest width of the microgametocyte I find hard to credit unless this is intended to represent the width of a large specimen clear across the host cell and not the true width of the body between the cell and nuclear membranes of the host erythrocyte. My average granule counts of 15 and 16 for microgametocytes and macrogametocytes respectively, compare favourably with those of Coatney and West, 17 and 15. It appeared from Doré's (1920) figure of 10μ for the average length of his *Haemoproteus* from *Turdus ericetorum,* and from his rough sketches of this parasite, that his measurements must have been made in a straight line between the end limits of the body instead of following the curving centre line. This was found to be the case on a re-examination of one of Doré's slides in the Victoria College collection.

No smears were obtained from *Alauda arvcnsis* during the survey, and none of Doré's slides of the *Haemoproteus* from this host could be found in the small collection of his material at the Dominion Museum, Wellington. There is nothing in Doré's (1921) description to separate this parasite from *H. danilewsky,* but opinion must be withheld until fresh material has been obtained and compared with the descriptions of *H. danilewsky* and of *H. alaudae.*

Leucocytozoon fringillinarum Woodcock, 1910

Plate 1, Figs. 13–22

Leucocytozoon fringillinarum was described by Woodcock (1910) from the blood of three chaffinches, *Fringilla coelebs,* in England. A year later Prowazek* quotes Schaudinn as recording this parasite from the same host in Berlin. The present infection is recorded from an adult specimen of the type host which was

*According to Wenyon, 1926.

obtained in Wellington in a dying condition in May, 1947. It is doubtful whether the presence of the parasite was more than a contributory factor towards the death of the bird, as the infection is a light one (fewer than 30 parasites per slide). Smears from two other chaffinches collected in Wellington in February, 1948, were negative for haematozoa.

Huff (1942) states that young gametocytes of *L. simondi* are found in lymphocytes, monocytes, myelocytes, and polychromatophile erythroblasts, and that the cells containing fully grown gametocytes appear to be macrophages. Host cells of leucocytozoa undergo rapid changes in the initial stages of invasion by the parasites, making it far from clear in many cases whether erythroblasts, mononuclear leucocytes or both kinds of cell are involved, as de Mello (1936) points out. Woodcock (1910) himself states that the host cell is " . . . undoubtedly a uninucleate leucocyte, and not an immature red cell or erythroblast. . . ." He bases this conclusion on the superficial resemblance of the most recently invaded cells to leucocytes rather than to erythroblasts, as seen in Romanowsky-stained material. Two polychromatophile erythroblasts are illustrated in Pl. 1, Figs. 13 and 14. These cells have deep blue staining cytoplasm and a large nucleus with many chromatin blocks, which is placed more or less centrally. It is true that, as Woodcock (1910) says, cells recently parasitized by *L. fringillinarum* have an eccentric nucleus with a few large chromatin masses and light blue staining cytoplasm, strongly suggestive of the normal condition of the mononuclear leucocyte. Nevertheless, hypertrophy of the nucleus accompanied by a marked change in the condition of its chromatin, together with displacement of this structure towards the side of the cell distant from the *Leucocytozoon*, might well be an early consequence of the invasion of an erythroblast. The staining reaction of the host cell cytoplasm—which in the earlier stages of infection (Pl. 1, Fig. 17) resembles that of later erythroblasts (Pl. 1, Fig. 15) as closely as that of leucocytes—similarly does not necessarily indicate leucocyte affinities. During the course of an infection, this staining reaction becomes less and less marked, until the cytoplasm appears as an ill-defined blue band at the periphery of a whitish area (Pl. 1, Fig. 21) and finally disappears altogether (Pl. 1, Figs. 20 and 22). Wingstrand (1947) established that the kidney shape of the nucleus of a cell parasitized by *Leucocytozoon* is marked at as early a stage of infection as when the parasite measures only 1μ in diameter. This author states that "in the few cases when I have been able to establish its identity the parasitized cell has been an erythroblast." I do not believe that there are sufficient grounds for considering the host cells of *L. fringillinarum* in my material to be leucocytes; and regard them as erythroblasts, the normal development of which has been grossly altered by some agent secreted by the parasite during the early stages of infection.

The genus *Leucocytozoon* embraces two distinct types of parasite, which de Mello (1936) maintains are sufficiently clear-cut to warrant their consideration

as separate genera. The one type is elongated and its host cell is fusiform with tail-like prolongations, while the other is rounded and occupies a cell which does not show any tendency towards this type of hypertrophy. Representatives of the first type, through their habit of rounding off as in preparation for fertilization in the blood of the dead vertebrate host, may become confused with those of the second (Wenyon, 1910). In such cases the relationship of the parasite to the host cell nucleus, and the condition of the host cell itself, which is ruptured and disorganized (Mathis and Léger, 1910), gives evidence of the true nature of the *Leucocytozoon* concerned. *L. fringillinarum* is of rounded form and occupies host cells showing no signs of tail-like prolongations, and thus belongs to the second type of parasite described above.

Male and female gametocytes at all stages of development occur in my material of *L. fringillinarum*. The microgametocytes have rather hyaline cytoplasm which stains a very light blue with Giemsa and is not markedly granular. Small masses of extra-nuclear chromatin may be present (Pl. 1, Figs. 18, 19, 20). The nucleus itself is large and rather diffuse, and stains light pink. Rounded microgametocytes vary in diameter from 3.1μ (youngest form seen) to 9.0μ, in the case of adults, while ovoid forms (Pl. 1, figs. 18, 19, 20) measure from 6.6 by 4.0μ to 8.5 by 4.0μ in their greatest dimensions. The cytoplasm of the macrogametocyte is more granular than that of the microgametocyte, and takes a much darker blue stain. Wingstrand (1947) refers to such well-defined deeply staining cytoplasmic granules as are seen in the fully developed macrogametocyte illustrated in Pl. 1, Fig. 22, as pseudopigment. The nucleus is more compact than that of the microgametocyte, and stains deeply, showing prominent dark red granules. It may be somewhat elongated and of irregular outline in younger forms (Pl. 1, Fig. 17) or appear as a line of granules (Pl. 1, Fig. 21), but in fully developed macrogametocytes (Pl. 1, Fig. 22) it is usually rounded. The size of the macrogametocyte is a little larger than that of the microgametocyte, varying between 4.6 and 10.0μ in diameter in rounded forms and from 7.2 by 5.0μ to 9.5 by 7.0μ in ovoid forms. Woodcock (1910) states that the diameter of rounded individuals averages 8.5 to 9.5μ, the female form attaining a slightly larger size than the male.

The *Leucocytozoon* recorded from *Fringilla coelebs* in Wellington agrees so closely with Woodcock's (1910) description of *L. fringillinarum* from the same host as to leave no doubt that it is conspecific with the latter parasite.

Plasmodium relictum (Grassi and Feletti, 1891)

Plate 2, Figs. 1–12

Doré's (1920) generic record of Plasmodium from *Turdus ericetorum* is now expanded to *Plasmodium relictum* on the basis of an examination of one of his preparations in the Victoria College collection and of fresh material (three of eight thrushes shot at Mangere in July, 1947, one of these birds also being infected

with *Haemoproteus danilewsky* as mentioned earlier). *P. relictum* is also recorded from another of Doré's hosts, *Turdus merula*, two birds shot at Mangere in July, 1947, being infected, out of a total of 14 examined. *Passer domesticus* is now listed as a host for *Plasmodium relictum* for the first time from New Zealand (two out of 11 birds infected, one collected at Mangere in October, 1944, by a member of the staff of the Royal New Zealand Air Force medical laboratory, and one at Wellington in October, 1948). The English sparrow is well known as a host for *P. relictum* in other countries (Coatney and Roudabush, 1936). The parasite rates for all three New Zealand hosts were rather light, averaging fewer than 20 plasmodia per 10,000 erythrocytes.

In addition, an extremely light infection of *Plasmodium* sp? is recorded from one of 210 specimens of *Anas poicilorhyncha*. The parasitized bird was shot near Lake Wairarapa, Wellington, in May, 1947. *Anas poicilorhyncha* is a new host for *Plasmodium*. During these studies no material was examined from *Anthus novaeseelandiae* and *Alauda arvensis*. Doré's description of *Plasmodium* from these hosts are too general to be of much assistance in specific identification, and the slides which he deposited in the Dominion Museum, Wellington, are too badly preserved to be of use in this respect.

Trophozoites of *P. relictum* in my material have rather alveolar cytoplasm staining sky blue with Giemsa, and a small chromatin mass staining bright pink. Ring-forms are some 2μ in diameter, and amoeboid forms (Pl. 2, Fig. 2) measure from 2.8 to 5.6μ by 2.0 to 4.0μ in their greatest dimensions. Three trophozoites only have been found in a smear of the peripheral blood of the specimen of *Anas poicilorhyncha* referred to above. These are elongate reniform bodies (Pl. 2, Fig. 3) of more regular outline than is usual in trophozoites of *P. relictum*. As neither schizonts nor gametocytes are present in the preparation, specific identification cannot be made. Wolfson (1939) inoculated *P. relictum* into ducks (*Anas boschas domestica*), and found that in the first transfer parasites could only be demonstrated by subinoculation of the blood of infected ducks into canaries. At a later stage, gametocytes of *P. relictum* found in the blood of the ducks were atypical, being elongate instead of round. Wolfson suggests that the differences in morphology between *P. relictum* in ducks and other hosts may be due to physico-chemical differences between the red blood cells concerned. From the facts that only one of 210 specimens of *Anas poicilorhyncha* examined for haematozoa was positive for *Plasmodium*, and that the infection is so extremely light and the trophozoites atypical, it appears likely that this duck is not normally a host for *Plasmodium*. The presence of all but the youngest trophozoites of *Plasmodium relictum*, also those of *Plasmodium* sp? of the grey duck, within a red corpuscle, usually causes displacement of the host-cell nucleus to a greater or lesser extent.

Schizonts of *P. relictum* encountered in heart-blood smears from the song thrush (Pl. 2, Figs. 5–9), blackbird, and sparrow (Pl. 2, Fig. 4) have alveolar cyto-

plasm which stains sky-blue and from eight to sixteen chromatin masses staining light to deep pink. A varying amount of brownish black pigment is present. The young red cell containing a schizont with 12 nuclei seen in Pl. 2, Fig. 6, has been engulfed by a large mononuclear leucocyte. This was found in Doré's smear from a song thrush heavily infected with *Plasmodium relictum* and *Haemoproteus danilewsky*. Schizonts vary in size from 4.9 to 7.9μ by 4.0 to 6.0μ. Host cells containing them are often distorted and slightly hypertrophied, and their nuclei are markedly displaced.

Macrogametocytes (Pl. 2, Figs. 10 and 12) have rather dense cytoplasm which stains deep blue and an irregularly shaped nucleus staining deep pink. The pigment granules, which are scattered throughout the cytoplasm, are round or ovoid and variable in size. They are never elongate or rod-like as are those of *Plasmodium cathemerium* (Manwell, 1938). Macrogametocytes are usually round or ovoid in shape, and dimensions range up to 7.0 by 6.5μ. Microgametocytes (Pl. 2, Fig. 11) are somewhat smaller than macrogametocytes. They have rather hyaline cytoplasm which stains light blue, and a diffuse nucleus rather larger than that of the macrogametocytes and staining light pink. The pigment granules resemble those of the macrogametocytes but are fewer in number. Host cells containing gametocytes have their nuclei markedly displaced, and they are usually distorted in outline and slightly hypertrophied.

The *Plasmodium* recorded from *Turdus ericetorum, T. merula* and *Passer domesticus* during the present survey is identified as *P. relictum* from the morphological features seen in Giemsa-stained blood smears. Its gametocytes are round, oval, or irregular in shape, a feature shared by only five well-established species of *Plasmodium* from birds, three of these each being restricted to a single host species (Manwell, 1938). The other two species, *P. relictum* and *P. cathemerium*, may be distinguished by the shape of the pigment granules of the gametocytes, those of the former species being round or ovoid and those of the latter elongate or rod-like. As the pigment granules of the gametocytes of the species under discussion are round or ovoid, this parasite is identified as *P. relictum*.

Plasmodium relictum (Grassi and Feletti, 1891)
var. ***spheniscidae*** (Fantham and Porter, 1944)

Fantham and Porter (1944) described *Plasmodium relictum* var. *spheniscidae* from blood smears taken from four species of penguins in their natural habitats. These authors justified their description of a new variety on the grounds of the large vacuoles of the ring stages, the large size of the schizonts, the high level of intraerythrocytic schizogony together with the low gametocyte level, and the small size of the gametocytes, as compared with the corresponding stages of *Plasmodium relictum* in other hosts. One of the infected birds (*Eudyptes*) = *Megadyptes antipodes* (yellow-crowned penguin) was taken in Foveaux Strait between the South Island and Stewart Island.

During my survey I found the same variety of *P. relictum* in smears taken from one of two examples of *Megadyptes antipodes* in Campbell Island, also in preparations from three of 28 examples of *Eudyptes pachyrhynchus* (drooping-crested penguin) collected at the Snares Islands. The latter host is a new one for *Plasmodium*, and both localities are new. In all cases the infections were very light. This variety of *P. relictum* is mentioned here only because it has previously been recorded from New Zealand, and it is proposed to incorporate a full description of the material from Campbell Island and the Snares Islands in a paper on the haematozoa of the subantarctic islands which is in course of preparation.

Toxoplasma sp.?

Plate 2, Figs. 13–16

Organisms answering to the description of the genus *Toxoplasma* Nicolle and Manceaux, 1909, were found in heart blood smears of a specimen of *Zosterops lateralis* (silvereye) collected at Masterton in August, 1947. Smears of the peripheral blood of 124 birds of this species, all collected at Masterton during August, 1947, were examined during the survey. One of these smears contained an artifact which closely resembled an early stage of *Haemoproteus*, and, as a special watch was being kept for parasites of this genus in view of their discovery in the same host in Australia (Cleland and Johnston, 1910; Lawrence, 1946), the bird was killed and heart blood and organ smears were made. The heart blood smears showed the presence of not *Haemoproteus* but *Toxoplasma*. Although this parasite was not recorded from any of the other *Zosterops* examined, its presence might easily have been overlooked, due to the fact that infections are often confined to the internal organs and are consequently not apparent from the examination of peripheral blood smears (Hewitt, 1940).

The *Toxoplasma* from *Zosterops lateralis* was found in the cytoplasm of endothelial cells and mononuclear leucocytes, some 20 per cent. of the latter cells being infected.

It is of elongate-oval, crescentic or reniform shape, one end often being more pointed than the other. The cytoplasm stains whitish-blue to light blue with Giemsa. It may be rather granular (Pl. 2, Fig. 14) or maculated (Pl. 2, Figs. 13 and 15), and often contains a number of small vacuoles (Pl. 2, Fig. 16). The nucleus, which may be central in position (Pl. 2, Figs. 14 and 15) or situated towards one extremity (Pl. 2, Figs. 13 and 16), is an irregularly shaped structure staining light pink. It frequently contains numerous small granules of chromatic material staining deeper pink. The average measurements of twenty individuals at their greatest dimensions are 8.5μ (7.0 to 10.4μ) by 3.4μ (2.9 to 4.5μ). The nuclei of these parasites measure some 4.0 by 2.7μ (range 2.9 to 6.2μ by 2.1 to 3.3μ). Parasitized leucocytes show a marked hyperchromatosis of the nucleus, and their cytoplasm may become pale staining and markedly alveolar, as described

by Plimmer (1916) in an account of avian *Toxoplasma*. No cases of double infection of a leucocyte nor any indications of schizogony have yet been seen in the material from *Zosterops lateralis*.

There is no previous record of *Toxoplasma* from New Zealand. The only Australian record is that of Lawrence (1946), who found an oval organism similar to the type II *Toxoplasma-like bodies* of Wolfson (1940) in the mononuclear leucocytes of 27 of 91 sparrows (*Passer domesticus*) examined at Sydney.

There is much doubt as to the systematic position of the toxoplasms. Wenyon (1939) gave it as his opinion that these organisms do not belong to the Protozoa at all. Because of the failure of investigators to demonstrate any other means of reproduction than binary fission for *Toxoplasma,* this author considers the genus to be of vegetable nature and related to *Histoplasma capsulatum* or some other such yeast-like parasite. Some of the organisms from *Zosterops lateralis* superficially resemble the gametocytes of *Hepatozoon* and other intracellular haematozoa, as Hewitt (1940) found to be the case for a toxoplasm from the Mexican house-finch. They also resemble the Type II *Toxoplasma-like bodies* of Wolfson (1940), but differ from these in having a predominance of crescentic and reniform forms rather than round or oval ones. No definite developmental series can be traced out from the material available. I thus follow Hewitt (1940) in not applying a specific name to the *Toxoplasma* described above, believing that the application of such a name would only lead to confusion in the present unsatisfactory state of our knowledge of these organisms.

TABLE 2

A list of the birds examined from which no haematozoa were recorded. (An asterisk denotes a non-indigenous species.)

Systematic position	*Common name*	*Number examined*	*Locality*	*Month and year*
AVES				
SPHENISCIFORMES				
Eudyptula minor (Forster, 1781)	Little blue penguin	1	Trio Island	9/48
PROCELLARIIFORMES				
Diomedeidae				
Diomedea epomophora Lesson, 1825	Royal albatross	2	Wellington	6/47
Diomedea exulans Linnaeus, 1758	Wandering albatross	2	Ninety-mile Beach	3/47
Thalassarche melanophrys (Temminck and Laugier, 1828)	Black-browed mollymawk	1	Wellington	2/47
Thalassarche bulleri (Rothschild, 1893)	Buller's mollymawk	1	Wellington	6/47
Procellariidae				
Macronectes giganteus (Gmelin, 1789)	Giant petrel	1	Wellington	5/48
Pachyptila desolata (Gmelin, 1789)	Dove prion	2	Wellington	6/47
Pachyptila turtur (Kuhl, 1820)	Fairy prion	2	Wellington	6/47
			Auckland	8/47
Pachyptila vittata (Gmelin, 1789)	Broad-billed prion	1	Wellington	6/47
Puffinus griseus (Gmelin, 1789)	Mutton bird	7	Trio Island	9/48
Pelecanoididae				
Pelecanoides urinatrix (Gmelin, 1789)	Diving petrel	2	Wellington	7/47
PELECANIFORMES				
Phalacrocoracidae				
Phalacrocorax carbo (Linnaeus, 1758)	Black shag	1	Lake Wairarapa	5/47
CICONIIFORMES				
Ardeidae				
			Lake Ferry	5/47
Botaurus poiciloptilus (Wagler, 1827)	Brown bittern	1	Parengarenga	3/47
Demigretta sacra (Gmelin, 1789)	Reef heron	2		
ANSERIFORMES				
Anatidae				
**Anas platyrhynchus* Linnaeus, 1758	Mallard	21	Smears examined from throughout New Zealand during May and June, 1948–9	
Anas rhynchotis Latham, 1801	Shoveller	26		
Tadorna variegata (Gmelin, 1789)	Paradise duck	12		
**Cygnus atratus* (Latham, 1790)	Black swan	99		
FALCONIFORMES				
Falconidae				
Falco novaeseelandiae Gmelin, 1788	Bush hawk	1	Tararua Mountains	3/47
GALLIFORMES				
			Wellington	10/47
**Gallus bankiva* Temminck, 1813	Domestic fowl	165	Nelson	5/48
**Lophortyx californicus* (Shaw and Nodd, 1797)	Californian quail	6	Tauranga	7/48
**Phasianus colchicus* Linnaeus, 1766	Pheasant	2		
GRUIFORMES				
Rallidae				
			Nelson	12/47
Gallirallus australis (Sparrman, 1786)	South Island weka	2	Various localities, May and June, 1947–48	
Porphyrio poliocephalus (Vieillot, 1819)	Pukeko	16		
CHARADRIIFORMES				
Charadriidae				
Anarhynchus frontalis Quoy and Gaimard, 1830	Wrybill plover	1	North Auckland	3/47
Laridae				
			Wellington	3/47
Larus dominicanus Lichstenstein, 1823	Black-backed gull	20	Lake Wairarapa	5/48
			North Auckland	4/47
Larus novachollandiae Stephens, 1826	Red-billed gull	7	Wellington	4/47

Systematic position	*Common name*	*Number examined*	*Locality*	*Month and year*
COLUMBIIFORMES				
Columbidae				
**Columba livia* Gmelin, 1789	Rock pigeon	95	Wellington	10/47
			Wellington	7/48
PSITTACIFORMES				
Nestoridae				
Nestor notabilis Gould, 1856	Kea	3	Travers Valley	12/47
			Tasman Glacier	1/48
CUCULIFORMES				
Cuculidae				
Lamprococcyx lucidus (Gmelin, 1788)	Shining cuckoo	1	Wellington	10/49
CORACIIFORMES				
Alcedinidae				
Halcyon sanctus Vigors and Horsfield, 1827	Kingfisher	2	Wellington	4/48
PASSERIFORMES				
Acanthisittidae				
Acanthisitta chloris (Sparrman, 1787)	Rifleman	1	Cape Reinga	4/47
Muscicapidae				
Rhipidura flabellifera (Gmelin, 1789)	Pied fantail	2	Wellington	9/47

DISCUSSION

Doré (1918) suggests that " . . . it may be found possible to connect the comparatively rapid disappearance of New Zealand native birds with the introduction of exotic protozoa through the medium of the imported fauna. . . ." Myers (1923) elaborates this suggestion, stating that " . . . the hypothesis of an introduced avian disease which might conceivably commit the same havoc among the indigenous birds as measles among aboriginal races of man . . . supplies perhaps the only theory which can even partially explain the wholesale disappearance of certain species from untouched areas either before weasels or stoats were introduced or before they or any other cause of sufficient magnitude had conceivably reached the area in question." More recently, Wingstrand (1947) lists disastrous epidemics caused among domestic birds by Leuocytozoon, saying, " . . . I would emphasize the necessity of taking also the blood parasites into consideration when the changes in the Swedish bird populations are discussed, . . . ," and Fisher (1948) draws attention to the desirability of examining blood smears from birds imported into Hawaii in order to guard against the possible transfer of exotic haematozoa to indigenous birds.

A very full investigation of the haematozoa of New Zealand birds, both indigenous and exotic, will have to be made before any decision can be reached concerning the effect of these parasites on the native avian fauna, as Doré himself informed Myers (1923). It was felt that such an investigation lay outside the scope of this survey, especially in view of the protected status of most of the native birds and the great amount of time which would be required to trap sufficient numbers of each species to justify such a study once the necessary governmental sanctions

were obtained. For the present, it is urged that blood smears should be taken from all livestock imported into this country, particularly domestic birds, and submitted to expert examination for the presence of haematozoa. This procedure offers the only real safeguard against the introduction of such parasites as the *Simulium*-transmitted leucocytozoa, which may cause fatal epidemics among ducks (O'Roke, 1934) and turkeys (Skidmore, 1932). The widespread *Simulium australe* might serve as a vector for these parasites in New Zealand. As Fisher (1948) remarks, "It seems insufficient to allow the entry of birds on the basis of a clean bill of health as testified by the importer or by a veterinarian in the country of export."

Apart from two species of penguins (*Megadyptes antipodes* and *Eudyptes pachyrhynchus*) which breed on the subantarctic islands south of New Zealand, from which *Plasmodium relictum* var. *spheniscidae* is recorded, the only indigenous birds as yet known to be hosts for haematozoa are *Anas poicilorhyncha* (*Plasmodium* sp?) and *Anthus novaeseelandiae* (*Plasmodium* sp?). In so far as the indigenous portion of the New Zealand avian fauna has been examined for haematozoa (Table 2), it appears to be exceptionally free of these parasites. No material has yet been examined from any of the migratory birds, which offer the only avenue other than the agency of man for the introduction of avian haematozoa into this country. It is of decided interest in this connection that *Toxoplasma* sp? is here recorded from *Zosterops lateralis*, a species which reached New Zealand apparently from Australia or Tasmania in 1856 (Oliver, 1930).

Australian native birds have a rich fauna of *Trypanosoma*, *Haemoproteus*, *Leucocytozoon*, *Plasmodium*, and *Microfilaria*, and Lawrence (1946) records a *Toxoplasma* from *Passer domesticus* in Sydney. Neither *Trypanosoma* nor *Microfilaria* have yet been recorded from birds in New Zealand. Cleland (1915) records *Plasmodium biziurae?* from the black swan (*Chenopis atrata*) = *Cygnus atratus*, one specimen of two examined in Australia being positive for this parasite. Following its introduction into New Zealand during last century, *Cygnus atratus* has become common and widespread, and is now regarded as a game bird. Smears from 99 specimens of this bird were examined during the survey, but all proved negative for haematozoa. Cleland and Johnston (1910) and Lawrence (1946) record a *Haemoproteus* from *Zosterops lateralis* in Australia. Two of 14 birds examined by the former authors and one of three examined by Lawrence were infected with this parasite. As *Haemoproteus* was not recorded from any of the 124 specimens of *Z. lateralis* examined during my survey, it seems likely that the parasite did not accompany its vertebrate host to New Zealand, or, at all events, has failed to become established in the Wairarapa, the part of the country from which my material was obtained.

None of the 95 examples of the common pigeon *Columba livia* examined were infected with *Haemoproteus columbae* Kruse, 1890, which has accompanied its host to most other areas into which this bird has been introduced. However, as

no material has yet been examined from lofts infected with the arthropod vector of this parasite, the ectoparasitic fly *Lynchia maura,* it is too early to regard *Haemoproteus columbae* as definitely absent from New Zealand.

SUMMARY

No indigenous species of haematozoa have yet been described from New Zealand birds. *Plasmodium relictum* var. *spheniscidae,* recorded by Fantham and Porter (1944) from *Megadyptes antipodes* in Foveaux Strait, is apparently of circumpolar distribution. The other Haemosporidia specifically identified during this survey were originally described from Europe, whence their hosts originate. It is likely that *Plasmodium* sp? recorded from the indigenous birds *Anas poicilorhyncha* and *Anthus novaeseelandiae* will prove to be *Plasmodium relictum* when further material becomes available.

Neither trypanosomes nor microfilariae have yet been recorded from birds in New Zealand. The haemosporidian genus *Leucocytozoon* is now listed from this country for the first time, as is *Toxoplasma,* the systematic position of which is still in question. Doré's (1920) record of *Plasmodium* from *Turdus ericetorum* and *Turdus merula* is expanded to *Plasmodium relictum*; and his tentative identification of *Haemoproteus danilewsky* from these same hosts is confirmed. *Anas poicilorhyncha* is given as a new host for *Plasmodium* sp?, and *Passer domesticus* is recorded as an additional New Zealand host for *Plasmodium relictum.*

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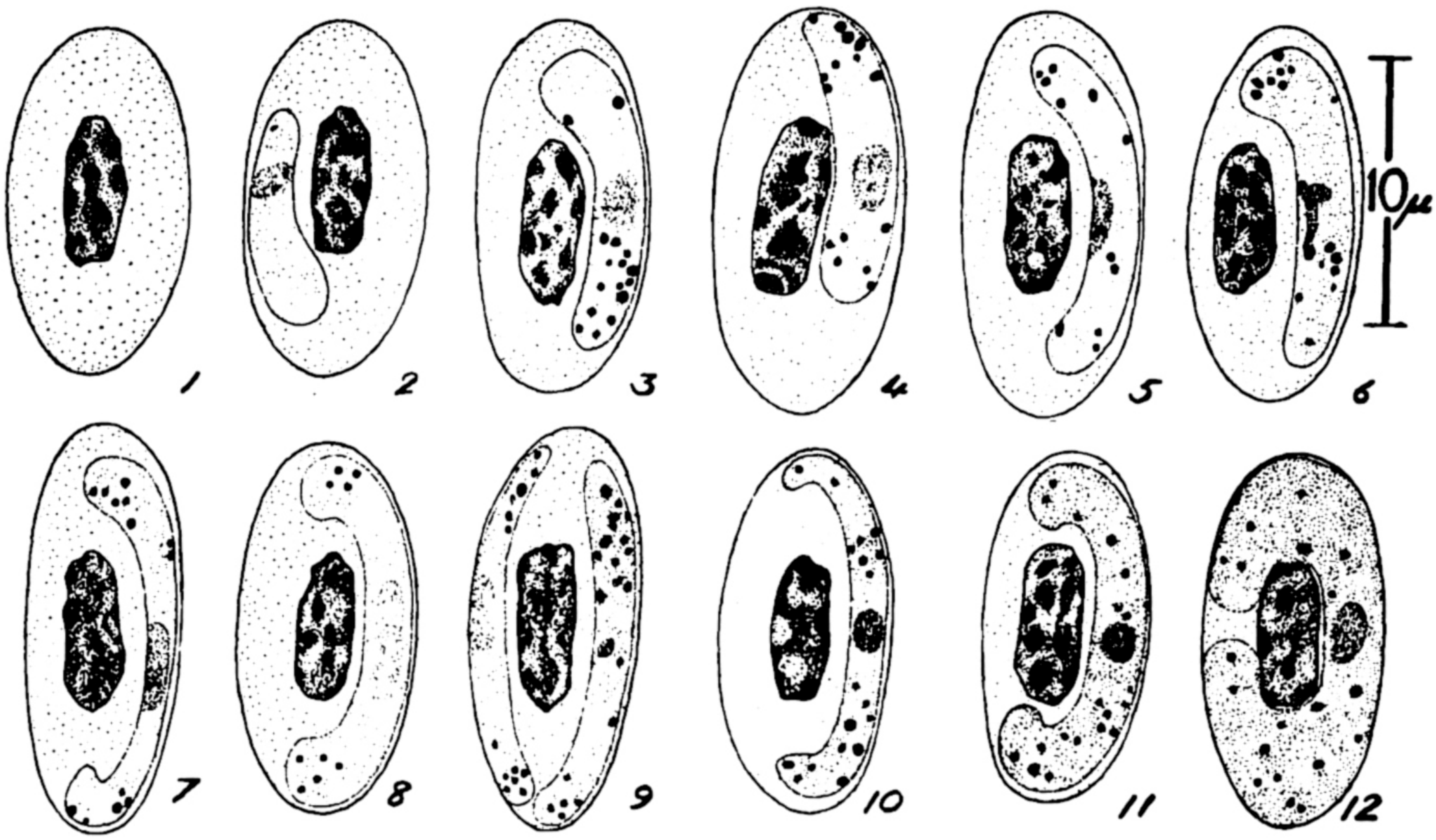
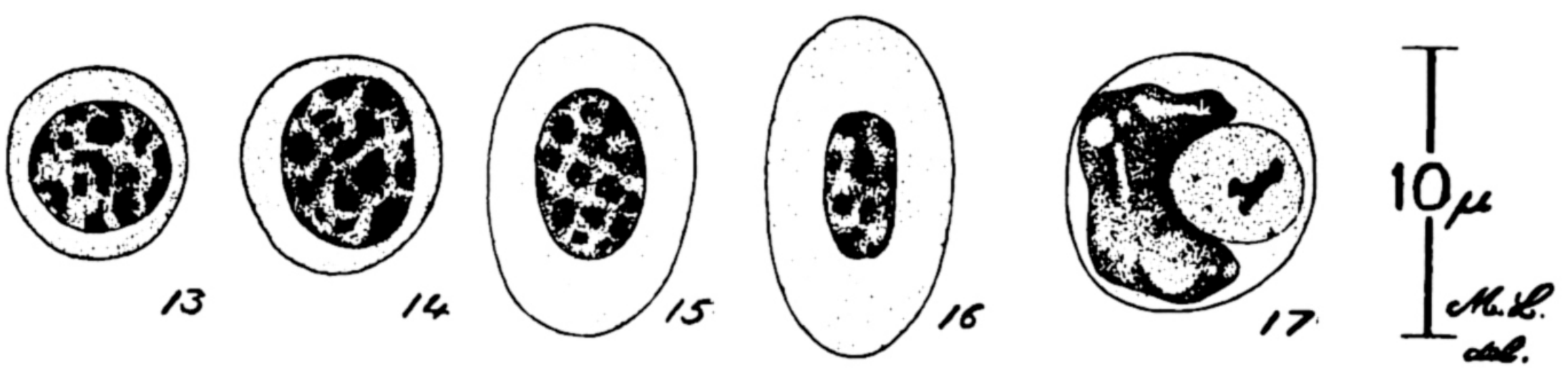
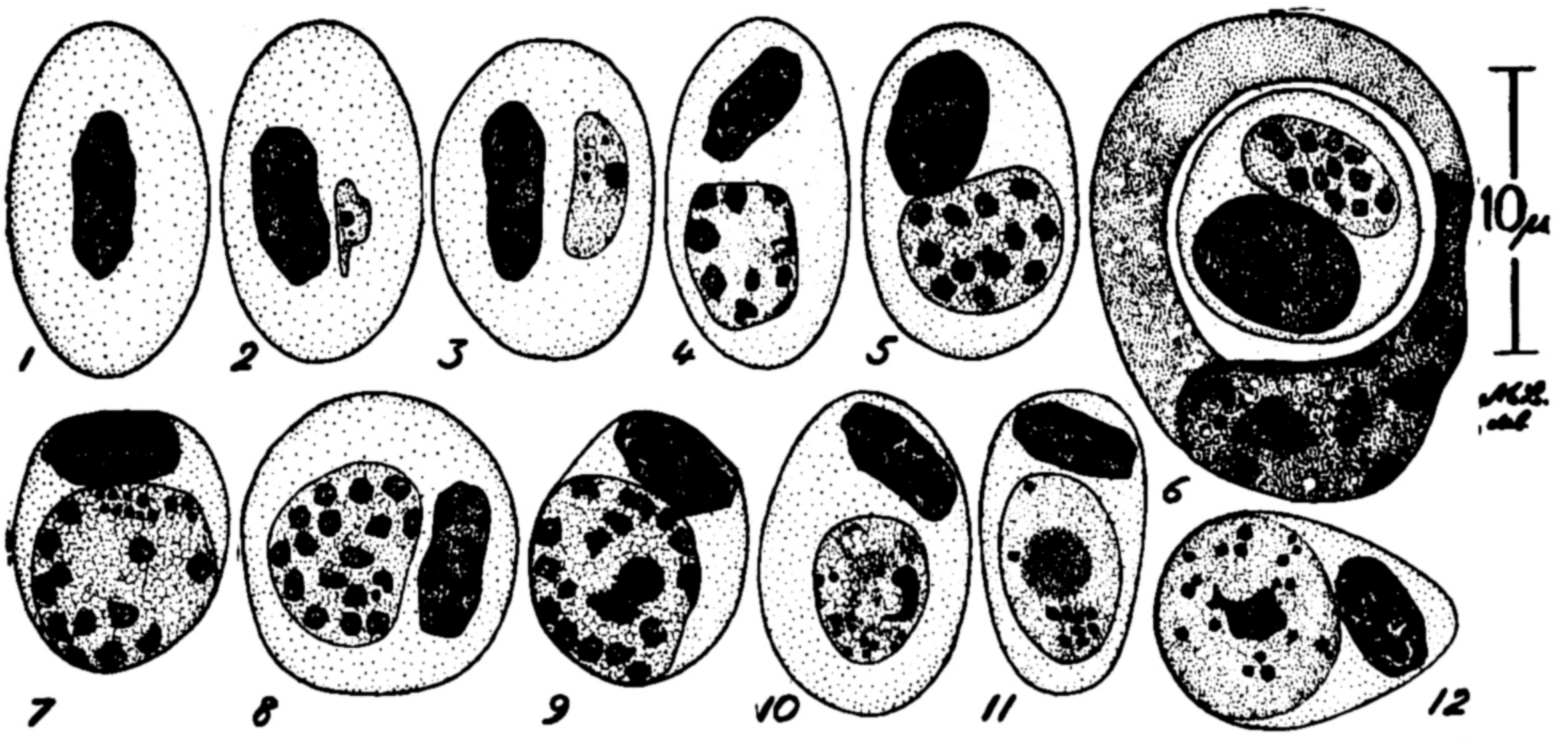


Haemoproteus danilewsky Kruse, 1890.

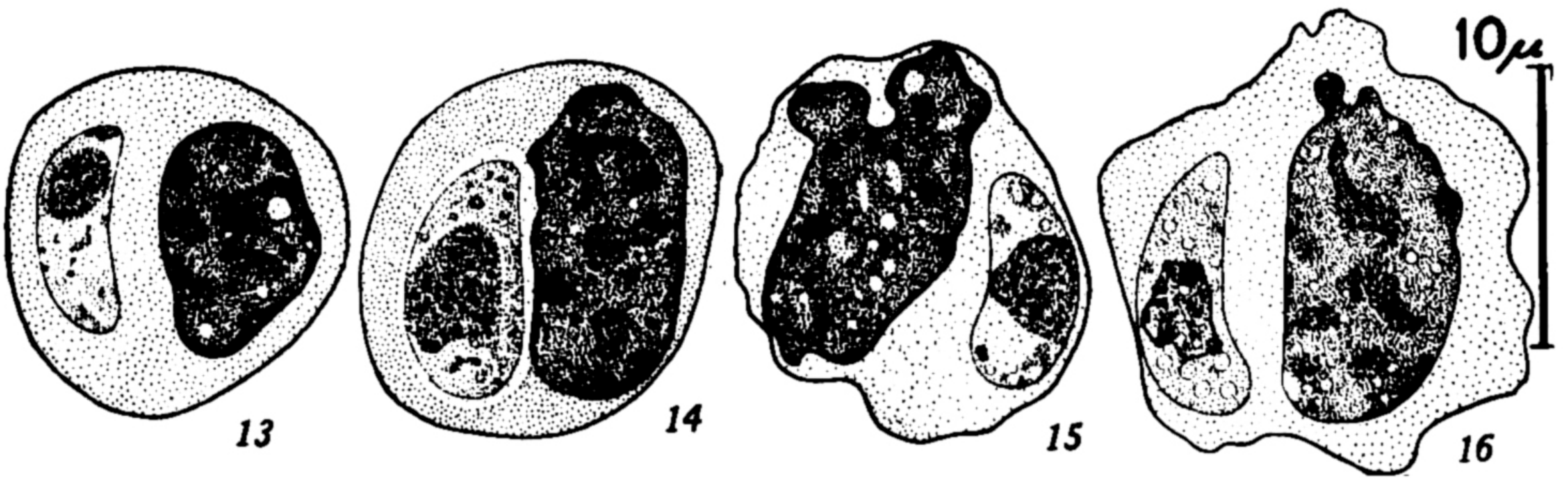


Leucocytozoon fringillinarum Woodcock, 1910.

Plate 1



Plasmodium relictum (Grassi & Feletti, 1891).



Toxoplasma sp?

Plate 2

EXPLANATION OF PLATES 1 AND 2

All figures drawn at a magnification of 2,400 from air-dried smears of heart blood fixed with absolute methyl alcohol and stained with Giemsa.

PLATE 1

Haemoproteus danilewsky Kruse, 1890, from *Turdus cricetorum*

Fig. 1.—Normal erythrocyte of *T. cricetorum.*
Figs. 2–6.—Developing gametocytes.
Figs. 7 and 8.—Microgametocytes.
Fig. 9.—Double infection of an erythrocyte by a microgametocyte and a macrogametocyte.
Figs. 10–12.—Macrogametocytes.

Leucocytozoon fringillinarum Woodcock, 1910, from *Fringilla coelebs*

Figs. 13 and 14.—Basophil erythroblasts of *F. coelebs.*
Fig. 15.—Polychromatophile erythroblast of *F. coelebs.*
Fig. 16.—Normal erythrocyte of *F. coelebs.*
Fig. 17.—Young gametocyte.
Figs. 18–20.—Microgametocytes.
Figs. 21 and 22.—Macrogametocytes.

PLATE 2

Plasmodium relictum (Grassi and Felletti, 1891) from various hosts, and *Plasmodium* sp? from *Anas poicilorhyncha*

Fig. 1.—Normal erythrocyte of *Turdus cricetorum.*
Fig. 2.—Amoeboid trophozoite from *Turdus merula.*
Fig. 3.—Trophozoite of *Plasmodium* sp? from *Anas poicilorhyncha.*
Fig. 4.—Schizont from *Passer domesticus.*
Fig. 5.—Schizont from *Turdus cricetorum.*
Fig. 6.—Phagocyted corpuscle of *Turdus cricetorum,* containing a schizont.
Figs. 7–9.—Schizonts from *Turdus cricetorum.*
Fig. 10.—Young gametocyte from *Passer domesticus.*
Fig. 11.—Microgametocyte from *Passer domesticus.*
Fig. 12.—Macrogametocyte from *Passer domesticus.*
Toxoplasma sp? from *Zosterops lateralis*
Figs. 13–16.—*Toxoplasma* sp? within mononuclear leucocytes of *Z. lateralis.*

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